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DESIGN, TECHNOLOGY AND COMMUNICATION IN THE BRITISH EMPIRE, 1830–1914

Annie Tindley and Andrew Wodehouse

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For Colin
For Lorna, Ruby and Archie

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CHAPTER 1

Introduction: Designing the Empire

Abstract This introduction outlines our key concern with the role of design in facilitating communication and applying industrial technology to culturally diverse imperial locations between c. 1830 and 1914. It surveys the relevant imperial contexts and presents a literature review encompassing the key themes in design and engineering, imperial history and business history. It also describes the research framework and questions addressed in the book, consisting of four stages of design communication: identification, specification, conceptualisation and production. To illustrate the workings of the framework we outline six primary case study industrial technologies: railways, steam ploughs, sheep shears, bridges, sugar production and road steamers.

Keywords Design process · Research framework · Industrial technology · Inter-imperial communication · Colonial knowledge

The locomotive was a symbol of design that reached the most remote corners of the British Empire: an engineering marvel of a scale and complexity staggering to those unfamiliar with such machines. Heaving through the colonial bush, it could induce 'stampedes of the natives,' with a blow of its whistle, and served as a reminder of Britain's power as much as solving logistical issues.[1] Successful and sustainable adaptation of technology, however, meant a deep understanding of colonial conditions was crucial. What

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commercial factors influenced the chosen route? How was the line plotted and the engine specified to cope with the local environment? Who collaborated to manufacture and assemble the locomotive itself? And what relationships formed in the installation and operation of this new mode of transport? The stories behind not just locomotives but many of the iconic technologies of the industrial revolution are bound up in the process of their realisation – their design in the broadest sense of the word.

In focusing on the intensely collaborative nature of design, we examine the multifarious links formed in supporting the industrialisation of Britain's empire and uncover the motivations, dynamics and legacies of those working within its structures. There has been broad historical debate on the nature of imperial linkages, with networks, bridgeheads, nodes and webs among the proposed structures and definitions put forward. The long-standing discussion around, firstly, the diffusion, and latterly, the transfer of technology, has contributed a great deal to this wider debate and has built a postcolonial historiographical position that decentres Europe and emphasises instead the circularity of imperial connections. *Design, Technology and Communication* seeks to add to this debate by focusing not on the technologies themselves, but on their exploitation and the way the design process acted as a conduit for communication between, across and within Britain and the empire.

Our central research question interrogates the role of design in communicating and applying industrial technologies to culturally diverse imperial locations between c. 1830 and the First World War. Rather than examining the impacts of the technologies – particularly revolutionary technologies and their multiple incarnations, such as steam power – we focus on incremental and adaptive design developments, which account for the majority of innovative activity in this period. Through the processes of identification, specification and application to and for new environments, we argue that design acted as a conduit for intra-imperial communication in the long nineteenth century, that is, as a form of communication within and across the different internal British contexts and the myriad, expanding imperial contexts. We examine not only the adaptation of industrial technologies for specific purposes but also the practical communication and links that emerged as necessities of their realisation.[2] *Design, Technology and Communication* utilises detailed archival case studies to explore the mechanics of collaboration and poses two fundamental questions: what was the nature of design in the British Empire with regard to location, stakeholders, motivation and format?

And what do both the opportunities and restrictions posed by the imperial context tell us about how design functioned as a conduit for communication?

We also hope to shed fresh light on the semantics, politics and conceptualisation of the term 'design'. 'Design' is such a widely used term (noun, verb, adjective, cross-sector, positive/pejorative) that it is difficult to define, both historically and particularly in contemporary contexts. There has been an increasing consideration of 'design thinking' and how it can aid innovation. Yet during the chronology studied here, the terms 'design' and 'innovation' were entirely unused, or barely so. Instead, the 'betterment' that was part of the overall conception of the empire project and the assertion of new ways of life were tied up with the growing faith in the developments in technology, science and medicine that were taking place.[3] Often, significant engineering risks – and all the design work documented here was undertaken by engineers – were taken, and huge resources spent on projects: contextualising these in relation to the tentacles of empire at each stage of the product development process should be illustrative for both design scholars and historians. Design in this book is therefore considered a conduit for communication. As the mechanism by which ideas became reality, it enabled links between people and organisations through the exchange of information, logistical movement of goods, installation of facilities and use of equipment. Design has also been described as a social process, and the necessity of engaging a range of stakeholders made it a critical component in understanding the establishment and development of links between and within Britain and the imperial territories.[4] While the installation of finished artefacts (railways, production machinery, agricultural equipment, bridges) signified the reach of the British Empire, it was the *process of design itself* that helped to reinforce these links. In applying these interpretations as a framework to examine how technologies were used and applied in the British Empire, we hope to contribute to the understanding of the nature of design during this period. The rapid technological breakthroughs, environmental challenges, disparate markets and institutional networks are the backdrop to the story of how the process of design was a powerful driver in shaping the relationship between Britain and its colonies.[5]

As such, *Design, Technology and Communication* situates itself in three key areas of historical enquiry and literature: the imperial – including imperial economics and shifting ideas of colonial knowledge; the industrial – including business models and patents; and, lastly, design and innovation – both theoretical and practical.[6] It seeks to make a contribution to each of these areas by utilising a detailed case study approach that encompasses a range of industrial technologies (railways, steam ploughs, sheep shears, bridges, sugar production and road steamers) to test some of the wide-ranging claims and ideas debated in the overarching literature.

In order to understand our case studies, we have had to consider carefully the very different imperial contexts in which technologies were identified, designed and developed. These included formal and informal imperial structures, the financial and economic linkages of empire, widely varied constitutional and institutional structures, and professional networks. A key intellectual context for our work has been that of P. J. Cain and A. G. Hopkins, with their emphasis on the financial and economic linkages of empire and 'gentlemanly capitalism'.[7] The development of design was at the heart of an international economy: an extension of capitalism into and across wildly varying territories over the globe.[8] The importance placed by these authors on the financial and economic circuits of empire and their 'gentlemanly' drivers are borne out at least to some extent by our work. In nearly all of our case study technologies, elite wealth, but more importantly, elite connections – be they British or among and across colonised peoples – were key.[9] Most involved incremental improvement to existing industrial equipment, rather than the revolutionary inventions or technology systems that dominate popular thinking about the industrial revolution, such as steam power or the telegraph. What we show is the importance of elites – British or colonial – and their patronage, networks and funds in the innovation process. This was as true for the formal empire of crown colonies and dominions as it was of the informal empire, such as Cuba, Argentina and Peru.[10]

Laidlaw describes a general transition from 1830 onwards from imperial control towards more pragmatic forms of administration and management in colonial settings.[11] Variances in socio-economic, technological and cultural status, however, meant different imperial territories absorbed technologies at different rates. Part of this particular strand of the literature directs us to a discussion around the impact of constitutional and institutional imperial structures and to what extent any imperial territory (formal or informal) was a 'captive market' for British engineers and businesses looking for new opportunities. This contributes to a long-standing debate in the literature, with more recent work by Thompson and Magee nuancing – indeed, breaking down to some extent – the idea of the captive market, particularly in relation to the dominions.[12] Requiring separate consideration is the status and governance of British India: most historians agree that India was different, both from the dominions of course, but also from other crown colonies, particularly those in the African continent. The level of centralised control wielded by the Government of India and its specific strategic, military and economic drivers does set it apart.[13] However, this does not matter so much to our interrogation. Design was still the conduit across all the different colonial settings, including India, and – crucially – within different settings within Britain too, which was often the locus of design activity.[14]

This brings us to one of the other major themes of imperial and technological histories: that of the forms and structures of inter-imperial communication – the networks, webs, nodes and circuits that have variously been suggested as constituting the structures of communication between and within Britain and its empire.[15] *Design, Technology and Communication* subscribes to the postcolonial model put forward by Arnold which describes a circularity of information, experience and expertise through a variety of feedback loops, rather than a simple model of either diffusion or transfer.[16] The notion of bridgeheads has also been developed as a model for communication specifically within the engineering profession, and although useful in that context, it is not a model that we closely adhere to here.[17] The less structured concept of circuits of empire fits what we have traced in the history of design communication more closely.[18] One of the reasons for this is the importance in our framework of the geographies of motivation for creating and then exporting or importing new or adaptive design in both the British and imperial contexts. As will become clear, we are interested not just in the work itself but where and how it was being undertaken through the stages of the design process – identification, specification, conceptualisation and production. By focusing on this, we stress the importance of the circularity of inter-imperial communication rather than a hierarchy-focused approach.[19]

Another important contextual consideration is the structure and setting for design activity within businesses and organisations, including their search for new work and opportunities, expansion via establishing overseas branches, partnerships with other companies, and the requirement to develop design and manufacturing protocols.[20] Often, even if a particular product became obsolete over time, these structures remained as the legacy of the design process and the communication therein – and the circuit through which future and new design was realised. To help situate our thinking in this particular field, we also utilise business history literature, including that which examines the family business model, the impact of social and/or religious networks on business formation and the frequent mergers and collaboration of businesses to meet large or challenging projects.[21] This also connects our thinking to the nature of professional networks in the design context and how they can be uncovered and analysed through the archival evidence of design work – the journals, letters pages, reports, correspondence, newspapers and trade journals which form the foundations of an emerging profession.[22] Our research found these forms of communication more imperative than those represented by the patent system, although patents did play a role in some of our case study technologies.[23] The literature continues to debate whether patents in the nineteenth century were more of a restriction than an opportunity, and although we would not suggest they acted uniformly as a restriction in the examples explored here, we would certainly not argue either that they acted as a primary driver for innovation.[24]

One final area of contribution to the imperial literature is around the concept of colonial knowledge, and the kinds of opportunities and restrictions it generated in the communication of design.[25] Our research suggests that assumptions on the part of British engineers and companies about colonial territories and their peoples often led to the restriction rather than the best exploitation of new opportunities. It is important not to attempt to see the impact of colonial knowledge as something static, however: it changed over time and in different ways. What people thought they knew and how they applied their assumptions also altered according to geography as well as temporality, and the key to understanding this is how British people viewed and understood their empire.[26]

Framework, Case Studies and Archives

Design, Technology and Communication has been structured around a set of four stages defining the design process, which allow for the distinct characterisation of communication through the innovation cycle. These are identification, specification, conceptualisation and production. For each stage, multiple case study technologies are utilised to illuminate what was actually happening on the ground. This concern with the practicalities of the communication of design has informed the book's structure, approach and archival methodologies.

As the first stage, the principles of identification for both design and market opportunities in Britain and the imperial context are interrogated. In order to understand the drivers for new or adapted design we must define the mechanisms of market identification, and the processes by which technologies were aligned with emerging opportunities. The possession of the formal (and informal) empire did not necessarily provide unfettered access to markets – there were as many obstacles to the communication of design as there were advantages. The second stage is specification, whereby the requirements of the imperial context were more closely mapped out according to the specific user and/or customer requirements.[27] A significant part of this stage of the design process was the impact of competition: including highly influential contracting competitions staged by various imperial authorities and administrations, principally to build major infrastructures such as bridges and railways.[28] As such, much of the specification for these designs already existed in outline, and engineers and companies had to respond directly to these. The third stage in the process is conceptualisation, the means by which engineers generate, evaluate and refine new or adapted design configurations. This includes patterns of design generation, the role of collaboration, and a discussion as to whether patents acted as a form of communication in this specific context. The fourth stage combines detailed design, production and distribution: the designed product made real. This includes the processes by which designs were converted into working prototypes and tested, the establishment of production processes, identification of labour skills and the transfer, or distribution, of the technology.

It is important to outline and define our terminology: most importantly, what do we mean by design communication? We take it to constitute multiple forms of knowledge and information exchange rather than an event: by engaging in the design process, individuals and businesses collaborate to achieve a shared goal. That is, communication is what is happening as part of the design process. *Design, Technology and Communication* questions where the centre of gravity in these processes lies, how that might change according to period, technology and location, and how legacies of communication were created. To encompass the British Empire, the informal empire and other territories where Britain had influence or British firms operated, we have used the term 'British World'. What emerges is a multiplicity of connections in the dissemination and development of design. The design process, as defined here, is a conduit: a temporary undertaking which brings together stakeholders around one design or artefact and then dissipates, often leaving permanent links or traces behind – whether in the form of documented protocols, standards, and institutions, or more intangible legacies in cultural perceptions and social relationships. As well as being a conduit, design is also a motivator which draws on people, businesses and resources in the creation of new connections to meet the desired outcome; it is a means to develop networks that facilitate the successful transfer of information and technologies. Lastly, we must consider those who were behind new and adapted design. We do not use the definition 'designer', as this was not a recognised term in the period under discussion. Instead, many roles might be taken on by one individual – at once an inventor, engineer and entrepreneur. Collaboration and collaborative working was vital throughout the design process, and our examples will show exemplars within and across companies, between engineers, their customers, and labour forces, and in many other forms depending on the context.

Constituting an interdisciplinary team of historian and design engineer, the authors combine different methodologies in order to throw light on the ways in which design acted as a conduit for communication during the height of Britain's imperial project. In order to uncover the working design practices in this period – from the initial identification of markets through to the final application of designs in new contexts – six key technological case studies have been utilised, all industrial in nature. While an examination of domestic or consumer products may have proven illuminating particularly from a cultural perspective, we would have found more instances of self-contained development by companies who, despite shipping to colonial markets, did not engage in the same depth of communication. Furthermore, it is not the purpose of this book to explore in detail what happened to technology after it was embedded in the imperial context: extensive and valuable work has already been done on this aspect of the movement of technology and design.[29] Instead, we set out to break down the social processes and circuits by which design opportunities were developed by British companies, entrepreneurs and engineers. Industrial examples typically involved large, complex machines that required a diverse range of stakeholders to bring them to life, and therefore suited the nature of our investigation. Undoubtedly linked to the greater number of collaborators, the associated archives in these areas were also more extensive, allowing a richer recreation of communication patterns. In focusing on industrial technology, some areas were clearly attractive: trains, bridges and sugar production were key instruments of empire and well documented in the archives. We interrogated these from a holistic perspective, attempting to connect design information (technical drawings, engineers' notebooks, etc.) with economic and social documentation (correspondence, catalogues, order books, news reports, etc.). Our other technologies – steam ploughs, sheep shears and road steamers – are more focused and experimental areas where response to the colonial context was central to their development. Tracing the evolution of these examples over time was particularly informative.

Most of the archives have come via the British headquarters of businesses, although the records of the myriad networks of overseas partnerships, governmental administrations and other contracting structures have also been vital to our understanding of the role of design.[30] We have been able to utilise examples from the archives at almost every stage of the design process, allowing us to reconstruct the journey from initial identification of a problem or opportunity to the design and application of a new technology. However, there were also many gaps and silences in the archival records. These were particularly evident around the working practices of engineers and on shop floors. In many cases, only very sketchy materials were left to the archives – perhaps a rough hand-drawn sketch, with a few guiding notes, might be all we had to discuss how design detailing actually happened. We have therefore to some extent drawn on modern processes and thinking around design to fill some of these gaps. It should also be noted that much of the communication we are interested in at these stages must have been, firstly, primarily verbal in nature, and secondly, left in the hands of the mechanics and technicians on shop floors to work out for themselves. It is clear that many engineers worked in relatively unstructured ways, particularly compared to contemporary norms, even those employed by some of the largest British engineering firms, such as North British Locomotive, Sir William Arrol & Co., or Head, Wrightson & Co.

The structure of *Design, Technology and Communication* broadly follows the chronology of the design process. Chapter 2 explores the identification of design opportunities within Britain and the empire, examining the mechanisms of market identification, the processes by which opportunities were identified and leveraged to allow the initial development of technology to begin. The nature of the communication between and within the British industrial-economic context and the colonial context is also explored, through discussion of the maturity of technology, colonial opportunities and restrictions and, lastly, ownership structures and partnerships. Chapter 3 examines the design specification stage, that is, how engineers or inventors prepared to design products according to the user and customer requirements, existing competition, and, lastly, the technical requirements. Chapter 4 looks at the conceptualisation stage – the processes by which engineers generated and evaluated their ideas for new designs or adapted technology. It then seeks to understand the structure and nature of collaborations between engineers and the users and/or commissioners of products in the embodiment of these designs. It also gives consideration to the role of patents and intellectual property as a potential conduit for communication in its own right. Chapter 5 examines the concluding production-related activities of the design process: detailed design, manufacture and distribution. That is, the processes by which concept designs were converted into working prototypes, tested and then applied to the required contexts. This includes a discussion of the experimentation, analysis and iteration of designs based on feedback. It then traces the communication of the new design from workshop to the shop floor and the beginning of the manufacturing process. Lastly, it explores the imperial linkages put in place to move designs and products to new contexts – and how these reinforced communication channels within and across empire.

Design, Technology and Communication aims to develop a more nuanced understanding of the interaction of design across the British World. Due to the nature of the design identification, specification and detailing in the period under examination, much of the activity takes place within the British geographical context, but we are careful to highlight the differing contexts within the metropole throughout. We start our examination with the identification of design opportunities and how British and imperial markets acted as a conduit for – but also sometimes restricted – communication.

Notes

1. Museum of English Rural Life, TR FOW, PI/A6, John Fowler & Co, catalogues, vol. 8 (1900–1903).
2. See for example, P. Palladino and M. Worboys, 'Science and imperialism', *Isis*, 84:1 (1993), pp. 97, 99. (Palladino and Worboys 1993)

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5. Arnold, 'Europe, technology and colonialism,' pp. 89–90. (Arnold 2005)
6. M. Adas, *Machines as the measure of men: science, technology and ideologies of Western dominance* (Oxford, 1989), pp. 15, 143–4, 310. (Adas 1989)
7. P. J. Cain and A. G. Hopkins, *British imperialism: innovation and expansion, 1688–1914* (London, 1993), pp. 17–29, 243 (Cain and Hopkins 1993); S. Dubow (ed.), *Science and society in Southern Africa* (Manchester, 2000), p. 3. (Dubow 2000)
8. Cain and Hopkins, *British imperialism*, pp. 233, 316–18. (Cain and Hopkins 1993)
9. A. Thompson, *The empire strikes back? The impact of imperialism on Britain from the mid-nineteenth century* (Harlow, 2005), p. 164 (Thompson 2005); Cain and Hopkins, *British imperialism*, pp. 327–33. (Cain and Hopkins 1993)
10. J. Gallagher and R. Robinson, 'The imperialism of free trade, 1815–1914,' *Economic history review*, 2nd ser., 6 (1953), p. 14; Cain and Hopkins, *British imperialism*, p. 235 (Cain and Hopkins 1993); C. B. Davis and K. E. Wilburn, *Railway imperialism* (London, 1991), 'Introduction', R. Robinson, pp. 2, 5 (Davis and Wilburn 1991); Arnold, 'Europe, technology and colonialism,' pp. 95–6. (Arnold 2005)
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13. R. Floud and D. McCloskey (eds.), *The economic history of Britain since 1700, vol. 2: 1860–1939* (Cambridge, 1994), pp. 206–7, 213 (Floud and McCloskey 1994); N. Charlesworth, *British rule and the Indian economy, 1800–1914* (Basingstoke, 1985), pp. 11–13. (Charlesworth 1985)
14. For example, consider the differences between geographical locations in the UK such as Leeds, Manchester, Glasgow, Norfolk, London, lowland Scotland: A. Tindley and A. Wodehouse, 'The role of social networks in agricultural innovation: the Sutherland reclamations and the Fowler Steam Plough, c. 1855–c. 1885', *Rural History*, 25:2 (2014); A. Offer, 'Costs and benefits, prosperity and security, 1870–1914' in A. Porter (ed.), *The Oxford history of the British Empire; the nineteenth century* (Oxford, 1999), p. 706. (Porter 1999)
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17. See Andersen, *British engineers and Africa*, pp. 3, 5, 161–4. (Andersen 2011)
18. A. Lester, 'British settler discourse and the circuits of empire, ' *History Workshop Journal*, 54 (2002), pp. 24–44 (Lester 2002); K. Raj, 'Colonial encounters and the forging of new knowledge and national identities: Great Britain and India, 1760–1850,' *Osiris*, 2nd ser., vol. 15 (2000), pp. 119, 133 (Raj 2000); A. Lester, 'Imperial circuits and networks: geographies of the British Empire,' *History Compass*, 4:1 (2006), pp. 124–141. (Lester 2006)
19. There is a significant body of literature on this debate already: G. Basalla, 'The spread of Western Science,' *Science*, 156: 3775 (1967), pp. 611–22 (Basalla 1967); R. MacLeod, 'Introduction,' *Osiris*, 2nd ser., vol. 15, Nature and empire: science and the colonial enterprise (2000), pp. 1–2, 6, 10. (MacLeod 2000)
20. See for example, Y. Bektas, 'The Sultan's messenger: cultural connections of Ottoman telegraphy, 1847–1880,' *Technology and Culture*, 41:4 (2000), pp. 688, 695 (Bektas 2000); R. A. Buchanan, 'The diaspora of British engineering,' *Technology and Culture*, 27:3 (1986), pp. 502–3, 507. (Buchanan 1986)
21. See for example, J. McIntyre, R. Mitchell, B. Boyle and S. Ryan, 'We used to give and get a lot of help: networking, cooperation and knowledge flow in the Hunter Valley wine cluster,' *Australian Economic History Review*, 53:3 (2013), pp. 247, 253; J. Frawley, 'Prickly pear land: transnational networks in settler Australia,' *Australian Historical Studies*, 38: 130 (2007), 324. (Frawley 2007)
22. These networks could have a number of different bases, for instance, family, ethnicity, professions, religions or economics: see G. Jones and M. B. Rose

(eds.), *Family capitalism* (Brookfield, 1993), p. 9; S. Ville, 'Business development in colonial Australia,' *Australian Economic History Review*, 38:1 (1998), pp. 20, 27 (Ville 1998); Andersen, *British engineers and Africa*, pp. 161–4 (Andersen 2011); A. Thompson, 'The power and privileges of association: co-ethnic networks and the economic life of the British imperial world,' *South African Historical Journal*, 56:1 (2006), pp. 46, 50, 53, 58 (Thompson 2006); J. Weiler, 'Colonial connections: Royal engineers and building technology transfer in the nineteenth century,' *Construction History*, 12 (1996), pp. 3, 7, 16 (Weiler 1996); Tindley and Wodehouse, 'The role of social networks in agricultural innovation'.

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24. C. MacLeod, 'Reluctant entrepreneurs: patents and state patronage in new technosciences, c. 1870–1930,' *Isis*, 103:2 (2012), pp. 333–4 (MacLeod 2012); J. Andrew, J. Tann, C. MacLeod, and J. Stein, 'Steam power patents in the nineteenth century – innovations and ineptitudes,' *Trans. of the Newcomen Society*, 72 (2000–2001), pp. 17, 25, 33 (Andrew et al. 2000–2001); C. MacLeod, J. Tann, J. Andrew and J. Stein, 'Evaluating inventive activity: the cost of nineteenth century UK patents and the fallibility of renewal data,' *Economic History Review*, 56:3 (2003), pp. 539–40, 560. (MacLeod et al. 2003)
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27. For example, in sugar production technologies: A. H. Adamson, *Sugar without slaves: the political economy of British Guiana, 1838–1904* (London, 1972), p. 6, 9, 171–2 (Adamson 1972); M. Craton and J. Walvin, *A Jamaican plantation: the history of Worthy Park, 1690–1970* (London, 1970), pp. 156, 219–22. (Craton and Walvin 1970)
28. For example see, P. S. A. Berridge, *Couplings to the Khyber: the story of the North Western Railway* (Newton Abbot, 1969), pp. 80, 209 (Berridge 1969); Headrick, *Tentacles of progress*, pp. 51–2, 82 (Headrick 1988); F. Lehmann, 'Great Britain and the supply of railway locomotives to India: a

case study of "economic imperialism"', *Indian Economic and Social History Review*, 2 (1965), pp. 298, 301–2. (Lehmann 1965)

29. J. R. Ward, 'The industrial revolution and British imperialism, 1750–1850,' *Economic History Review*, 47:1 (1994), pp. 44–6. (Ward 1994)
30. A full list of the archives used in this study is given in the Bibliography.

CHAPTER 2

Acquiring Markets – The Opportunities of Empire

Abstract This chapter explores the identification of opportunities in the imperial context. It begins by examining the market with regard to the design capability of British industry, and how establishing relationships became a conduit for communication. It also examines the nature of the communication between and within the British industrial-economic context and the colonial context and considers three thematic areas, each of which contributes to the process of identification: the maturity of technology, colonial opportunities and restrictions and, lastly, ownership structures and partnerships, including the ethical dimensions to these.

Keywords Market · Identification · Adaptation · Technology transfer · Ownership structures

Introduction

Britain's status as the first industrial nation, and its associated period of imperialist expansion, meant it was replete with opportunity for companies or entrepreneurs willing to look beyond the domestic market.[1] This chapter discusses the nature of imperial prospects during this period and how they set the agenda for subsequent design development and the communication therein. As such, it examines, firstly, the mechanisms of market identification and, secondly, the processes of technological identification to support potential design development and transfer.[2]

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It concludes by reviewing the nature of communication between and within the British industrial-economic and colonial contexts via the wider international financial and economic linkages of empire.[3] The earliest and most fragile stage of technology transfer is that of identification. It was one matter for inventors, engineers or entrepreneurs to recognise a potential context for a new or modified design; it was quite another to design and implement a viable solution, and later chapters will explore that process in detail.

We argue that three basic elements had to be in place before transfer or adaptation could be initiated. Firstly, how mature (a relative notion in its own right) did technologies have to be before transfer across the British and imperial contexts, and how did this affect the rate of adoption and adaptation of technologies? We ask whether there were any identifiable patterns, or whether it simply varied according to the technology and the metropolitan and imperial contexts in each case.[4] This informs discussion on whether identification was simply about recognising problems or inefficiencies with existing technologies in order to develop a market opportunity or whether there were broader, ideological, forces at work in the communication of design.[5]

Secondly, we consider the impact of the various colonial opportunities and restrictions. How did prospects find their way to the companies involved, and how proactive were they in seeking new outlets? This requires consideration of the communicative aspect of identification, highlighting areas of smooth or promoted transfer of design and technologies, but equally, examination of the blockages, interruptions or restrictions on this movement. Although representing overall a vast and multifaceted opportunity for those seeking to profit, the various imperial contexts (geographical, economic, strategic, financial) also presented a number of challenges, even in markets traditionally identified as 'soft', such as the dominions.[6] That restrictions and challenges applied can most obviously be seen in the extensive evidence found for activities in extra-imperial locations such as South America and Europe. These imperial restrictions were created due to specific colonial circumstances, such as war, economic depression and the growth of indigenous economies.[7] Lastly, we examine the impact of company ownership structures on the identification of design opportunities; that is, what were the institutional drivers of identification? Business expansion, survival and efficiency were key among these and shaped the subsequent collaborative design networks. We therefore explore the nature of these networks, including how they were defined according to factors such as class, religion or patronage, and whether these definitions changed according to time and place.[8]

Maturity of Technology

Communication was critical in assessing the relative level of maturity of a design or technology before its transfer. Our case studies demonstrate that while context was crucial, patterns do emerge. Identification could take place in Britain, or within the colonial context, and then be communicated back, or across and between Britain and the imperial territories.[9] There are countless examples of this type of complex movement, as with the development of animal-shearing technologies, which took place across and between Australia and Britain, demonstrating an intricate relationship between technology resources and context of use, and the circularity, rather than linearity of communication.[10]

Identification could also depend on the maturity of the technology itself – it could be well established and heavily utilised, or still emerging and limited in its range of application. Where the case study technologies described here sat on that spectrum depended a great deal on the designs themselves, the problems they were meant to tackle and the context, both British and imperial. In other words, the maturity of the existing technology was not the first concern, not least because there was not necessarily a link between the level of maturity and the speed of its application. What does appear to be crucial in this regard is the level of demand for a new or adapted design solution. It was this that set the pace of the communication, driven by priorities in the colonial context such as cost, labour, or power-saving requirements.

A relatively straightforward example can be found in the technologies around bridge-building, and in particular that of riveting. Of course, bridges have a long history with extensive geographical applications from classical times, and by the late nineteenth century, established designs and construction processes were in place. But innovations in structures, materials and construction techniques, not least the introduction of iron and steel, meant new adaptations and efficiencies were soon identified. Among these were innovations relating to mechanical riveting for greater working efficiency and speed, but also for the improved safety of workers – a growing concern in the context of increasing unionisation and governmental intervention on workplace safety and conditions. Workplace safety increasingly became a concern in the colonial context too, as evidenced by the renewal of patent No. 13471 for a riveting cage in August 1901, by Sir William Arrol & Co., the company which built the Forth Rail Bridge, in time for its work on an iron bridge over the Nile at Cairo to begin in 1902.[11]

Another example can be found in coin-minting technologies. Like bridges, minting was an ancient process, but an opportunity was identified early in the development of steam power for its application to the faster production of coins.[12] This process was spread incrementally over a 20-year period, and all took place in Britain under the auspices of a number of engineers and inventors, including James Watt, Matthew Boulton, Peter Ewart and James Lawson.[13] By March 1806, plans were coming together to supply up-to-date equipment from Boulton and Watt to the new royal Mint.[14] These technologies were later exported across the empire, from Bombay to Ottawa, meeting a demand imposed by the British state to support overseas minting capacity.[15]

One of the most common identifiers for design intervention was in the development of cost-saving technologies for imperial contexts, where high capital costs for equipment or materials and their importation and transport meant cheaper alternatives were required.[16] The sugar production industry in India gives us another example of an ancient technology already in place, which was diagnosed as failing to keep pace with the demands of the imperial economy, and for which an affordable solution for Indian cultivators had to be found.[17] Already in place – from approximately the fourteenth century – were pestle and mortar mills, the best of which were made of stone, but most of which were made of wood.[18] In the nineteenth century these were in decline, gradually being replaced by roller mills made by Indian artisans, at first in the southern regions of Gujarat and Maharashtra but spreading to the north too. However, these had disadvantages, requiring replacement every five years and being relatively inefficient in juice extraction, extending processing times.[19] To British officials in India, it was clear that this technology had plateaued and represented an opportunity for intervention. This came in the early 1870s through introduction of new materials rather than a fundamental change in the design, with the iron Bihea sugar mill made by a British firm, Thompson and Mylne in Bihea, India.[20] One of the Bihea mill's many benefits was that it was transportable, but more importantly it halved the work input from people and bullocks and reduced production time considerably.[21] It was a cost-saving adaptation made on the back of development and maturation in the colonial India context and was wildly successful, with around 250,000 constructed between 1874 and 1891.[22]

Local identification of opportunities was also evident in sugar crushing technologies in the West Indies. Again, the problems identified were around the capacity, speed and labour requirements of the existing mills, which from the mid-seventeenth century had been of a vertical three-roller design.[23] Work was slow due to the poor power capacity, as described by one visitor in 1794: 'The great obstacle at [crop time] to the planters . . . is the frequent failure or insufficiency of their mills . . . which is such a heavy and laborious piece of machinery that the heart sickens at beholding it work'.[24] As in India, several adaptations were made and patented locally but as they aimed simply at economising on the power required to run the mills, they were incremental in nature. This left an opportunity for more revolutionary developments, which came from British firms such as Smith Mirrless of Glasgow.[25] In the case of the West Indian sugar crushing mills, the geographies of motivation were centred in the West Indies, but the technological changes were transferred from Britain.

The sugar industry generated a number of technological innovations, as it became steadily more valuable from the eighteenth century. Both economic and technological opportunities were identified, such as that of vacuum pans, which converted cane juice into sugar. The essential innovation in this example was the way in which the vacuum pan reduced the boiling point of the cane juice and thus greatly economised on fuel, delivering a welcome cost- and power-saving adaptation to West Indian plantations. The identification of imperial applications and European (not strictly British) networks of information and ideas were crucial in developing this technology.[26] The inspiration for the new processes and equipment came initially from refineries in Europe and research in the sugar beet industry.[27] Although first developed and patented in Europe in 1813, the first sugar cane planter to use a vacuum pan was in 1832, on the Vreed-en-Hoop estate in Demerara. Faced with the economic ramifications of the abolition of slavery, an opportunity had been identified in the West Indian context to save on costs via technology, rather than labour, and the resulting design innovations were communicated across the British, European and imperial contexts.[28]

Even in what appear to be relatively straightforward examples of the movement of technology, the process of identification was geographically complex and could take place over an extended chronological period. This point can be developed in the case of Frederick York Wolseley and his work on mechanical sheep-shearing equipment. Although the initial innovation was made in Australia, the inventor returned to Britain in order to develop the technology to a suitable level of maturity, before taking it back again to the Australian market for the final development and distribution of his design. It was there he bought a large sheep farm near Walgett, New South Wales, to test and perfect the invention.[29] Wolseley had emigrated to Australia aged 17 in 1854, and along with many others working in the burgeoning sheep industry there, identified a key restriction in the volume and speed at which sheep could be sheared by hand. He therefore set about replacing the traditional shearing blade with a mechanical clipper. Wolseley was, however, not the only one working on the problem, with a number of horse- and human-powered contraptions in development at the same time.[30] Nevertheless, achieving a sufficiently reliable, flexible and powered clipper remained elusive. Wolseley returned to Britain in 1889 where he set up a new company that purchased the rights and patents of the Australian company.[31] It was in Britain that he had access to the engineering skills and industrial infrastructure that allowed him to refine the design and economically manufacture a machine, complete with a universal joint to allow movement around the animal and a stationary steam engine distancing the power source from the shearers, for export back to Australia. The intriguing story of its evolution and the persona of Wolseley were actively used to market the product, as illustrated by the advert in Fig. 2.1.

When considering the maturity of existing technologies in relation to the identification of design opportunities, the picture is both complex and fluid. Most of the technologies outlined here were long-standing, even ancient, in origin, and the adaptations being made were identified as meeting the particular needs and requirements of new contexts, or new drivers, such as cost or labour saving.[32] As such, they might be labelled incremental, rather than revolutionary, although the impact of the speeds and efficiencies that might be achieved via steam instead of human or animal power of course could have revolutionary impacts.[33]

Colonial Opportunities and Restrictions

Engineers, inventors and businessmen found there were a number of barriers in acquiring colonial business. It often required a proactive attitude: there are many instances of intrepid individuals taking long and

1877-1927

These 50 years have seen:

Mr. Wolseley's pioneer invention

A revolutionised shearing industry

Wolseley machines maintaining their supremacy

1877—FIFTY YEARS since the Patent was granted to Mr. Wolseley for a rope driven machine

1887—FORTY YEARS since the adoption of the friction drive machine

FORTY years ago this year! It was in the good old days before the crisis and the great drought. A group of distinguished citizens in top hats and pastoralists in low-crowned bowlers assembled in Goldsbrough Mort's wool store at Circular Quay, Sydney. Before their eyes machinery was achieving yet another miracle.

The late Frederick Yorke Wolseley—on the left with walking stick—demonstrating an important improvement

A photographer caught the scene and his very interesting picture appears above. It shows the reason for the gathering. The inventor of the shearing machine, Mr. Wolseley, is demonstrating a big improvement on his first design—the first introduction of the friction-drive principle.

Ever since these pioneering days, Wolseley has maintained an alert and progressive policy of improvement. The whole of this practical experience is incorporated in the Wolseley to-day.

Mr. Wolseley benefits both pastoralist and shearer

This occasion was a proud moment for the enthusiastic inventor, yet much more uphill work still lay before him, uphill work which has now been forgotten. The human elements turned out to be harder to conquer than mechanical ones. He had to convince the pastoralist of the advantages of the machine over the blades, which he did by showing that the machines obtained every ounce of wool from the sheep's back, and that the animals were less roughly handled Next he had to convince the shearers, which he did by showing that they could now do their work easier and more efficiently with a resulting increase in earnings.

Year after year of progress

Frederick Yorke Wolseley.

Mr. Wolseley's invention, from its infant years of 1887, was nurtured with careful study and scientific watchfulness. Everv year saw something done, some benefit gained from practical experience on the boards, until to-day shearing by machinery is recognised as the only safe and profitable method of harvesting wool for pastoralist and shearer alike. The evolution of the Wolseley machine from its initial stages in the eighties of last century has been gradual, thorough and complete, and the original design and measurements established by the late Frederick Yorke Wolseley have not been altered; rather they have been adopted as a standard and Wolseley truthfully claim and can substantiate having developed the most complete, durable and efficient machine of the present day.

An interesting comparison

Installations—old and new

It is interesting to go back to those old days and see the installations put in by Mr. Wolseley. They consisted of the overhead gear, tube and handpiece and in the earliest days were rope-driven as shown in Fig 1 overleaf. What a contrast with our modern installations, perfected by a half a century of practical experience!

Fig. 1.

Reproduced from—
WOLSELEY JUBILEE CATALOGUE
OF 1927.

Fig. 2.1 Reproduction from the Wolseley Jubilee Catalogue of 1927 arduous journeys to form relationships and secure work, both from established firms looking to expand on proven success, and nascent businesses looking to identify and secure a foothold in the market.[34] These were supported to some extent by the institutional linkages of the empire, as well as the personal and professional networks that operated within it.[35] But equally there were cases where restrictions applied due to specific colonial circumstances, and very significant activity took place in the extra-imperial world, particularly in South America and, of course, Europe.[36] This suggests that despite superficial advantages, not all the best business was identified within the imperial territories.[37] Rebellion, war, trade disputes and simple logistics such as small market scales and population shortages made some businesses baulk at the idea of developing an Australian or Indian market at the expense of, for example, the Austrian-Hungarian empire or the Baltic states. Likewise, easier opportunities could be found in South America or elsewhere where a more robust market for a particular design might have been identified. Indeed, until shipping technologies moved to steam power, combined with the opening of the Suez Canal in 1869, the logistics and costs of technology transfer to the East were considerable, whatever the design and market opportunities identified.[38]

This highlights an important point: the huge variation of colonial opportunity and restriction via the types of colonial enterprise, chiefly the various constitutional structures which impacted upon the effective communication of design issues.[39] In the dominions, for instance, settlers were operating within long-settled lands and societies of indigenous peoples, generating a unique range of both opportunities and restrictions. We can best understand technological transfer and adaptation in these cases as feedback loops, such as patenting and sales, from the dominions – although they also developed their own industries fairly quickly. These markets were hard for British companies to crack and not as ‘soft’ as claimed by some historians.[40]

The importance of relatively captive financial and commodity markets folded into the economic debate that raged during most of the imperial period over free trade versus protectionism.[41] British companies were supporters of free trade, which would allow them continued access to dominion and imperial markets.[42] Some companies went to surprising lengths to attempt to influence these debates, as in Australia in 1889, when an employee of John Fowler & Co. of Leeds requested £200 for election expenses from the firm so that he could stand as a member of the legislative assembly. As he argued, 'As the continuance of this business is to a great extent dependent on free trade, it must be in your interest to support that party.... I should be fighting the battle of free trade on your behalf, both on principle and by occupation.'[43] It is clear that the imperial territories were not unbound opportunities and that the wider political context and changing fashions in political economy could affect access significantly.[44]

There were other motivating factors for design engagement, however, even if these were less important than economic and financial sustainability. The empire – particularly the settlement colonies – could generate a kind of utopian appeal, one that played on images of abundance, virgin territories ripe for development via the application of modern technology.[45] This was in turn a reflection of experience in Britain and Ireland in the later eighteenth and early nineteenth century, when the mania of 'improvement' and, in the 1850s, High Farming gripped agriculturalists, inventors and landowners.[46] There was much in the way of romantic imagery around 'nature', while at the same time, an urge to develop it into a state of economic productivity.[47] In northern Scotland in 1869, the 3rd duke of Sutherland began a major land reclamation project using specially modified steam ploughs provided by John Fowler & Co., shown in Fig. 2.2. He had been inspired by the potential of his land. As one report he commissioned put it, 'We could not help thinking that what we saw was the Garden of Sutherlandshire although in a state of nature. We are satisfied that these places are not bringing the third of the rental they are capable of producing.'[48] This kind of language was applied overseas too, for instance in Argentina in the 1880s.[49] David Angus, an engineer working on the Buenos Aires and Pacific Railway in 1886, noted that 'We thought to ourself [sic] that if European statesmen were up to the mark these weary wastes of fertile land would be utilised to meet the wants of the surplus pauper population of Europe. Two hundred thousand paupers in London, if started in these camps, with a trivial outlay would convert the Pampa into a garden and this highly dangerous London element into a thriving, happy and prosperous people.'[50] One of the perceived opportunities of empire was the way in which technology could be applied, free from the normal restrictions of the metropole – in this case to address a shortage of agricultural land and perceived oversupply of people. But in the non-white empire, perceptions were different again, emphasising the plurality of experience. These colonies had smaller markets in general, although opportunities might arise over specific

Fig. 2.2 The Sutherland steam plough, with the 3rd duke at the helm

extraction industries, such as sugar or tea. The exception to this was, of course, India, which was regarded as one of the most important markets for Britain well into the twentieth century.[51]

How were opportunities and restrictions identified by businesses, engineers and designers on a practical level? As noted above, one useful tactic in identifying new business and design opportunities was in sending out employees to targeted territories to report on what they saw and meet potential customers face to face. John Fowler & Co. did just that in 1906, when it sent out R. H. Fowler to report on 'Asia Minor, Egypt and Cyprus' to examine the technologies already in use and thereby identify opportunities for expansion. An extract from one of his reports gives a flavour of his activities:

> As to Egypt & Cyprus … A cultivator and clod-crusher used as you describe are not in my opinion likely to produce good crops – The land is not broken deep enough to hold water long & it will be left very loose, & then sun will soon evaporate what rain soaks in in the wet weather…. Our difficulty in Egypt is that the cultivator is the only implement much used … [because] if

> land was ploughed in Egypt then cotton grew into fair-sized trees & did not yield half so much cotton as the low bush that grows on land cultivated and not ploughed.[52]

Magee and Thomson observe that the empire's settler societies were a particularly important market for Britain, identifying the tendency of consumers to become more 'wedded to the British product'.[53] While this phenomenon may have been more prominent in relation to branded consumer purchases, it was also a factor in the engineering sector for administrations when selecting suppliers for contracts. Business decisions were affected by practical factors including preferential trade agreements, established transport and communication links, and government policy. These decisions were ultimately made by individuals, however, and the engineers making them for local companies were usually British-trained, with over a thousand members of its professional bodies based in the colonies.[54] For these individuals, the attraction of maintaining interaction with the culture and institutions of the metropole, a pride in 'British made' and an implicit confidence of working with experienced manufacturers were also important. This helped buoy purchases of British products, equipment and supplies.[55]

Understanding local conditions and preferences was key to identifying imperial market opportunities, but this was often in tension with a prevailing sense of superiority of knowledge among British visitors and observers.[56] Their confidence in the transformative power of technology (alongside science and medicine) often led them to assume Western technological superiority was invested with 'civilising' power.[57] In India, John Fowler & Co. was supported by direct governmental promotion for the importation of their steam ploughs as early as the mid-1860s ('as the best suited to the wide plains of India') for 'European' use. Indians were assumed as not having the capital to buy the ploughs themselves, as had been the case in the Scottish Highlands. In the 3rd duke of Sutherland's land reclamation scheme, it was an orthodoxy that only a rich patrician landowner could afford to invest in such capital-intensive technology.[58] Design often followed the flag; for example, in the 1840s, the East India Company looked to develop cotton cultivation technology in order to set up a rival to the mighty American cotton industry, with slave labour fuelling growth.[59] India was always something of an exception, regarded as being a key plank in Britain's economy and the international economic system it had created.[60] It was entirely subverted to imperial needs, evident in the absence of protective tariffs and in a purchasing policy that stimulated British rather than Indian industry.[61] We can see this clearly in railway contract tendering, where Indian alternatives were not considered, making the colony a significant market for new British railway and locomotive design. As one Indian government official put it in 1864, 'There seems no reason why contractors should not be found in England to undertake the construction of the larger [railway] bridges on terms as favourable to the Railway Company.'[62]

Clearly, this represented an enormous opportunity for British manufacturers. The East India Company had provided a guarantee on the interest for investment in railways of 4.5–5 % from 1847, making it as safe an investment as could be obtained, and this system was continued under the Government of India after 1858.[63] This meant Indian railways secured British investment, but also that Indian taxes were being used to subsidise British technological investment.[64] Also, from a technological and design point of view, this guarantee meant there was little financial incentive for companies to economise in their production practices. This system also operated to prevent local innovation, as designs had to conform to standard types, while British firms also had little incentive to lower prices as they could rely on lobbying to keep their share of the Indian market. Headrick notes that 80 % of the total railway engines used in India (14,420) were built in Britain, equating to two-thirds of capital raised for Indian railways being spent in Britain.[65]

A good example of this can be seen in 1898 when unusually high demand from India meant that many British firms were unable to fulfil all of their orders. Railway companies in India therefore looked further afield to satisfy their demand, especially to Germany and the USA.[66] Alarmed at this trend and the potential loss of future orders, British firms appealed to the Secretary of State for India to intervene, in the hope that he could restrict outside access to the Indian market.[67] This he duly did, not directly, but by introducing a system of standardisation to the Indian railway system.[68] These designs were developed by the British Engineering Standards Association, and five models (4-4-0, 4-4-2, 0-6-0, 4-6-0 and 2-8-0) became the standard Indian locomotives.[69] This allowed British companies to build up stocks of parts in order to deal with any future rushes, but also interrupted both Indian locomotive production and international competition since firms had to win special sanction to build any non-standard machine, adding to their production costs for other countries and markets. In short, British industry was able to use the administrative framework of the Government of India to further its own interests and secure its market opportunity.[70]

India is a somewhat unique example in respect of the railway engineering opportunities described above, but there were opportunities elsewhere in the colonial empire. In Egypt, a market for bridges was established from the mid-1880s, and the Egyptian government, headed between 1883 and 1907 by Evelyn Baring, Lord Cromer, advertised contracts and encouraged British firms to compete.[71] He also set a precedent in holding meetings with company representatives, as reported to the board of Head, Wrightson & Co., the Teeside engineering firm who were competing to build a new iron bridge across the Nile at Cairo.[72] The opportunity was available for companies to develop business, and while they were advantaged in the sense that they had only to compete with other British companies, there was still an element of competition which drove innovation in a bid to win contracts.[73]

An East India Company-led programme of identification of technological gaps and inefficiencies in the refining of sugar drove the communication of technical knowledge in the 1830s and 1840s.[74] In some places and for some industries, the government actively encouraged (and thereby financially protected) design and innovation, for example in the Madras Presidency in 1839 which reported, 'the measure we had adopted for the encouragement of the manufacture of sugar . . . and recommending that mills of the most approved construction should be sent out from England'.[75] However, there is evidence of resistance from some British officials in India to developing sugar technology with general scepticism among colonial administrators as to whether technological change would ever penetrate the Indian countryside, given the existing levels of technological development and the undercapitalised nature of the agrarian economy. Exactly the same doubts were expressed about parts of rural Britain also.[76] This highlights again the restrictions imposed by assumptions of knowledge and expertise by many British individuals and institutions, which could act as a barrier to pursuing identified opportunities.

However, others saw non-commercial opportunities as a form of advancing the civilising mission of a humanitarian empire, although this too ebbed and flowed according to chronology and geography.[77] For example, a visitor to Jamaica in 1824 wrote in his journal, 'I was shocked today beyond measure at the inhumane, cruel manner Mr Spencer directed a poor old female Slave to be punished. . . . I am of opinion that much manual labour might be saved in this country if the Plough was introduced in place of the Spade.'[78] Similarly, John Fowler, the inventor and developer of the steam plough, was first inspired to begin his work by a trip to Ireland in 1848 as part of a Quaker delegation, at the height of the Great Famine. Horrified by what he saw, he determined to develop the steam plough design to cheapen the production of food.[79] Design for the greater good was also evident in an 1807 proposal to build a 160-mile long canal from Calcutta to Palmura to reduce the dangers of the Hoogley River, which was responsible for the deaths of 'not less than 200 Persons annually drowned by ship' or killed by 'Tigers after getting onshore'.[80]

Scarcity of food – or safety from tigers – was not the main driving force in identification of opportunity or restriction; we must also consider the relationship between innovation and the presence of labour in the colonial context. Sometimes, designs that required significant labour forces could be introduced because in the colonies (as in the British context), labour was cheap or even free, as in the case of slave labour in the pre-abolition West Indies.[81] But in many other instances, labour and population shortages were the biggest issue facing industries, for example in the tea plantations of Ceylon in the 1870s. These plantations faced acute labour shortages and had instead to make heavy capital investments in machinery.[82] Interestingly, according to a pamphlet on tea-planting in Ceylon from this period, the author assumed that only in those areas of labour scarcity would a plantation find it worthwhile financially to import machinery, indicating that it was not always wise to rush towards the latest technology.[83]

It should be clear from the foregoing that the relationship between colonial opportunities and restrictions was a complex one, and which changed according to geographical and chronological context. Some products and technologies had straightforward imperial applications, for instance in the export of steam-powered minting technology to imperial locations.[84] However, just having a nominally captive market did not mean the battle was won by companies; they still had to compete with other private enterprise, both British and European. A Ransomes, Sims and Jefferies Ltd representative working in India in the 1870s highlighted the pressures of even limited competition when he reported, 'I am sorry to say that your name [Ransomes] is altogether unknown in these districts, while Claytons seems to be known everywhere. This is the result of long & careful advertising and the working up of the trade in various ways. Whether you would care to take all this trouble I, of course, do not know, but without it no trade can be got here.'[85]

Likewise not all British officials were convinced that British-designed and -made products were for the best. One report from 1864 to the India Office outlined the perceived obstacles to agricultural development: 'I have had great difficulty in finding anything well suited to the wants of the Indian ryots [sic].... I would urge the Government to allow me to seek for tools and machinery in America, or the poorer parts of Europe, as being countries more likely to supply what is required. The implements of England are too heavy, and too costly, to be taken up by the cultivators of India.'[86] Too *advanced* seems to be the subtext here, particularly as he went on to report that steam ploughs were required for European farmers in India, and recommended John Fowler & Co. models for them. Potential opportunities could, therefore, be restricted by assumptions made as to what the market – the users – could cope with. Further factors of uncertainty in geographically distant markets included labour forces, operational knowledge and investors' jitters. When combined with wider political and economic contexts and changing ideas as to the purpose of empire – which at times encompassed economic and humanitarian concerns and the translation of the 'benefits' of empire to colonised peoples – the opportunities were often far from straightforward.

Ownership Structures and Partnerships

The companies and engineers behind the identification of imperial opportunities were driven by pragmatic concerns such as efficiency improvements and routes to expansion. Ownership structures and partnerships, however, formed an overarching concern. How open were these networks and how were they defined – by class, religion, opportunity or patronage? And did any or all of these factors effectively close networks to 'outsiders'?[87] The global and colonial scale of buyers' networks in the wider British World can be demonstrated in the records of almost any company: to take one example here, Sharp, Stewart & Co., whose order books included the Darjeeling Himalayan Railway, the Swedish & Norwegian Railway, the Bengal Nagpur Railway, the Valencia & Tarragona Railway, the Baden State Railway, the Tasmanian Government Railways and the Demerara Railway.[88] In the creation of these extensive networks and their resulting business generation, we argue that a range of different types of networks were in place, including professional, information and social networks, all of which contributed to the identification of market opportunities.

There is no doubt that part of identifying opportunity was patronage and social connections. The politically or financially powerful could make the difference between commercial success – or at least an opportunity to bid for that success – and failure, due to being locked out of the market.[89] An example of social influence, first British and then international, can be seen in the development of strong working and patronage relations between the 3rd duke of Sutherland and John Fowler & Co. The 3rd duke was one of Fowler & Co.'s most important customers in the 1870s, and not simply because he purchased eight steam plough sets for his own land reclamation projects.[90] It was in Egypt, on the banks of the Nile, that the 3rd duke first watched a demonstration of steam ploughing undertaken by Max Eyth, a German employee of Fowler & Co. The 3rd duke was inspired to import the technology into his estates in the far north of Scotland, working closely with senior Fowler employees, including Eyth, Robert Fowler and George Greig.[91] Cain and Hopkins' influential thesis of the 'gentlemanly capitalist' and networks as key drivers of imperial investment and identification of opportunity are certainly in evidence for the 3rd duke; he was rich and well connected, and a keen proponent of investment and 'improvement' overseas.[92]

The network supporting Fowler & Co. was not only British, but contained an international dimension too.[93] One of the most important of Eyth's activities on behalf of the firm was for their overseas operations.[94] He worked closely with the 3rd duke of Sutherland, and this relationship garnered the firm important contracts elsewhere, such as for the Italian statesman Garibaldi, a personal friend of the duke, who had been recommended to John Fowler & Co. to fulfil his bold visions of steam cultivation in the Po Valley in northern Italy.[95] Eyth also travelled to France, Poland, Russia and Prussia; he was joined in this travelling by Robert Fowler and David Greig, who were in the vanguard to help drum up overseas business for the firm. [96] This effort would pay off in the early 1900s as the Fowler business boomed in Europe, Australia and South Africa.[97] As noted earlier, and is evident here, these networks also operated in extra-imperial contexts, and these would often form the platform from which imperial developments could take place.

Another example can be seen in the career and networks of Rookes E. B. Crompton (b. 1845, d. 1940), a pioneering electrical engineer and designer of steam road machines with a wide range of influential patrons and contacts – military and civil – including a viceroy of India, Lord Mayo. He also met the duke of Sutherland and the duke of Devonshire while testing his road steamer in Britain and was visited by Sir John Fowler.[98] In his *Reminiscences*, Crompton's passion for invention is evident, and he describes how he demonstrated these inventions in India before receiving the post of superintendent from the government and a position in Ransomes, Sims & Jefferies Ltd.[99] We can trace here the professional network linking Crompton to Ransomes, Sims & Jefferies Ltd, illustrating that the distinction between professional and buyer's networks could often be blurred.

As well as social networks, professional networks came into play, particularly in the partnership structures within and between companies. Mergers took place frequently, as did collaborative working between companies without formal mergers to bid for and complete contracts. These could be of mutual benefit for reasons of competitiveness and capacity. For example, in 1907, Sir William Arrol & Co. and Head, Wrightson & Co. combined forces to submit a bid to build new bridges in Egypt.[100] Overseas agents and representatives also played a key part in identifying market opportunities and in many cases directly facilitated the communication of design. British companies often used this model as a way of establishing themselves in a local market, as the partnership records in companies such as John Fowler & Co. demonstrate.[101] The model appears to have resulted in mixed success; many agents struggled in their positions, suffering from a lack of support from their parent companies in Britain and some failing to successfully represent the firms, for a variety of reasons.

In this type of 'man-on-the-spot' model, much depended on 'character' and the approach of individual agents in securing the reputation of the firm and making good on the market opportunity identified.[102] Two examples can be given here, both from overseas agencies run by John Fowler & Co. The first comes from the Bombay branch of Fowler & Co., run by Philip Johnson, who wrote to the Leeds headquarters in 1910 with bitter complaints about his colleague, Mr Goode.[103] Goode's main fault was a poor manner towards customers, particularly, 'native customers' of all ranks, with Johnson claiming 'that Mr Goode's attitude to the Maharajah of Gwalior and that alone is responsible for the lamentable relations between him and our firm'.[104] Offending a rich and powerful potential client was damaging for business in the Bombay Presidency overall and this adds an interesting additional angle to the discussion around the importance of 'gentlemanly capitalism' and how class could become a marker or driver of imperial networks. Fowler & Co.'s South

African agency had similar problems with a Mr Ritchie, who, as well as having a poor manner with potential customers, actually lacked the required technical skill in demonstrating the steam ploughs he was tasked with selling.[105]

In addition to agencies and partnerships, there are also the professional networks to consider, such as the Institute of Civil Engineers, an important clearing house for design and engineering information from across the globe.[106] Likewise, the publication *The Engineer* was widely read and contained a huge amount of technical detail, case studies and innovations for its readers to consider, and perhaps apply to their own projects. As the coverage of this journal demonstrates, engineers might be just as influenced by European technology, ideas and personnel as their imperial and British counterparts. We can therefore surmise that professional networks operated in ways that meant empire was only one factor in the dissemination of technical knowledge, practices and connections.

Conclusions

Different processes were used by businesses, engineers and inventors to identify opportunities in both domestic and imperial markets and to support the development and transfer of appropriate technology. Some of those processes began in Britain, as designs matured enough to facilitate the transfer and adaptation required for overseas application. Many, however, began in the imperial territories themselves, as individuals and agents identified gaps in the design world of new colonies and territories, or were invited to address issues identified by the administrations of those territories. This was made possible via the supporting structures of global British economic and financial systems, which constituted the institutional, economic and financial linkages of empire. Perhaps unsurprisingly then, the model of 'gentlemanly capitalism' becomes relevant in the identification of design opportunities; rich and influential elites, both British and imperial, were key sources of patronage, connection and business. British industry did not have it all its own way, however, and the empire threw up as many restrictions as it did opportunities, as evidenced by the importance of non-imperial international markets to most of the companies examined here. The next chapter will explore what happened to those opportunities which, after being successfully identified, progressed to the next stage of the design process to be more fully defined.

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CHAPTER 3

Defining Specifications – The Requirements of Empire

Abstract This chapter examines the definition of design specification, the stage of design development where the technological need for adaptation has been identified, and the collaborative process by which designers or engineers settled on appropriate design characteristics and targets. The three key areas this chapter explores are, firstly, the technical requirements of design specification; secondly, the customer and user requirements and lastly, the nature of competition and its effect on the specification process.

Keywords Design specification · User requirements · Colonial administration · Competition

Introduction

This chapter examines how communication underpinned the stage of design specification. This is where the technological need has been identified, and engineers or companies describe it according to the technical, environmental and user design requirements, and within the context of existing competition. Here, it encompasses the processes by which specification was communicated between and within the British industrial-economic and colonial contexts. As we have seen, the identification of market opportunities for new or adapted design occurred via a multitude of channels across the British World.[1] This chapter takes the same approach, with the emphasis lying on the fluidity of the colonial

A. Tindley, A. Wodehouse, *Design, Technology and Communication in the British Empire, 1830–1914*,
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world and the forms of interaction within it in undertaking design-related activity.[2] This requires a 'decentring' of Britain and Europe within the analysis to explore the ways in which both regional sites in Britain and the colonies were locations of development for new and adapted designs – and not simply a dumping ground for either mature or obsolete technology.[3] This allows us to identify which technologies actually mattered to colonial societies and which did not, a point we will consider further in the conclusion.[4]

In order to develop our picture of the communication of specification we return to the idea already advanced: that design acted as a conduit across imperial and British networks. To do so we firstly, and perhaps most obviously, examine the translation of market opportunity to technical specifications. In some cases the impetus came from a technology that was not working as well or efficiently as it might, or indeed there may have been no pre-existing technology at all. Sometimes, the existing technology was working perfectly well, but was regarded as primitive or backward according to the norms of colonial knowledge at specific times.[5] Either way, the technological specifications had to be developed and communicated within Britain and the imperial territories, but as often, across non-colonial possessions, including Europe.[6]

Secondly, and related to the technological specifications, were the customer and user requirements for new or adapted design, requirements that could span the technological, financial, political and strategic. These could vary significantly: sometimes the customer might be a colonial government or administration, and the users small farmers, cultivators or labour forces, as in imported plough designs in South Africa, Egypt and India.[7] Another example might be individual plantation owners in the West Indies purchasing sugar mills and vacuum pans to increase productivity and profit from their land, but those mills being operated by enslaved labour forces.[8] In the majority of cases collated here, the customer and users were separate, and much of the discussion and activities around the specification of design was between companies and colonial administrations, with communication between engineers and users coming at a later stage.

As such, we separate out the customer and user requirements and include a related discussion on the processes of contract tendering and the creation of estimates as forms of communication. In some cases, particularly those that focused on major industrial or infrastructural projects, the process of identification was undertaken by administrations, and the first stage at which inventors, engineers and companies joined the network of design communication was during specification. These were often developed through tenders and estimates to win potentially lucrative contracts.[9] This process of tendering for contracts is linked to competition and is the third element of focus in this chapter. We discuss competition in a range of forms between different businesses across the British World. Of particular interest are the ways in which design information was communicated through prizes, exhibitions, demonstrations and marketing strategies.[10]

Technical Specifications

How were technical specifications derived for the colonial contexts? There may have been an existing technology that was not working well, or no pre-existing technology at all, and an opportunity to address this through new design.[11] Alternatively, there may have been a pre-existing native or vernacular technology that already worked well but was not regarded as efficient by British observers – in which cases tensions between colonial knowledge and assumptions of the superiority of Western or European technologies came into play.[12] Or there may simply have been an opportunity to bring a new or adapted design to a relatively captive market, often via a government contract, to make a comparatively risk-free profit.[13] No matter how they were instigated, what design specifications often amounted to was the potential impact of specific environmental conditions on technical operation. For example, those engineers looking to build imperial India's network of bridges could face very challenging climatic conditions, which went a long way in defining their configuration. Charles Greaves, an engineer visiting India, reported in 1852 that 'The whole of the Bengal plain is nothing but a sea of mud, there is hardly a stone as big as a coconut or a hill as high as a house.'[14] Clearly, these environmental conditions were challenging and were compounded by the way in which major rivers could change course with the seasons, the monsoon contributing to this difficulty. Often the problems of specification did not come from designing new or adapted bridges, but in developing technologies to build the bridges in these conditions. Additionally, engineers had to work with the construction materials available to them in the colonies, where materials they were used to working with could not always be imported for practical or financial reasons. The specification of local materials and appropriate adaptations was, therefore, crucial.[15]

As part of the process of specification, some companies sent engineers on site visits to build a picture of local conditions, existing technologies and available materials. For instance, the agricultural machinery manufacturer John Fowler & Co. of Leeds sent employees to investigate practices and conditions in imperial (and non-imperial) territories in order to specify the technical requirements for new designs. We can see this in 1904, when Fowler & Co.'s agent for Egypt and Sudan, Alderson, was advised by a colleague at the Leeds headquarters that 'when new buyers come along you should always suggest as a preliminary and before submitting any estimates that it is always wise to have an expert go over the land & see for himself what are the best implements to supply.… It puts you into a much better position when you come to put the dots on the I's… & gives confidence to the buyer.'[16] Visits and surveys were an essential component in determining design specifications where these might be significantly affected by local environmental and climactic conditions, or traditional practices and vernacular design.[17] Some firms were able to use this knowledge to their advantage and tailor their design specifications accordingly.

An example of major technical system design decisions being made due to specific environmental requirements can be seen in the famous case of railway design in India. In late 1850, the East India Company decided that the railway gauge in India should be broader than that in the UK, due to fears over the stability of locomotives on lines passing through cyclonic winds. The gauge was agreed at 5 foot 6 inches, a decision made possible by the fact that railway technology was new to India and not replacing or extending an existing system. This decision was made at a high political level, and as such, the specification was clearly communicated to engineers and manufacturers in Britain.[18] The Indian Public Works Department made it explicit, for instance, during the tendering process for the construction of the Delhi railway in 1863–4, that all expertise and a good deal of the materials were expected to come from 'England'.[19] That this expectation was met can be seen in the technical records of Sharp, Stewart & Co., demonstrating that they were manufacturing locomotives for broad gauge railways in the Atlas Works, Glasgow, in the 1880s.[20] Of course, not all railways built in India met these centralised gauge measurements, particularly the mountain railways, such as the Darjeeling Himalayan Railway, with different and specific environmental conditions resulting in the narrower 2 foot 0 inches gauge.[21] A typical example of the highly distinctive engines developed for this line is shown in Fig. 3.1.[22]

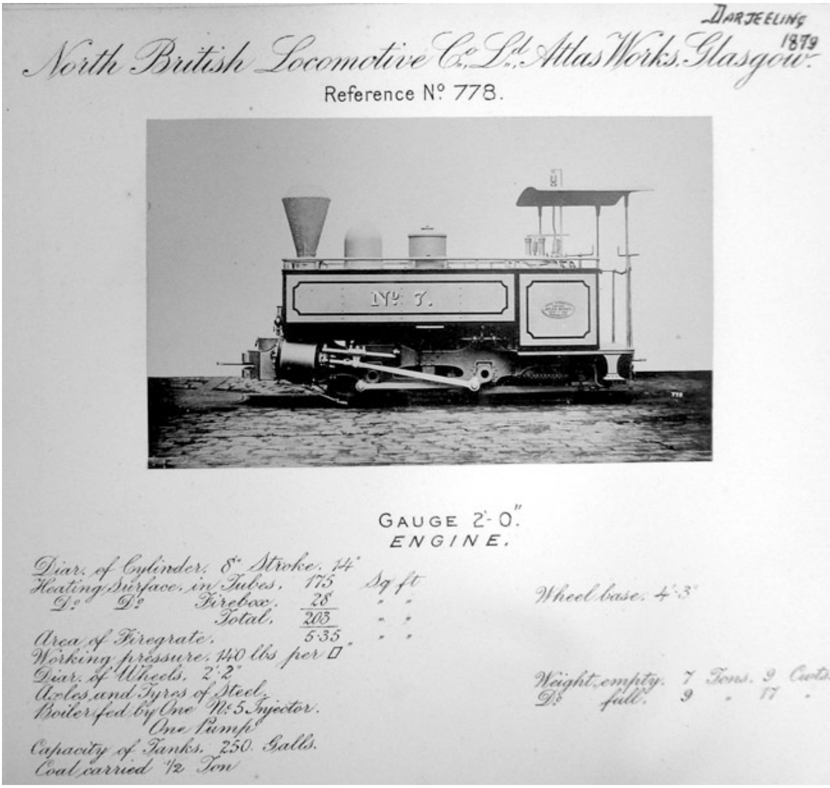

Fig. 3.1 Engine No. 7 for the Darjeeling Himalayan railway, with technical specifications

Built by the Atlas Works in Glasgow in 1879, the 'Toy Train' nickname they acquired over the years is unsurprising, given its diminutive stature and uncomplicated appearance when compared to the archetypal powerhouses of the era.

Engineers in India working on railway technologies – including approximately 116,000 bridges of all types and spans required to support them – recognised the importance of meeting the technological specifications by overcoming environmental challenges via design. These simply had to be met for a design to be viable. As Colonel J. P. Kennedy reported in 1854, 'All I maintain is, that the rivers and nullahs [a water course or ravine] in these districts [Tapti Valley] are like the rivers and nullahs in other districts of India, and that the engineer who is not prepared to deal with such obstacles had better turn his back upon India altogether. They are assuredly the chief subject requiring forethought and caution in the execution of public works in this country, and upon the mode in which we deal with them will depend the broad questions of whether our railway operations shall succeed or fail.'[23] Although specific environmental challenges required bespoke design specifications, their principles could potentially be applied in other locations with similar conditions, thereby spreading the cost and increasing profit margins. In describing these scenarios of use and their associated parameters, an exchange of correspondence was created, becoming a conduit for the communication of design. Developing design specifications was, therefore, an important stage in increasing the sophistication and detail of information shared by participants in the process.

Sugar crushing provides a good example of an evolving technical specification aimed at improving an existing technology's performance. Through most of the nineteenth century, the machines in use on sugar plantations were of the single mill type, which gave a relatively poor cane juice extraction percentage of around 65%. By 1885, four roller mills were imported from Smith Mirrlees of Glasgow into British Guiana which gave three crushings, and by the late 1890s almost all estates in that colony had double or triple crushing mills.[24] We can see a very similar process occurring in India in the 1850s.[25] A clear goal was set in these cases – to improve the extraction performance of sugar mills and therefore of profit – and this was communicated from the imperial to the British context, but also across the intra-imperial context of the West Indies and India.

The technical specifications changed dramatically according to the geographical context in question. The two most important factors considered here were environment and colonial knowledge, particularly when engineers were being asked to adapt an existing technology to a new climate or culture.[26] Specifications had to be developed according to differing environmental conditions, be they monsoon flooding or soil differentials. Likewise, when drawing up specifications, designers could not ignore existing vernacular technologies or preferences – or at least, could not ignore them if they hoped to be commercially successful.[27] They were also constrained by the materials and construction technologies available in the imperial context, and the type and cost of the workforce who might be expected to build, fabricate or assemble (as well as use) technologies once they reached their target market.[28]

Customer and User Requirements

Although intimately linked with technological specification, customer and user requirements can usefully be disaggregated and discussed. In particular, this relates to the specifications set in the contract tendering process and the development of estimates by companies bidding in those processes. The tendering process facilitated the translation from the identification to the specification stage in our framework, as engineers were required to outline exactly *how* they were proposing to meet an agreed need, such as a new bridge or railway line. They were in competition with other companies based not just in Britain, but increasingly during this period from the imperial territories themselves, as well as European, American and Japanese competitors.[29] We therefore consider the growing imperial industrial sectors, particularly in the settlement territories and dominions.[30] Historians have traditionally argued that these were 'soft' markets, where British firms and engineers could exploit the relative technological 'backwardness' or lack of engineering capacity they found there. More recently, Thompson and Magee have demonstrated that this was not always the case and that these could be difficult and demanding markets, albeit ones from which British firms could collate feedback in order to successfully adapt designs. In some cases this led to working with locally based engineers and inventors who understood the environmental and customer specifications more clearly, as in the case of Frederick York Wolseley's mechanical sheep shears.[31] It is clear from Thompson and Magee's work that dominion markets could be critical and canny and that consumers would look beyond British goods to secure better quality or lower prices.[32]

One manifestation of the fact that the dominions and settlement colonies were far from 'soft' markets can be traced through the wider political and global financial context. Shifts and trends in the increasingly globalised economy could throw even successful, established businesses off course; see for instance the impact of the debate over free trade versus protectionism in the late nineteenth century.[33] This was a hot topic in the British domestic context, and one which was rehearsed in the dominions too, much to British manufacturers' concern.[34] On the other hand, these events could be favourable and provide something of a leg-up for companies and industries. For example, on the outbreak of the American Civil War in 1861 John Fowler & Co. scented an opportunity in the nascent cotton-growing industry in Egypt, particularly as at the same time a serious disease was affecting draft animals in the Nile Valley.[35] These two circumstances combined to create a promising setting for the company to advertise its steam plough design and break into this market.[36]

As suggested previously, Egypt was a key market for a range of industrial products. It lay under British control from the 1880s and contracts were issued by the administration there for major engineering projects. This was an advantage exploited by British businesses.[37] A clear overview of the context was key to bids made by British companies, including non-technical issues such as pricing, conditions of work and legal liability, as we can see in the records of Head, Wrightson & Co., which teamed up with Sir William Arrol & Co. in order to bid for the contract to build a series of bridges across the Nile.[38] The development of preliminary designs did not always lead to the pursuit of contracts, however; sometimes a fuller investigation of the design requirements led to a rejection of projects. For instance, Sir William Arrol & Co. decided against competing for the contract for the design and building of the Sydney harbour bridge, Australia, because after costing out their designs they judged they did not have the staff capacity to support the work if successful. 'That we have so much work on hand', it was minuted, 'and that if we were to go in for this Contract and secure it, we would have our engineers taxed to such an extent that we would require to drop the connection we have in this Country [Britain].'[39]

The Nile bridges were quite another matter, however, and despite the challenges, Sir William Arrol & Co., in partnership with Head, Wrightson & Co., began developing the specifications for the design and build of these for the tender competition in 1905.[40] The main bridge between Rodah Island and Old Cairo is shown in Fig. 3.2.[41] Their engineers and designers found it very difficult to draw up the specifications and costings given the 'extraordinary and changing nature of the bed of the river', which meant the pillars of the arches would have to be sunk very deep.[42] However, they did eventually submit the tender, costed at £477,605.0.0, and it was successful due to (according to the official company history) 'its merit, particularly in the details of foundation work, the symmetrical proportions of girders and fascia

Fig. 3.2 Bridge across the Nile from the island of Rodah to Ghizeh, designed by Sir William Arrol and Co., 1909

work, and the conformity of the decorative features with Egyptian art'.[43] This included the design of the masonry pilasters at the entrance to the bridge, with a space provided for 'suitable statuary', if deemed appropriate by the Egyptian authorities.

Another example of designers and engineers deriving specifications to meet contractual demands can be seen in the career of the engineer and pioneer of road steamers in British India, Robert Crompton. This time, the environmental specifications looked promising, Crompton noting in 1879 that 'the Grand Trunk Road is laid out with easy and regular gradients, its metalled surface is smooth and well formed and consolidated. Hence it is not unreasonable to expect that, if higher speed traction engines could be made successful anywhere, they would be so under such favourable conditions.'[44] These conditions were all the more welcome, given the other contractual demands made by the Government of India for the development of these steam-powered road vehicles: 'One of the stipulations of . . . the Indian Government, when the former tendered for the supply of four high-speed road steamers, was that one engine at least should, as a test, travel a distance of several hundred miles, drawing behind it a load.'[45] Crompton therefore had to specify his design around reliability and power. Minting technologies provide us with a classic area requiring government contracting, although the specifications often related to reliability and longevity, as met by Boulton and Watt's 'new steam presses'. These mechanical steam-powered presses offered tremendous savings in labour costs, making redundant the teams of men who had traditionally been employed to swing the heavy arms of the screw presses.[46] Once this basic design was in place it was ready for export, but each contract demanded a new set of specifications and estimates according to the relative costs of manufacture, export and long-term operation.[47]

Boulton and Watt were also heavily involved in designing sugar technologies in the 1820s. Detailed records of cost estimates and initial specifications for the production and fitting of sugar crushing machinery, including estimates for specific plantations and estates in the West Indies, illustrate what was possible in terms of specification without access to the actual sites the machinery was destined for.[48] However, one of the chief obstacles to demonstrably superior technology failing at this stage was the heavy capital investment that many required. As well as the initial purchase, this included running, labour and repair costs. For instance, although the re-developed sugar vacuum pan had the potential to accelerate the speed and quantity of sugar manufacture, it was calculated that to equip and manufacture a thousand hogsheads of vacuum pan sugar a capital outlay of £40,000 to £50,000 was required. Perhaps not coincidently, in 1872 there was only one vacuum pan in use in Jamaica, on the Albion estate.[49] Of course, as discussed in relation to railways, this obstacle could be alleviated if government contracting or subsidies were on offer. Likewise, not all designed efficiencies had to be this expensive or revolutionary. Consider the activities of John Fowler & Co. in (non-imperial) Cuba, where they were working to develop a 'Scheme of Cane' in the mid-1870s, whereby small locomotive engines on tracks would be established to replace the mules and oxen traditionally used to move sugar cane around a processing site, in an incremental improvement to efficiency.[50]

One of the key requirements for the users of any technology was expertise in operation, and this had to be factored into the specification of design too. Having men 'on the spot' to demonstrate the workings of the technology to support customers once they had bought their machines could mean the difference between winning a contract or not. For example, a report by an agricultural engineer working for the Government of India in 1913 notes that of all firms, he would most recommend John

Fowler & Co. 'not only because they have longer experience and make more varieties of implements than other firms, but also, and chiefly, because they have a branch in Bombay with expert men of long experience in charge and are thus able to deal with all matters on the spot'.[51] This helps to explain the business sense in companies setting up branches and partnerships all over the world. Establishing these satellite offices entailed the utilisation of local administrative structures and workers, adding another level of communication infrastructure. In addition, protocols were developed, thickening the institutional context and leaving legacies even when the product became obsolete.

We can trace an interesting example of this particular requirement in the introduction of dredging machines in India. In 1875–6 a correspondence within the Government of India as to an order of engines to run dredgers from J. & G. Rennie of London highlights that they had not worked well, and neither had the operator or 'Mechanic' who had been sent out to run them. As such, one correspondent argued that 'We would also take this opportunity to suggest that, in future, in selecting firms for supplying dredgers etc., only those should be invited to tender who have been known to build many of the kind required, and are consequently experienced in the work.'[52] We can surmise there was a growing recognition by this period that there was no point in asking untested companies to reinvent the wheel and that the extent of government influence in business development was crucial in the specification of design, with the detailed demands of each contract driving its formulation.

It was not any easier when dealing with private clients, however. Take the experience of A. Fowler, sent by his firm, John Fowler & Co., to Abyssinia in 1905–6 to meet the emperor and attempt to open a line of business with the country. This was no exercise in the simple application of British technology, and the emperor had very clear ideas about what he wanted from the design specifications. 'I have now finished my interviews with [Emperor] Menelik,' wrote a weary A. Fowler. 'The interpreters were very clever but it is a very difficult thing and tiring to discuss mechanical points with such a man. He wants impossible things like a child and it was most difficult to get him to leave such points with me. However it is now settled and we shall send him some road rollers and a stone breaker.'[53] Ransomes, Sims and Jefferies Ltd tried a similar tack in India, where it sent an employee to report on potential opportunities. He was very clear as to the kinds of plough design specifications the market would bear: 'the implement wanted here must not have an iron beam. The natives will not look at it for a moment; it must be made of wood so that they can repair it themselves easily.… It should then be sold in Bombay for about £4.10.0 and in that case I think there is a tremendous opening for such a plough.'[54]

Both the customer and user requirements bearing down on design specification were complex and occasionally contradictory, and alongside the technical and environmental requirements, set a stiff challenge for nineteenth-century engineers and businesses. This is not to play down the range of opportunities offered via imperial governments and contracts: these were key to the growth and success of some companies, although monopolies could develop too, freezing out others.

Competition

We have already discussed competition across a range of formats, including competition between businesses for contracts. Here, we expand that focus and examine business marketing techniques, official prizes and competitions set up to support and encourage new design along specified lines, as well as exhibitions and demonstrations of new or developing technologies. We also consider just how far, and in what contexts, the inherently unequal nature of imperial power structures gave an advantage to British firms bidding for contracts against competition from within the imperial territories and internationally, against European or American companies. The obvious example is Indian railways where all the main engineers were British, trained in Britain and part of British professional networks. Additionally, being part of a wider British world, including its professional, class, religious and information networks, was instrumental in access to and influence on design specification.[55] We might also ask whether only the richest social elites both on the British and colonial sides, or the most powerful institutions, such as the various arms of the British state and colonial administrations, were able to lever business.[56] We have already cited examples featuring the 3rd duke of Sutherland and the emperor of Abyssinia in the promotion of the John Fowler & Co.'s steam plough. But how typical are these? These questions are addressed with reference to the openness (or not) of competition in the development and communication of design specification.

Despite the inherently unfair nature of imperial power structures, companies still had to work hard to generate business. In many cases, they did this by developing specifications around the local and colonial context they hoped to sell their products in. Some companies limited this process to marketing and sales techniques, such as the North British Locomotive Company, whose representatives carried trade cards when they visited railway companies and would show them as a way to garner orders.[57] Most companies developed detailed printed catalogues, and the naming and marketing of their machinery was targeted at the imperial market, with Ransomes, Sims and Jefferies Ltd leading the agricultural technologies pack with their 'Colonial' plough, aimed principally at Egyptian cultivators, and their 'All Conqueror' disc plough, marketed specifically for South Africa.[58] Unsurprisingly, there was fierce competition between firms to make sure the right people saw their advertising; one Ransomes, Sims and Jefferies Ltd employee noted that 'the advertisements are seen by the Political agents & Engineers of the various states [of India] & Engines are bought from them in consequence'.[59] These catalogues could be far more than simple advertising; they were also used to celebrate the success and longevity of firms, as in the Wolseley Jubilee Catalogue (1927) shown in Fig. 2.1, celebrating 50 years for the sheep-shearing firm.[60]

John Fowler & Co. went a step further and, as they had done in parts of Britain, set up a model farm in South Africa to demonstrate the efficacy of their steam ploughs and, they hoped, to increase sales.[61] These activities were an important communication route towards developing specifications collaboratively on the ground. If potential clients were able to see the existing capabilities of the technology in situ, they could much more easily make the next step of communicating local requirements based on environmental, social and logistical needs. The model farm was also an instructor area, where clients could learn how to use the technically challenging machines.[62] This approach cost the company a good deal, however: between 1910 and 1913, the South African model farm made a total loss of £19,667, balanced against a profit from the South African agency business of only £3,260.[63] Reflecting back on the venture in 1916, R. Fowler wrote to the Sydney branch that 'The Farming venture [in South Africa] was you know a great expense, and the expense was altogether too high for advertising or education.'[64] By the First World War, the volatility of world markets and the delicate political situation between Britain and South Africa had taken a toll; the venture was seen as too expensive and not worth further investment, despite the potentially lucrative nature of the South African market for agricultural machinery.[65] Another reason for this may have been the choice of demonstrator, Mr Ritchie, whose poor customer skills and surprising lack of technical competence in demonstrating the steam ploughs were clearly losing the company business, emphasising again the importance of the ability and attitude of the 'man on the spot'.[66] Other demonstrations were more successful; for instance, when Robert Crompton in 1873 gave a demonstration of his steam road machines at the military manoeuvres at Rawalpindi, which so impressed Lord Roberts (later the commander-in-chief of the Indian Army) that over 25 years later Roberts chose Crompton to take charge of the Mechanical Transport Section in the South African War.[67]

John Fowler & Co.'s poor return on the South African scheme was not replicated in other imperial territories. The company was immensely successful in Australia, and a large part of the reason for that success was the identification of local specifications and the development of additional tools and designs. For instance, the 'excavating scoop' created large water storage ponds or reservoirs for Australian sheep farmers and came with a long list of competition awards. These were clearly important endorsements in helping differentiate their designs.[68] Other companies opened up opportunities to develop design specification in similar ways, for instance Head, Wrightson & Co. of Teeside, who were bidding for contracts all over the British world, in Egypt, Australia, India and Canada for bridge building, and in East Africa for stamp mills.[69]

In many cases, prizes, exhibitions and competitions were set up to generate designs to meet user and customer requirements in the quickest and most economical way. There are several examples of government-sponsored shows and prizes in India in the 1860s; for instance, a range of prizes were available to exhibitors in the Nagpore Exhibition 1865, as reported in the *Central Provinces Gazette*: 'In delivering the medal award [for the "Machinery and implements" category] to Messrs Platt, the Chief Commissioner remarked on the excellent working of this machine, as seen at the Exhibition, and on the desirability of adapting it for the use of the cotton districts of these Provinces.'[70] This exhibition – held in the colonial context, not the British – had clear imperial overtones, as a speech made at its opening suggests: 'An omen of progress to this part of the country, and a proof of the extent to which European energy – whether directed to the finer arts, or to the sterner industries – is permeating even the remote parts of India.'[71] The perceived link between the imperial mission and technology is made very clear here.

For engineers and inventors, these competitions set clear parameters, with a chance of generating business and strong public recognition if successful.[72] For instance, in 1870 Crompton put his road steamer design through an 'exhaustive' trial to meet the tight stipulations made by the Government of India. This constituted the road steamer *Ravee* making the 'celebrated double journey between Ipswich and Edinburgh in October 1871'. All of the technical particulars were recorded meticulously, such as the total fuel and water consumed and average speed, under heavy loads; the 425 miles took nine days, giving 47 miles as the average distance per day.[73] As many engineers did upon developing new designs, Crompton gave a paper to the Institute of Mechanical Engineers in 1879 on the working of these traction engines in India, demonstrating again the circularity of knowledge in the imperial world.

Conclusions

Once markets had been identified and opportunities determined, technologies had to be refined according to the specifications of the imperial context, and it is in this sense that communication channels deepened. Colonial feedback forged links, agreements, standardisations and protocols that often outlived the technologies themselves. The various means by which design-related information was communicated created complex circuits of communication.[74] One of the driving forces behind specification was the economy of contracting, principally by imperial administrations. This is why customer and user requirements have been separated out here; they were often very different, although as discussed earlier, if one of the largest impediments for users was the often heavy capital investment required for the latest industrial design, this could be alleviated if government agencies were leading or subsidising that investment.

This chapter has shown the range of factors influencing design specification, principally those of environmental, customer and user requirements. All three of these could operate as the context of a single design and were sometimes contradictory, setting considerable challenges for engineers. This complexity was played out against a backdrop of wider imperial pressures – political, economic, environmental and cultural – in which colonial knowledge both restricted and opened up design opportunities. This brings us back to a key question over specification: which technologies mattered to colonial societies and which did not? The answer to this question depends to some extent upon time and location, but new or incremental technical innovations were not simply greeted with open arms in the colonial context, despite the best efforts by companies to market their designs, win competitions or demonstrate them in situ. Rejection or acceptance came down to the ability of companies and engineers to accurately understand the nature of the requirements around design projects. The more successful recognised this and sent out engineers to the imperial context to capture the specifics.

But who were these 'men on the spot' and who were they dealing with in the colonial context? Aside from the rags-to-riches tales of many of Britain's most successful engineers and inventors (men such as Sir William Arrol and Sir John Fowler) there is much evidence to suggest that the networks they operated within were supported and peopled by British and imperial social elites.[75] From the aristocratic pinnacle of the dukes of Sutherland and Westminster, to governing elites such as the personnel of the Government of India or the military officer classes, elite networks communicated design specification between and within the imperial context. Likewise, there is a body of evidence that points to the ways these linkages operated in tandem with colonial elites, for instance the princely states in India. Overall, colonial knowledge of technologies and design appears to have been largely mediated by elites. What this might mean for the nature and communication of subsequent design development is an issue that will be explored in the following chapters.

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CHAPTER 4

Conceptual Development – The Embodied Empire

Abstract This chapter looks at how designs were realised and begins by defining conceptualisation in design: the processes by which designers and engineers explore and develop their initial concepts for new innovations or adaptations based on existing technologies. It does this in three ways: it examines the nature of design generation and evaluation (in the British and colonial contexts); the structure and nature of collaborations between designers and the users and/or commissioners of new design; and the role of patents and intellectual property in the development process.

Keywords Conceptual development · Design configuration · Collaboration · Intellectual property

Introduction

In our framework of design and communication, conceptualisation pertains to the stage where a technological need for adaption has been identified and specified, and engineers and companies then work to deliver a solution to meet this need. We have so far examined the opportunities provided through the formal and informal networks developed as part of the imperial project.[1] This chapter is primarily concerned with the design practices that were utilised to serve the new specifications for these distant

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markets. While building on established products and technologies widely used in Britain and elsewhere, their adaptation for use in the colonies often posed significant challenges in terms of environments of use, and delivery and installation of equipment. This resulted in distinctive designs that often deviated from type – such as the narrow gauge railways for the mountainous terrain of the Darjeeling line, Crompton's road steamer, or the prefabrication of bridge sections for ease of assembly in Egypt – but are useful in allowing an assessment of how design innovations were instigated, communicated and, finally, embodied during this period.[2]

Firstly, in exploring how design generation and evaluation took place in a practical sense we examine the absorption of information from remote contexts of use, the generation and documentation of new designs, and the testing and evaluation of these. Secondly, as nascent ideas developed into concepts, we review how information and opinion from a range of sources were incorporated into the decision-making process. In doing so we consider concepts as a vehicle for collaboration as new designs emerged. Finally, we consider the wider innovation landscape in terms of patents and intellectual property, and their role in the protection and commercialisation of emerging designs.[3]

Creating and Documenting Design Ideas

In Chapter 3 we detailed how the derivation of design specifications was an important driver of communication in setting the stage for further collaboration and development. These specifications provided the parameters within which engineers could work. With these clearly defined boundaries, we can see evidence of how iteration, experimentation and building on existing knowledge were all important elements of innovation. In terms of communication, much of the sharing of information was between British-based stakeholders and, to a lesser degree, within and between the colonial contexts. As such, the evidence for our argument in this chapter comes largely from workshops and businesses in Britain, as engineers – fed identification and specification materials from colleagues 'on the spot' overseas – began to build detailed designs for new or adapted technologies.

The development of new design concepts consists of two modes of thinking: the divergent and convergent. These can be correlated to generative and evaluative activity in relation to the delivery of new solutions.[4] During this phase of the innovation process, designers typically collaborate to generate a broad range of ideas before selecting one, usually against a set of criteria or specifications, for further development. Criticism and rationalisation are deliberately suppressed so that daring and imaginative ideas might emerge.[5] However, this is not always the case; in the technical engineering sector a more methodical and analytical approach can be adopted where a solution is deduced through linear reasoning. Additionally, in smaller organisations or where communication is limited it may be through individual working that the majority of development work takes place. Our case studies show strong logistical and cultural influences that resulted in a pragmatic approach to the construction and testing of design variants against set criteria. While there were no doubt many conversations, sketches and working prototypes which would demonstrate more abstract and creative thinking, these have not always survived for us to interpret. The thinking and approaches deemed important enough to capture and record are therefore of a more structured nature and reflect the methodical approaches typical of industrial and engineering sectors.

Bounding the solution space to ensure that the concepts generated were practical, and capturing this information through design specifications, were essential for the companies in our case studies. Given that these specifications were often derived either from notes or letters from overseas trips or at second hand from individuals who had been 'on the spot' they were not always, however, of a highly technical nature. In the form of correspondence to employers, government administrations or departments and company headquarters, they often centred on observation of current practices and markets and required further translation into engineering parameters such as power requirements, life in service, transport constraints and so on. To take an example used in the previous chapter, a Ransomes, Sims and Jefferies Ltd employee wrote back from India in 1876 to head office on the requirements for a new plough, observing that the 'implement wanted must not have an iron beam – the natives will not look at it for a moment . . . it must be extremely light, not go deeper than about 4 to 6 inches at the most and must make the kind of furrow which you yourselves have already described in your Catalogues.'[6] Given that the plough is a relatively simple product, the translation into engineering requirements would have been fairly straightforward: the material, depth for furrow and maintenance requirements could readily be incorporated through variances in the current product line. For larger or more complex technologies such as railways or sugar machinery, this was not so easy. The major design changes required for the Darjeeling Himalayan Railway locomotive in 1888, carried out by Sharp, Stewart & Co. at the Atlas Works in Glasgow, is a good example.[7] These changes included key components such as the cylinder, boiler and firebox dimensions, but barely reveal the unique environmental challenges that the engine would be subject to. The level of technological familiarity and confidence in documenting these changes ('In details generally follow E810') and the informality of presentation suggests there was regular and significant communication of tacit information, which has not survived for historians to analyse.

Much of the conceptual development work serving the British World was therefore broadly evaluative: engineers had to make technical adaptations to meet requirements, often within tight time and financial constraints. Indeed, Magee and Thompson highlight how British superintending engineers could be demanding, placing provisional orders and readily sharing their views on necessary modifications.[8] While this sets the scene for some colourful correspondence, the limits of time and distance in the communication meant there was little opportunity for types of generative activity such as brainstorming that we might associate with contemporary creative working environments.[9] Nevertheless, the distributed stakeholders and limited interaction did not preclude creativity – indeed the 'imaginative non-conformists' that often struggle in large, highly bureaucratic organisations perhaps had more room to flourish in the greater autonomy of smaller workshops and more sporadic communication patterns.[10] We can see the evidence of this in engineer's notebooks, which across a range of industries and settings often displayed a dense narrative, supplemented with sketches and illustrations (see Fig. 4.1). Given that the externalisation of ideas tends to occur through expressive means such as sketching, conversation and gesture, the remaining drawings available to us are an important way in which we can interpret how engineers in this period developed and communicated concept design.[11] As a shared 'external memory', they embody the engineer's initial response to the environmental, cultural and contextual specification, and as such can reveal elements of the tacit and organisational knowledge they drew upon to address these. Through sharing and evolution, they become an important facility in understanding the rapport and ethos within companies, as well as relationships with remote customers such as colonial agents. Not all sketches have been retained, of course – possibly only those that were considered important by the engineers for future reference or those used in correspondence. However, those that survived

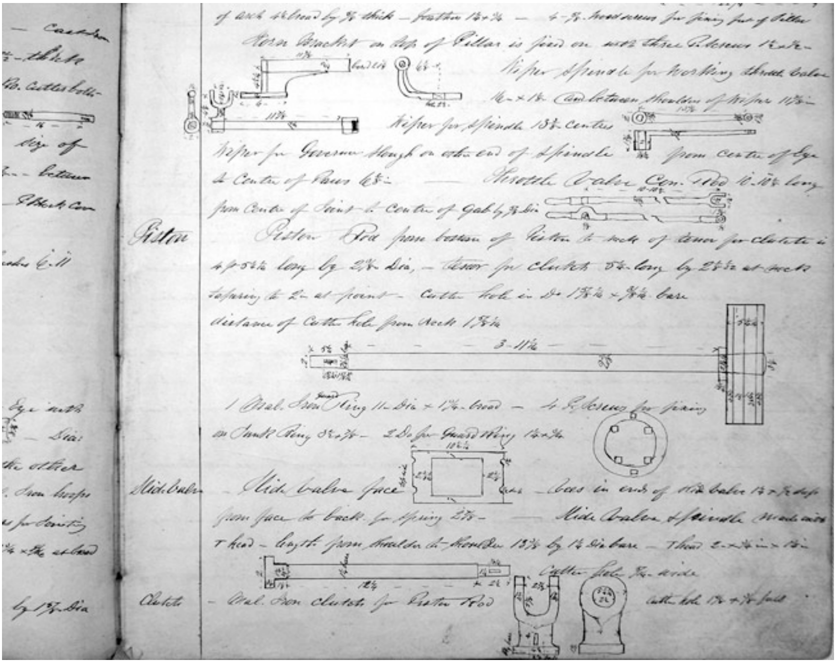

Fig. 4.1 Example of engineer's notebook detailing piston arrangement[12]

in the archives help us to make some inferences regarding the approaches to problem solving and communication. The consolidation of information and linear design evolution displayed by discrete sources such as the notebook shown here is indicative of an emphasis on individual responsibility for the successful development of new design configurations and their possible use for reference purposes at later stages of the design process.

While it may have been the case that an individual or small group of engineers were working in a concentrated way to develop a product or system, inevitably further communication across distance was necessary as designs evolved to resolve emerging or unexpected issues. The limitations of correspondence (letter or telegram) seriously curtailed the frequency and depth of exchanges – it was not viable to pause the development process for months at a time to clarify every small issue. This meant there was not necessarily the scope for the incorporation of detailed feedback in designs as they developed; instead, changes continued to occur throughout the manufacturing and distribution processes, including on-site testing and evaluation, as discussed in more detail in Chapter 5. When engaged in detailed design and engineering work, information that was received from agents or customers in remote locations could be valuable in developing insights on issues such as material choice and geometric configuration.[13] A letter from Hauffmann & Co. in Peru (an extra-imperial territory, but still illustrative) to Ransomes, Sims & Jeffries Ltd in 1887 is an example of this.[14] It describes the local shift to rice, rather than sugar cane production, and the agricultural requirements therein; the procedures employed and their design requirements are carefully outlined, suggesting an appropriate form for a 'strong light all iron & steel plow [sic]', that was suitable for oxen.[15]

The (usually) greater sophistication in production capability in Britain during this period allowed designs to be realised that would not always be possible using indigenous materials or techniques in the colonial setting. In these cases, innovation depended on engineers linking the colonial design requirements with new or emerging practices. An example is Ransomes' 'Colonial Plough', which advertised the fact the frame was forged in one piece, 'thus securing great rigidity', which was preferable for difficult soils and environments.[16] Additionally, this avoided the need for nuts and bolts, which would require maintenance and access to appropriate tools for repair or replacement. Despite the fact that the geometry of the plough is not especially complex and the tolerances not critical, the reliance on steam engines to generate the pressure to forge larger, more complex parts in one piece meant that there were limited colonial settings where these could be successfully produced.[17] Other examples of ploughs aimed at particular markets were a double-furrow plough for South Africa that was highly adjustable for different kinds of soil and terrain, and a very simple plough for India, 'modelled after the native ploughs in Oriental countries', but using enhanced materials and manufacturing techniques for stronger construction.[18] We can see here that, even if the designs were being detailed and produced in the British context, the absorption of colonial knowledge was essential and helped build networks that supported the design process.[19]

A similar case of adaptation to meet environmental conditions was a straw-burning engine designed by Ransomes, Sims & Jefferies Ltd.[20] This was an 8-horsepower portable single-cylinder steam engine designed for

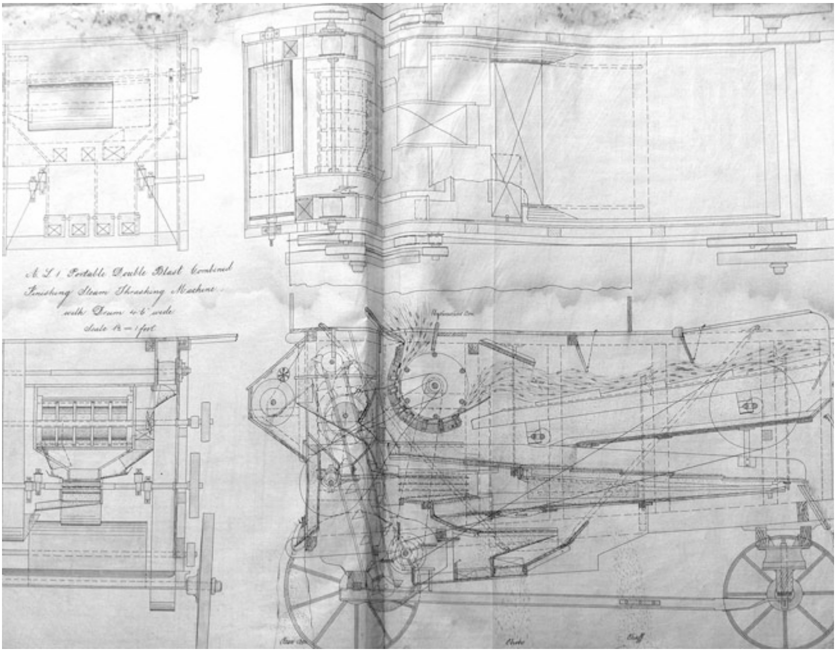

Fig. 4.2 Element of steam engine with straw feeding mechanism by Ransomes, Sims & Jefferies Ltd[21]

use in locations that did not have easy or economic access to coal and utilised a self-acting feeding apparatus and boiler configuration to allow the burning of straw and other vegetable refuse as fuel instead. An elaborate feeding mechanism became necessary due to the volume of material required to sustain the engine. A sample of the drawing of the mechanism is shown in Fig. 4.2.

In the longer term, collection of feedback once new innovations were in place was critical to the circularity of communication: the transmission of information in terms of how well the machines operated in their environment of use allowed for further improvements. While the limitations of geography and time meant these could not always be incorporated as part of the initial development, they could be used in subsequent iterations of the design cycle. This can be illustrated by the case of the evolving configurations of rollers for crushing sugar cane. As it became clear that vertical mills tended to concentrate crushing on the lower portion of the rollers, horizontal mills became established as the norm.[22] Even distribution of the cane was critical to their smooth operation, but their inflexible position meant that they were susceptible to choking or breakages if overfed or tramp iron (stray objects or particles fed along with the cane) entered the rollers. Over time, larger rollers and greater numbers were introduced, as noted during a parliamentary commission on the depression affecting the sugar industry in 1898: 'Mr Levy, owner of a number of estates in Jamaica, introduced an improved mill in 1896 and was agreeably surprised at the 70–75% extraction obtained, when 65% extraction was considered to be very good on most muscovado estates.'[23] By the late nineteenth century, as well as double or triple crushing mills most estates were using hydraulic attachments to ensure that proper compression was given to the feeds.[24] This series of adaptations resulted in incremental increases in the overall levels of juice extraction from about 50% in 1816 to 92–96% by 1916.[25]

Not all adaptations were made for purely functional purposes, however. The embodied design was another means of communication and a powerful way to translate cultural values and tastes; product form and the aesthetics of an artefact inevitably communicate notions beyond the technical. Three key factors identified as playing a role in Victorian attitudes to design include a strong sense of history, which expanded the range of motifs and stylistic elements employed; an attitude towards design that valued decorative rather than structural features; and the importance of religion, which tended to assign moral significance to many aspects of life.[26] In the late Victorian period, for example, the Arts and Crafts movement developed alongside, and to some extent in reaction to, heavy industry and resulted in the inclusion of detailed decorative elements in engineering components, products and installations. This juxtaposition was a reflection of the desire of manufacturers to emulate the ideals and standards of skilled craftsmen using the new materials and processes that facilitated the manufacture and distribution of goods to a far wider market than previously possible. In essence, decorative elements could make a design seem more expensive and desirable and although it was at odds with the intention of producing goods as cheaply and efficiently as possible, it was not until the modernist movement of the early twentieth century that dissenting voices emerged. An example of the incorporation of decoration in a functional component can be seen in a typical Victorian park bench – situated in parks all over the imperial territories – made of wooden slats slotted between heavy iron castings at either end. These would typically be embellished with ornamental foliage designs that did nothing to improve their functional performance but made them more attractive to park users and are a reflection of the aesthetic values of the time.[27]

While it can be argued that the decoration of a park bench can help align it semantically with its environment of use and bring some pleasure to its users, the desire for decoration was strong enough that it was not only products to be used or displayed in public arenas that were treated in this way. Facilities such as the Abbey Mills sewage pumping station in London, constructed between 1865 and 1868, with its ornate ironwork and architectural motifs, show that even industrial installations were imbued with a sense of grandeur. Though the Abbey Mills interior would only be viewed by those working in or visiting the plant, it made a statement about the power and sophistication of the society that created it. Kriegel outlines the role that museums, too, played in generating enthusiasm for the imperial project – South Kensington Museum in particular acting as a showcase for manufacture and trade with the British Empire.[28] In colonial settings, design became a tool to symbolise the imperial mission and British self-declared technological superiority.[29] There are numerous celebrated architectural examples, such as Bombay Central Railway Station, that effectively reproduced the prevalent British architectural style in a colonial setting and made a grand statement regarding imperial presence.[30] Similar examples can be found in transportation and infrastructure; for instance, non-functional decoration can be seen in the Cairo bridges, which were noted for their aesthetically pleasing ironwork (see Fig. 3.2).[31]

In summary, colonial requirements were transmitted and incorporated into the designs of engineers in a number of ways, with correspondence and notes proving critical in providing feedback on early development. The limitations of the depth and frequency of communication with the colonies meant that a large degree of autonomy was retained by engineers in the embodiment of a design. Detailed sketchbooks archived by companies illustrate how new configurations evolved out of these requirements and led to original, though largely incremental, innovations that built on previous knowledge and expertise to meet the needs of colonial use. The designs produced also represented the many values and ideals of empire: even industrial products would be endowed with decoration and aesthetic details that were not essential to their operation. These were reflective of

Britain's evolving technological and imperial status and the tensions that could arise when supplanting traditional vernacular designs.

Implementation

We have identified two distinctive examples where the advancement of a design prompted stronger links between owners/buyers, engineers and workers across the empire: Crompton's road locomotive, designed for use in India but tested in Britain, and the Sutherland steam plough, designed in Britain, tested in Egypt and reworked (in our case study) for the challenging environment of the Scottish highlands. Both feature charismatic entrepreneurs who, in developing their respective products, generated business and personal linkages that utilised and reinforced the institutional structures as well as the more informal feedback loops of empire.[32] They also illustrate the multidirectional nature of the communication of technology in this period, decentring Britain.[33]

Robert Crompton was an engineer in the 2nd West Yorkshire Regiment and pioneered a road-going locomotive for use on the Grand Trunk Road in India.[34] Crompton's case highlights the value of taking a network approach to the issue of technological innovation and communication. In this case Crompton developed his design first in correspondence with, and later by working alongside, Robert W. Thomson of Edinburgh, who had developed a prototype road engine that used rubber tyres. Crompton then went on to test it in another imperial context, the Dutch East Indies, although no further detail can be found as to how and why he chose that location.[35] After his own tests in India on a prototype he transported from England, Crompton was sent by the Post Office (under whose supervision he worked at the time) to Scotland to work with Thomson in developing the design and then to Ipswich to supervise the construction of four machines by Ransomes, Sims and Jefferies Ltd.[36] In fact, it had been Ransomes who had offered to build the engines in the first place, having heard of their work through engineering circles.[37] This illustrates the interchangeable geographies of conceptual design and development: Crompton, Thomson and Ransomes were attempting to adapt the design for imperial environments with the intention of securing future markets, in this case, India. An example of their collaboration, the *Chenab*, 14-horsepower road steamer fitted with Indian rubber tyres, is shown in Fig. 4.3.

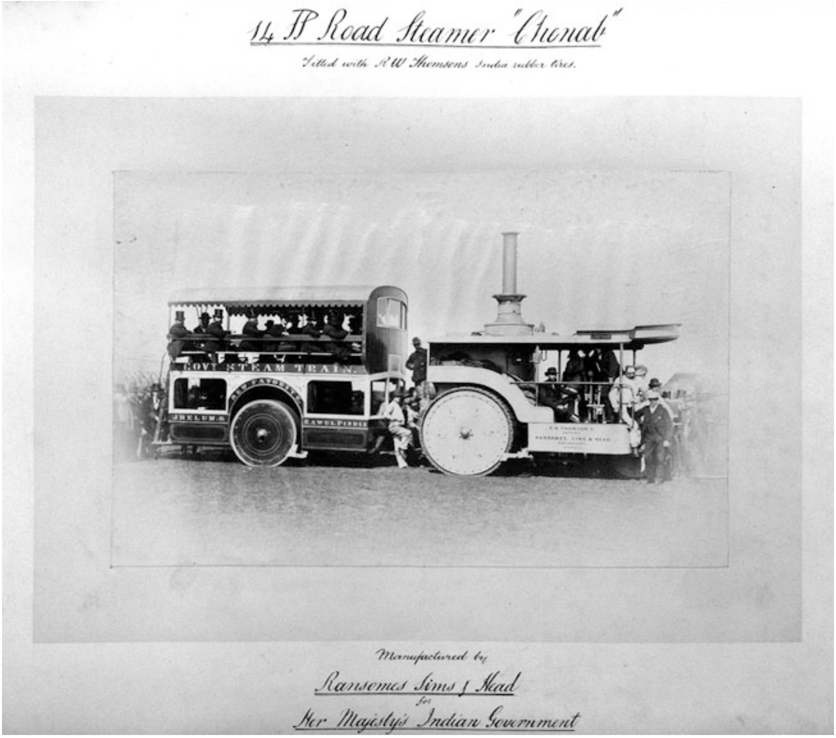

Fig. 4.3 Chenab road steamer built by Ransomes, Sims and Jefferies Ltd

Social and professional networks were vital in allowing Crompton to develop his ideas – the financial, production and marketing capacity of a company such as Ransomes being key to any hope of commercial success. He had initially been able to set up a workshop in India to build his design when on leave, helped financially by a number of high-ranking military officials with whom he was acquainted, either through his own military service or his brother's. These connections included Cluny MacPherson and Sir Herbert MacPherson from the Highland regiments, and Field Marshall Charles Henry Brownlow, a senior Indian army officer. Later, having been appointed to the staff of the commander-in-chief in India, Sir William Mansfield, Crompton would meet many men of high station at the Umballa Durbar, including the viceroy, Lord Mayo, with whom he often went out riding after this time, and George Byng, later Lord Torrington.[38] In short, his personal, family and (later) professional networks were vital in getting him the patronage and finance necessary to develop his ideas independently and then in partnership with an influential British engineering firm. Both Crompton and Thomson were also active in the Institution of Civil Engineers, and these connections help to explain how Ransomes became interested in building his machines. In fact, when he was testing the engines in Britain, the dukes of Sutherland and Devonshire visited him, along with Sir Frederick Bramwell and Sir John Fowler.[39]

Crompton and Thomson tested a number of engines in Britain (although they were always intended for use in India) and made some modifications based on their evaluations.[40] As noted in the previous chapter, Crompton then took one of his models, the *Ravee*, on a trial journey from Ipswich to Edinburgh and back, and made further modifications on the basis of this journey. Following this, the machines were sent out to India in 1873, with Crompton claiming that one machine had run for 2,000 miles without needing repairs.[41] However, he did need to make further adaptations to suit local conditions, including changing the ratio of the differential gears to put less pressure on the crankshaft and running the engine on countershafts that could be easily repaired on the road.[42] At the 1873 military manoeuvres at Rawalpindi his general scheme was inspected, and although the total cost had been £17,000, the postal run on which his machines operated had made a profit of £61, and his experiments were allowed to continue.[43] In fact, at this point the cost per ton mile of his engines was half that of animal haulage and just as reliable as the railways.[44] However, Crompton was not to get much further with his designs and returned to England in 1875, a fact that he put down to the deaths of Lord Mayo, Lord Sandhurst and Lord Monteith.[45] This demonstrates that having a proven design or prototype was not always enough to guarantee the next step to commercial development and success: networks of patronage – and luck – were also required.

Crompton's later experience in South Africa is also illustrative. In 1896 he approached the War Office with the suggestion that he and Dr John Hopkinson form a corps of electrical engineers for the Volunteer branch of the Royal Engineers.[46] When war broke out in South Africa in 1898, Crompton joined up as commander of this volunteer corps, but soon found himself in charge of a detachment of Royal Engineers who were employed on the reconstruction trains. Here, he adapted the existing engines so that they were able to cross the soft ground of the Veldt – a design, in fact, he would later use in helping to create tanks for use in the First World War.[47] He also undertook a review of traction engines being used in South Africa and made enquiries with their makers as to the potential for adapting these machines for military purposes.[48] He then designed an engine to haul large field guns into action, built by Ransomes, thanks to his old connection with them. However, this machine was found to be too heavy, and in his *Reminiscences* he suggested that the engines made by Foden, Sons & Co. of Cheshire were the best for this purpose.[49]

In all, Crompton's is an engineering career conducted across Britain and the empire, in which he frequently modified and combined existing British technologies to suit local conditions. Crompton often collaborated with other engineers in these modifications, not least Thomson and the engineers and shop floor workers at Ransomes, and learned from the experiences of other innovators working in Britain and elsewhere. But it is also clear that the initial innovation stages owed much to the patronage and networks of imperial and financial elites, at least in part because Crompton's profession was firstly that of an army officer, and only secondly as an inventor and engineer.[50] In this case, investment in networks and patronage was made in a technology that failed to establish itself as a staple feature of life in India or Britain, although the reasons for this owe as much to unfortunate circumstances as the general financial restrictions surrounding the case.[51]

The second example of innovative design championed by social and imperial elites, and bringing together a collaborative network of engineers and inventors, is the Sutherland steam plough. The introduction of steam ploughing in the nineteenth century was a radical departure from what had gone before and is an instructive case of Victorian optimism communicated via a heady combination of environment and engineering.[52] 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. The project was partly fuelled by the duke's personal enthusiasm for the latest steam technology, in particular the steam plough, being developed at this time by John Fowler & Co. of Leeds. The duke first saw the steam plough in operation in Egypt on the banks of the Nile, where they were being demonstrated on the rich soils. He was immediately convinced the technology could transform his unproductive northern acres in Scotland.[53] In partnership with Fowler and Co., the duke adapted the eight steam plough sets he purchased from them to the specific difficulties of the Sutherland environment and landscape.[54]

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 and can typically pivot around a central axis to allow it to work in two directions. In the case of the Sutherland reclamations there were significant environmental challenges: the land to be reclaimed 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.[55] 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 boggy ground. This configuration was found to perform well in ground where there were no obstructions, but the majority of the 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, a steel disc placed in front of the share, cutting the soil to a depth of two inches below.[56] When meeting a large stone, it would lift the plough over it. A further improvement was 'the Duke's Toothpick'.[57] 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 further.[58] 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 a sufficient deterrent for cattle and horses, coils of wires with 'spikes … twisted at intervals into them' were developed – now familiar as barbed wire.[59] 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.

The use of steam ploughing was not financially or environmentally viable in the challenging conditions, however.[60] 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 high-altitude, boggy terrain around Loch Shin where the bulk of the reclamations took place. A huge workforce of mainly local men was employed to assist in the scheme; indeed, labour and wages were the biggest single cost in the project.[61] Problems with engaging them can be attributed partially to their pragmatic and sceptical view of the work, with many continuing to use more primitive methods independently with better results.[62] However, it can also be attributed to poor communication between Fowler & Co.'s on-site engineers and the duke in the overarching aims and objectives of the work. As a result, the imposition of the technology to this rural setting was not a success on a financial or agricultural level.[63] Nevertheless, the series of design innovations as part of its evolution exemplify similar characteristics to remote colonial technological assignations: the transmission of new requirements, iterative adaptation of existing designs and a failure to anticipate the wider issues of implementation.

These two examples demonstrate that in many cases, design concepts were a vehicle for collaborations (some more successful than others), which came in many forms and demonstrate the circular nature of communication taking place across Britain and the empire.[64] The steam plough demonstrates this perfectly: designed in Leeds, after John Fowler was inspired by the horrific conditions he witnessed in Ireland during the Great Famine, a slow home market encouraged overseas activities. The 3rd duke of Sutherland saw the steam plough in operation in Egypt, after which he imported and adapted the design to his estates in the north of Scotland. Similarly, in the development of his road steamer, Robert Crompton tapped into the finance and influence of military elites as well as Ransome's engineering expertise, in a journey that took place in India, the Dutch East Indies and South Africa. As well as polyvalent geographies of design, both cases demonstrate the importance of networks in the communication of design. Whether these were of a social, political, patronage, religious or governance nature, their role within the empire has long been recognised, and design as a conduit for supporting these can clearly be seen.[65]

The Role of Patents

Given the modern emphasis patents and intellectual property carry as indicators of innovative activity, it is instructive to consider their historical role, particularly with regard to the communication of design concepts and information.[66] The purpose of a patent is to fairly recognise the effort and creativity of inventors by assigning a period of protection in return for them recording and sharing its workings. After the period of protection expires, others are free to utilise the invention, thereby increasing the level of technological advancement for all.[67] A clear system for the recognition and reward of entrepreneurs, and protection of national economic interests, were the chief motivators for the development and refinement of the system. Britain developed one of the first comprehensive patent systems, with detailed documentation of inventions routine by the eighteenth century.[68] Between 1760 and 1860, 46% of patents were awarded for machines: this was the era of the early development of motive power, and the refinement and application of the steam engine to a plethora of different areas meant that it naturally formed a large part of innovative activity during the period.[69]

However, this proportional increase obscures the fact that there were only seven patents registered in 1750 and 455 in 1850: they were not a dominant factor in the design processes. During this period, many ‘legally novel’ but minor innovations were not protected,[70] with costs, secrecy and changing patenting standards cited as the three principal reasons why patents did not truly reflect the volume of inventive activity.[71] Many companies instead relied on confidential practices to protect their ideas.[72] With increasing calls to address the financial and administrative burdens of the process, the sugar refinery business was one that argued against suggested reforms. They asserted that if it were made cheaper then ‘every trifling improvement, in every process of manufacture, would be secured by a patent’.[73] These vested interests and the toils of the entrepreneur were highlighted in fiction by Charles Dickens, when he lampooned the lengthy and expensive journey to secure a patent in his short story ‘A Poor Man’s Tale of a Patent’, documenting the interminable steps to secure protection for his idea, and questioning whether it was right that a man was made to ‘feel as if, in inventing an ingenious improvement meant to do good, he had done something wrong?'[74] In response to calls for its outright abolition, in 1852 the British system was instead finally overhauled making it cheaper, faster and easier to file, as well as establishing parity across England, Scotland, Ireland and Wales.[75]

Britain's position at the vanguard of the patent system proved advantageous for individuals and organisations seeking to exploit creative engineering solutions. It was also another agency of technological convergence and collaboration across its empire, as the colonies began to establish and refine independent patent systems to allow entrepreneurs and organisations to protect their ideas beyond the metropole.[76] An example of this is Frederick Wolseley, who emigrated to Australia from Ireland at the age of 17 and developed his mechanical sheep shears after extensive experimentation in the colonial setting. In 1887 he founded the Wolseley Sheep Shearing Machine Company in Sydney; however, it was necessary for him to return to Britain to better establish his intellectual property rights and commercialise his product, so in 1889 he relocated to Birmingham. There, he set up a new company that purchased the rights and some 40 patents of the Australian company for £75,000.[77] Many of these also list Herbert Austin, who was Wolseley's 'man-on-the-spot' in Melbourne, and represent the optimisation of the somewhat unreliable machinery to the point where it was unequivocally more efficient than shearing by hand. Austin was a gifted mechanical thinker who would later go on to found the Austin Motor Company. In general, the names and places listed in patent files associated with particular technologies or products are illustrative of the circular information flows that result from design innovation.[78]

It was not only in the patenting of new ideas that design was communicated: links were generated through licensing agreements. This can be seen in the sugar industry, where, as already outlined, a series of changes in mill configuration increased extraction efficiencies. While some of these innovations were through the use of non-exclusive licenses, others originated from the manufacturers in Glasgow. For example, Duncan Stewart patented hydraulic attachments for sugar mills, which in turn were widely adopted. Similarly, a spring toggle designed as a safety valve for crushing mills was patented by J. G. Hudson, a partner in Mirrlees, Watson & Yaryan.[79] While these discrete inventions are visible to us through the patent record and their subsequent use across the industry, many innovations were not deemed worthy of patenting. In these cases, imitation by competitors and the movement of workers between companies meant that features and configurations were gradually shared. The 'heroic' inventor model that the patent system was seen to encourage has been increasingly questioned by historians, with greater emphasis placed on the social and organisational forces that instigate innovation and its communication. Although they are unique in providing a documented record of design, patents do not reveal the motivations behind, development of, or success in technological innovation. Adapted designs, which were the most prevalent type of engineering for colonial markets, were less likely to have patents associated with them, with firms instead relying on secrecy to protect their designs for a sufficient period to gain competitive advantage, before they were inevitably acquired by competitors and became the norm.

Conclusions

This chapter has explored a range of design practices of engineers and inventors across a number of different technologies in order to examine the collaborative methods that supported design. It is clear that much of the work at this stage encompassed a wide variety of networks and methods and there was no standard approach. Networks might constitute a mix of social, political, religious and professional elements and were fluid across time and place. We have attempted to build an overview based on the written materials preserved, although we recognise that much informal concept design was based on conversations, notes, sketches and material now lost to us. Some of this can be recaptured by an analysis of the implementation of design, and through two key case studies this chapter demonstrated how this acted as a fulcrum for a network of people to collaborate. Lastly, and probably of least importance within our framework, we examined the role played by patents. Although on the face of it the most straightforward method of information sharing, as suggested by analysts of historical patent data, and matched in our archival findings, these were in fact the least influential route to communication – or collaboration. The next chapter brings us to the last stage of our framework: the manufacture and distribution of design.

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CHAPTER 5

Realising Production – The Tools of Empire

Abstract This chapter examines the production stage of the design process, encompassing detailed design, manufacture and distribution; that is, the processes by which conceptual designs were commissioned in readiness for application to the required contexts. Firstly, this includes a discussion of the communication of design information from design office to the shop floor and the beginning of the manufacturing and production process. Secondly, the chapter examines the protocols for testing and analysis of conceptual designs, highlighting the adaptations unique to their imperial application. Lastly, it explores the linkages put in place to move products to imperial contexts – and how these logistics reinforced communication channels within and across empire.

Keywords Production process · Technical drawing · Design evaluation · Distribution

Introduction

In the course of this chapter we explore how designs completed the process of development to artefacts that could be manufactured, tested and distributed: the final stage in our framework. This encompasses the installation, maintenance and continuing communication with engineers

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and manufacturers as technologies were transferred across Britain and the empire. The long-term adaptation and absorption of these technologies in their new locations is not addressed here; historians such as Arnold and Headrick have explored these themes elsewhere.[1] Instead, we focus on the nature of communication and collaboration through this production stage of the design process. This was often more specific and quantified, with information such as test results, installation procedures and supply logistics crucial to the successful deployment of what were often complex and unfamiliar technologies to the colonial context. Similarly, circular communication networks and feedback loops within Britain, whether from the design office to shop floor or suppliers to manufacturers, also led to the introduction and reinforcement of standards and protocols which often outlived the technological development they supported.

Firstly, we consider the processes that were necessary in order to manufacture industrial products: this encompasses the purchase or building of machines as well as the physical workshop environment. There was significant variance in the level of fabrication within Britain, with some designs shipped as completed products, while others were subject to modification or manufacture in the colonies. This required the exchange of information through technical drawings and organisational systems to ensure that production progressed smoothly. Labour skills were critical throughout this phase of the design process, and managing the operation of machinery, assembly lines and quality control posed distinct challenges in the British and colonial settings. Design was not only a driver for communication across the empire, but across organisations too, with technical drawings playing an important role in documenting finished components, products and systems. These often contained the most general of dimensions – it was left to technicians and machinists to work out the appropriate details on the ground, and this was rarely captured or preserved in company archives. We have attempted to reconstruct this as far as possible, and to outline the feedback loops that emerge at this stage in the communication of design.

Secondly, we explore the testing and evaluation necessary to finalise designs in advance of their production. While many pre-existing designs required only a subtle adjustment of components or configurations to meet the new demands of colonial contexts, others required more significant changes or led to the development of completely new product categories. Ascertaining appropriate test conditions and methods of evaluation required the communication of requirements vertically through the hierarchy in Britain and horizontally to colonial locations, making it a fundamental part of the circularity of communication outlined in our argument.[2]

Lastly, we consider the linkages that were developed in shipping and distribution and in engaging colonial labour to implement the products and technologies in the cases presented. The movement of goods helped reinforce existing communication channels, a point long established by historians of empire, finance and trade.[3] Contracting and collaborations within and across companies were key features of these channels, and specific geographic expertise supported collaborative practices through supply chains.[4] Together, these processes required the transmission of practical, quantified information, with the protocols necessarily generated often helping to form longer-term standards and institutions.

Realising Production

Both the infrastructure and organisational processes of production facilitated multiple lines of communication within Britain and across the empire. The fabrication of what were often large and complex machines involved either the adaptation of existing facilities or completely new installations in Britain for manufacturers to produce at the required volume. Alternatively, manufacturers might be required to adapt existing production processes to accommodate one-off design adaptations, such as those required for the Sutherland steam plough. Either way, physical artefacts had to be documented in technical form for manufacture in the workshop and for communication with clients or customers. As noted above, the management and business structures adopted to meet the logistical challenges of addressing geographically distant markets also led to the establishment of new procedures and protocols. In addressing both the technical and organisation requirements, communication within the manufacturer and across collaborating suppliers in Britain, and with end-users in the colonial setting, was all important.

The nineteenth century saw the engineering professions emerge from the workshops of the industrial revolution.[5] As the principle materials of industrial equipment shifted from wood to metal, there were stricter procedures in the production process. Where wood could be worked by hand to achieve a desired result, iron and steel required to be cast, forged and wrought according to stringent demands in terms of precision and strength. As a result, the planning and documentation of designs became more formalised. It was in this context that the profession of mechanical engineering emerged and developed, with a job as a draftsman often providing a route to becoming a fully fledged engineer.[6]

During the early industrial revolution (to c. 1830) drawing systems were not yet fully defined and their use was somewhat inconsistent across companies and industries. By the later nineteenth century, however, technical drawings became more prevalent in controlling and managing design information, with processes optimised to cope with the number of drawings being generated and more codified rules used to regulate their presentation.[7] The gradual formalisation of drawings during this period helped to separate 'thinking from making', as drawings would be prepared to establish the major design configuration and overall dimensions, but would still rarely include detailed dimensions. This meant there remained significant scope for machinists on the shop floor to reinterpret or adapt designs as required, around the limitations of the available machinery and processes.[8]

Technical drawing required a high level of skill and training, and most surviving examples from this period were crafted with great artistry. The drawing office as a working space was configured to create a focused and professional atmosphere, with plenty of natural light to facilitate the meticulous nature of the work.[9] Showing highly detailed penmanship, they were often augmented by watercolours that gave them the impression of works of art. Figure 5.1 shows the riveting machine and cage designed by Sir William Arrol & Co. for the Forth Rail Bridge discussed in Chapter 2.[10] The drawing itself is large, requiring a significant surface on which to view it comfortably, suggesting this would only have been done in a drawing office or designated workshop space. The scale used is ¾ inches to 1 foot, with the tower foundations at the bottom left giving some sense of the size – the cages were large enough for a gang of riveters to move around the outside of the 12-foot-diameter steel tubes. The attention to presentation and the engaging use of colour in the drawing echo the decoration and embellishment that was evident even in the industrial equipment of the era.

The design process for developing a new steam engine in the early years of the twentieth century at John Fowler & Co. of Leeds is illustrative of how drawings were used to manage production information internally. It began with a dimensioned outline of the engine with basic parameters such as power, flywheel, weight and cost developed. When confirmation was received that the job was to go ahead, a job number was issued with a

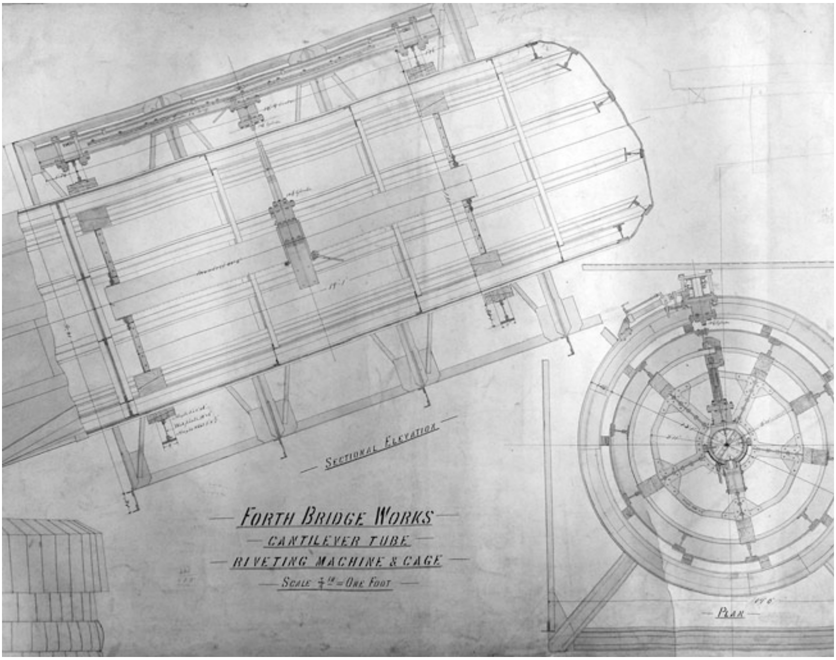

Fig. 5.1 Riveting machine and cage for the Forth Rail Bridge by Sir William Arrol & Co

written description of the job requirements. The drawing office then produced detailed drawings: a lead draughtsman responsible for the job constructed this from the preliminary drawings and assigned work to assistant draughtsmen as necessary. When the drawing was completed, reference information including the drawing number was added, taken from a book kept in the drawing office. On completion of the drawings, they were traced by 'a staff of girls set apart for the work'.[11] They would also ink in drawings, with a record of all tracings and drawings kept in logbooks in the drawing office. If a new tracing was made of a drawing, it was mandatory for the old tracing to be returned before the new one was handed out to prevent the possibility of confusion over alterations to designs. In this case, the steps in the composition of the technical drawings provide a template for production – the sequence of operations necessary to ensure consistency and robustness in the manufacturing process.

If technical drawings provided the template for work, the more practical operational issues of job allocations, stock replenishment and the control of materials were critical to producing the parts. The procedures and protocols that developed allowed not only effective internal communication, but for local suppliers and partner organisations to collaborate effectively in fulfilling orders. Occasionally, the design and manufacturing processes were completely separated, as in the case of Robert Crompton and Robert Thomson, who developed innovations around road steamers, but collaborated with Ransomes, Sims and Jefferies Ltd to manufacture them.[12] Where, as was more common, the two processes were concentrated into a single company, they strove to link these effectively across their organisation. In 1899, J. & G. Weir Ltd, the Glasgow engineering company, drew up and published pamphlets 'for the purpose of letting the shop foremen, leading hands and the staff generally clearly understand the New Costing Scheme, Contract System and new arrangements which are intended to be carried out and worked to during the next twelve months'.[13] The biggest change was the introduction of a new list of stock numbers to ensure better management of stock and process control. To simplify the flow of jobs, it was requested that employees attempt to ensure that they 'complete one contract before beginning another', and in issuing work, no work was to be done, 'without a Contract Note or Time Record Form'. As well as ensuring production flows were as smooth as possible, these processes highlight the coordination necessary to ensure goods were ready for distribution.[14]

Moving to the production of components, the workplace itself had a considerable effect on the ability of workers to communicate effectively. The workshops, foundries and smithies were dark, noisy, dirty and demanding places to work, in stark contrast to the bright and calm environment of the drawing office. This is an area in which Sir William Arrol became well known as an innovator. In constructing his workshops he used steel and glass to allow natural light to enter the spaces.[15] The first was constructed in 1887 for Dubs' Locomotive Works in Glasgow and included coloured glass to subdue sunlight and glare. By improving workers' ability to read drawings, operate machinery and interrogate components, there were benefits in collaboration and performance. In addition, the psychological benefits of experiencing natural light through the working day must have been readily apparent, and soon similar designs were implemented across the country.[16]

While we can clearly see the emergence of two distinct social and operational forces from the mid-nineteenth century – the professional engineer and the shop floor worker – a strong synergy between them remained a feature of British industry. This was perhaps reflective of the fact that many engineers had served apprenticeships alongside labourers, machinists and operators, resulting in an emphasis on developing bespoke design solutions, and with less consideration of longer-term production implications. Brown suggests that this was one of the main differentiators between Britain and the emerging engineering economy in the USA, where there was far less professional protectionism and a greater focus on business efficiencies.[17] As such, the British focus on developing pragmatic technology solutions for identified and specified problems often overrode efficiency requirements, particularly in cases where colonial and domestic government subsidy and support were in place, such as with Indian railways.

In addition to cultural and organisational factors that companies can influence internally, geography and the location of competitors and collaborators is also recognised as having a role in innovation. It has been noted that proximal organisations are better placed to coordinate, trade and share information.[18] This can be seen in the local and regional clustering of industry sectors as a basis for creative, dynamic working across associated organisations in the supply chain.[19] Mutually reinforcing networks tend to encourage increased industrial activity and lead to established centres of expertise. These innovation hotspots are transient, often generated by a particular set of circumstances, and liable to fade depending on changes in social, technological or economic conditions. An example of this during the late eighteenth and nineteenth century was the sugar technology industry around Glasgow, which consisted of a dense, complex web of companies that was arguably more dominant than its later shipbuilding industry. In Glasgow's case, it was made possible due to the engineering capability and skilled labour capacity the city had developed, as well as the opportunities provided through links with the slave, cotton and rum trades with West Africa and the Caribbean. As the scale of opportunity became apparent from the 1830s, previously general engineering firms began to specialise more.[20] A typical firm up to that point may have consisted of 'a foundry, a few simple machine tools, and an erecting shop, all controlled by a small partnership, composed of merchants supplying capital and time-served engineers'.[21] Firms also tended to share large capital equipment where necessary. Furthermore, most companies were still owned by individuals or families who were willing to spend profits on capital, and this was a significant factor in the level of risk deemed acceptable by firms during this era.[22]

There were three prominent exceptions to the Glasgow concentration of sugar machinery manufacture – Manlove, Alliott & Co. of Nottingham; Fawcett, Preston & Co. of Liverpool and Fletcher of Derby. These tended to specialise, such as in the provision of extremely large machines. Another exception to the rule can be traced at the colonial end of the process, with the fact that it was Cuba, not a British imperial territory, which was the chief Caribbean buyer of sugar technologies from Glasgow manufacturers. For example, the mill order books of Smith Mirrlees of Glasgow shows 58 sugar mills sold in Cuba between 1860 and 1870, compared to 44 in Demerara and 27 in Jamaica.[23] So while these local hotspots of industry formed to bolster collaboration, there remained strong commercial demands from across and beyond the empire that would look for the most effective solution, wherever its origin.

Testing and Evaluation

In workshops across Britain, companies were pressing, milling and stamping the components that would together form the physical and cultural engines of empire.[24] With an emphasis on transport, infrastructure and industrial machinery, the majority of effort was on improving and applying existing designs rather than wholesale reinvention.[25] Given the fact that the basic principles for the majority of the technologies in our case studies were well defined (for instance, at a systems level the locomotive or sugar production process did not change) innovation took place primarily at a detailed level. Optimising components, improving performance and adapting existing configurations to meet the particular design parameters of the colonial contexts meant that companies were principally responding to market demands and utilising familiar processes and materials.[26] Often, this was achieved through a long sequence of iteration, with these refined design configurations requiring engineers to review performance and reliability prior to shipping. There were exceptions to this, such as Wolseley's revolutionary sheep shears, which were a step change and required a long period of incubation and improvement before achieving success.[27] Overall, there was a pragmatic approach to development, with an economy of small companies conducting methodical and experimental tests that would allow them to verify that their product met operational requirements, without necessarily undertaking the kind of horizon-scanning research and development work that companies now factor in as essential to long-term business survival.[28]

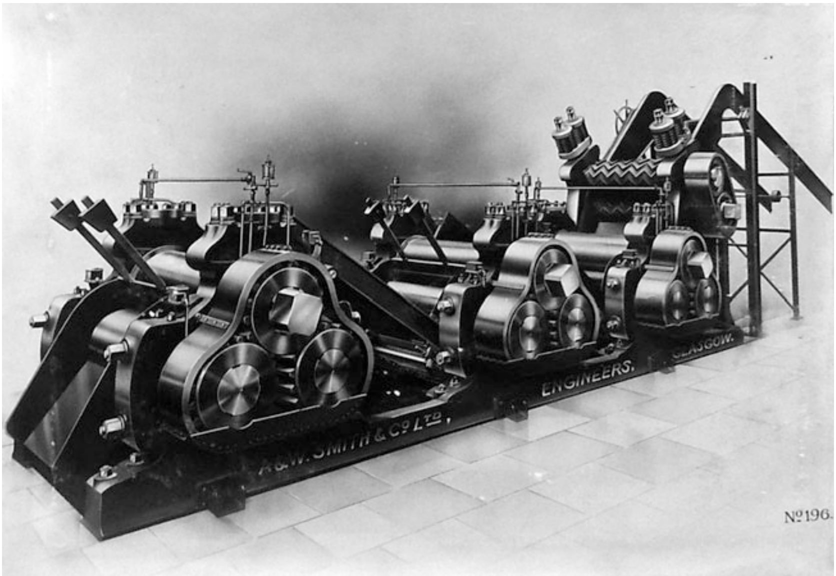

Fig. 5.2 Eleven-roller sugar cane mill by A. & W. Smith & Co., Glasgow[29]

The speed of communication again affected the frequency and quality of feedback provided from the colonial contexts during evaluation. A sugar mill, for example, would be shipped to its location and installed at great time and expense before any assessment could ultimately be made of its ability to perform in context. Figure 5.2 shows an example of an eleven-roller sugar cane mill by A. & W. Smith & Co. (associated with Smith Mirrlees), Glasgow. The rollers in this instance are listed as being of 26 inches in diameter, with the two grooved crushing rollers (at the far right of the mill) 24 inches in diameter; combined with the engine and gearing required to deliver power to the mills, these were huge installations. Given the level of effort and investment in the production of each mill, there was an understandable focus on accuracy of machining, sequences of assembly and effective workforce management: these all directly influenced the end product reliability. Whatever the pros or cons of particular designs, the careful reference to the performance of prior configurations and emphasis on functionality meant that the machines were engineered to last.

Given that the sugar cane crushers and rollers were subject to the greatest wear and tear, they were the focus of significant correspondence, testing and evaluation prior to shipping. For new orders and in the development of new designs, these were normally carried out on the manufacturer's premises incorporating as much information as possible from the initial specifications, as highlighted in Chapter 3. However, the long-term relationships established between colonial operator and the manufacturer could afford the opportunity to receive additional feedback on how the designs performed in the field over a period of time, and this could be incorporated into appropriate redesigns.

The casting of the sugar rollers in Britain was the type of heavy industry that defined the industrial revolution. Forging and casting installations were expensive to run and intensive in material and labour. The chain of information from the colonial location to the engineer, then on to the chemist who had control of the iron composition, casting temperature, cooling and other crucial factors, was linked with the desire to create a design that was fit for purpose – although the desired outcome was not always achieved. Detailed records of all of the relevant parameters, as shown in Fig. 5.3, were maintained to assist with quality control. For all

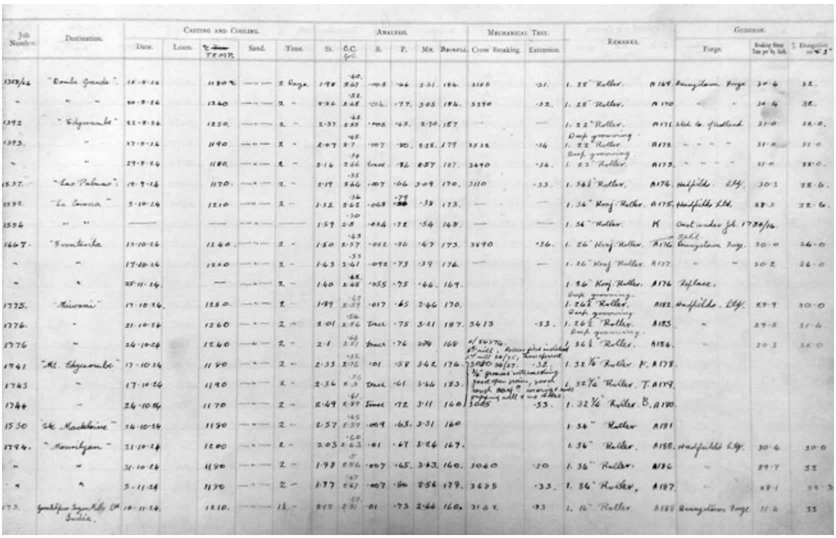

Fig. 5.3 Production records for a cast-iron roller produced by Smith Mirrlees[30]

rollers produced by Smith Mirrlees, information such as the composition of the particular iron (the levels of silicon, phosphorous, sulphur and manganese), casting temperature and cooling time was recorded. These were logged along with analysis of the castings such as the Brinell hardness test – where a ball is pressed onto the surface of the product and the subsequent indentation measured – and dimensional variations caused by the components contracting and distorting in cooling. In this way, the company could be as sure as possible of delivering a product that would meet customer expectations and perform reliably in use.

A similar systematic approach can be found in the development of suitable loading springs for Mirrlees' rollers. Engineers identified these through a series of tests where five spring lengths were tested in five stroke positions – 'averages of tests are calculated on the readings for ¼, ½ & ¾ stroke only, as the first and last are not reliable' – and the load delivered recorded.[31] With a typical target load of 45 tonnes, these were large components that were critical to the reliable operation of the mill. The extensive archival documentation suggests the set-up and testing was an onerous process that led to incremental optimisation of configurations for each job, and although it was not generally shared with customers it was fundamental in allowing the company to respond quickly in applying their accumulated knowledge and expertise to new designs and adaptations.

While detailed test data may not have been communicated externally, continuing collaboration between customers and engineers was critical in supporting the ongoing improvement of designs. An example of inter-imperial feedback loops both within a company and internationally can be seen in the records of communication with Jamaica over the assessment of pitted roller mills.[32] The report prepared by the Mirrlees engineer to the 'Chemist' contains a summary of feedback from a Mr Semple in Mandya, an administrative district of Karnataka in India, highlighting mechanical issues that were experienced in the field there, in order to improve what was being sent out to the West Indies.[33] While noting that in the main the rollers were working well, in particular that the rough roller faces, 'grips the cane very well', the chief issue of concern was the appearance of radial cracks in the grooved crusher rollers. The colonial feedback from Semple describes how 'in some cases there is no evidence of cause of cracks, but in others they start from marks caused by tramp iron'. It was subsequently suggested that a stronger iron should be used, 'even if we sacrifice a little roughness'.[34]

We can find a similar process of acquisition of design requirements and subsequent design evolution surrounding the steam plough, as highlighted in Chapter 4 in the Scottish Highlands, but which was also the case in both Egypt and South Africa. For some products, it was necessary for preliminary or prototype designs to be shipped to the environment of use for testing. This was particularly appropriate for agricultural machines, which were defined by the land they worked. The extensive trials of the steam plough on various terrain across the empire are a good example of the links developed between the engineers, manufacturers and potential customers as the viability of the technology was established in tandem with securing orders. One of the most comprehensive examples of this was the establishment in 1904 of the model farm in South Africa, mentioned above, by John Fowler & Co., under the superintendence of W. A. McLaren, in order to have a dedicated site for the demonstration and modification of steam plough sets for potential farming customers.[35] Although the farm lost money for the company it was still invaluable for the testing and evaluation of parts on the veldt and eventually led to lucrative government contracts for traction engines by 1910.[36] Testing on the boilers, plough beams, bolts and wire threads took place, and the farm was also used as a site on which customers could try out the tackle and learn how to use the technically challenging machines before having them shipped to their new homes.[37]

The testing and evaluation of products and designs meant considerable communication within companies, between engineers and with colonial customers and users. The protocols used to refine and perfect designs illustrate the nature of the design process in British companies at the time. The iterative and discrete innovations recorded through logbooks, with sporadic and restricted feedback from the colonial context, indicate a relatively high level of autonomy and confidence in the designs and their eventual, varied applications.

Distribution and Operation

While the distribution of goods across the empire necessitated practical links for their transportation, the utilisation of local workforces for further installation, operation or refinement created more complex interactions. Depending on the type of product and its intended destination, it was sometimes necessary to establish a colonial outpost with an appropriate level of technical capability to finish products and prepare them for use.[38] As indicated in the chapter introduction, we do not address in detail the long-term use, maintenance and adaptation of technologies in this book; instead, we focus on how design development acted as a conduit for communication across the empire. To this end, we address the networks that emerged through the logistically challenging task of installing what were often large and complex machines in the colonial setting.[39] These were pragmatic relationships that involved not only the physical movement of goods but the communication of technical information to allow successful set-up and operation.

The introduction of steam engines to drive the rollers in sugar machinery is illustrative of the logistical challenges that could emerge when trying to embed a new technology. A favourable change in tax laws in 1829 meant sugar was no longer classed as a luxury item, driving consumer demand to new levels. As a result, it was the first foodstuff to be produced industrially and as the industrial revolution progressed, attention turned to the colonial sugar plantations.[40] These were slave labour-intensive, time-dependent and inefficient.[41] A desire to raise production levels drove mechanisation of the gathering and refining process, as outlined in earlier chapters.[42] The fundamental practicality of utilising steam power to drive the mill rollers depended on improvements to engines rather than sugar mills *per se*: until engines were of a practical size and cost, they were introduced only sporadically and by the capital-rich.[43] In these cases, what was lost in earnings was gained in prestige, as the owners were viewed as improvers and innovators.[44] As steam power continued to evolve as a technology, the machines continued to pose major issues in terms of access to sufficient fuel and water, integration with existing infrastructure, and proper operation. These practical concerns did limit uptake: in 1862, 30 out of 500 estates in Barbados had a steam mill, and by 1897 this figure had only increased by a further 60 steam mills.[45] It also meant that even when the machinery was installed, the physical demands on the plantation workers were still onerous.[46]

Indeed, the sugar industry was a particularly stark example of appalling working conditions. The perishable nature of sugar cane meant that the work was particularly intensive in order to process it as soon as it was harvested. And although the utilisation of machinery for more and more of the production process (the word 'factory' was first used in reference to Jamaican boiling houses) was supposed to assist, the lot of the worker was not improved. Tired labourers often had hands caught in the millstones, and an axe would be kept close by as the mills were not allowed to stop. In this case, innovation was not driven by humanitarian concern but by profit.[47] There were, however, other instances when these two drivers were not mutually exclusive. In the development of larger infrastructure such as bridges there were very pressing concerns around worker safety. Sir William Arrol, who himself was sent to work in a cotton mill, aged nine, and served as an apprenticeship as a blacksmith before going on to specialise in boiler-making and founding his own company, demonstrated progressive tendencies in this regard.[48] His reputation was built partly on inventiveness in facilitating the building of his bridges, often to the benefit of both the worker and the company, such as that of the riveting cage, noted earlier, used in both Scotland and Egypt.[49] Other engineers were motivated by wider humanitarian concerns, such as John Fowler, who was initially inspired to develop his steam-powered agricultural machinery after he was a member of a Quaker delegation to Ireland during the Great Famine in the late 1840s, with a view to supporting efficient and productive agriculture and establishing basic food security.[50]

The transportation and initial installation of products and technologies was often a major undertaking in itself and might require significant preparation. The landing of John Fowler & Co.'s traction engines and waggons for 'pioneer' work (prospecting and mining for gold) in Accra, West Africa, in 1901 highlighted the logistical challenges that accompanied delivery to remote locations that lacked transportation infrastructure.[51] The company was keen to relay the findings of an article in the *West Africa* of March 1901 to other potential customers, as a demonstration of their commitment to supporting their colonial endeavours. The government, the article reported, had constructed a 'splendid road', from Accra to the village of Sansami, some 28 miles away, and from there to the local mines, John Fowler & Co. constructed a further road extension. The construction itself required considerable collaboration between company and local employees and followed four stages. Firstly, a European road constructor would proceed with a gang of 50 to 150 local labourers to cut back the bush with cutlasses along the line of survey. A second gang with axes would then clear all trees so that only the trunks remained. A third gang would dig drainage trenches either side of the road, and a fourth would grub out 'roots and other surface obstacles' and form the top surface.[52] Delivering the road steamer to a beach with no dock was the next challenge. The driving wheels alone weighed more than a tonne each, and to float them required the construction of steel cylinders 7 feet long, constructed in England. To get the machinery ashore, steam cranes lowered the cylinders with their load into the sea and surf boats and then towed them close to the shore.[53] They were then hauled ashore by gangs of men. The boiler of the engine proved a particular challenge, requiring several components to be disassembled and multiple cylinders to be lashed together to float it. A rising tide was used to haul it gradually under a temporary derrick to lift it onto its truck. Overall, the process took three weeks, which was deemed 'a very creditable performance!'[54] The result of this process was not only the legacy of physical infrastructure but the transmission of knowledge of road construction to local workers.

Supervision practices were also critical in ensuring the successful running of any operation, including economical use of materials. In a letter to Smith Mirrlees, Hawaiian Fuel & Furnaces boasted that they had the advantage over Demerara in that they had a skilled mechanic in each building, 'whose code is: "Thou shalt use no more coal."'[55] Furthermore, with a limited pool of skilled workers and remote location, it was common for managers to be promoted from engineers and to have a strong technical understanding. This trust between supervision and production staff is a reflection of the proportions of the workforce on both the British and colonial ends of the projects, as well as the development of British workforce practices.

Conclusions

Realising production meant the transformation from design concepts into tangible goods ready for delivery and installation. In this chapter we have reviewed the practices undertaken and the wide range of techniques and arrangements for testing and evaluation, production, distribution and engaging labour. The confidence of the engineers, both in their ideas and the ability of the workshop to bring them to life, was high. This was in spite of the fact that the technologies, which may have been working well in existing settings, were being applied to very different colonial contexts. The end-users in most cases remained fundamentally distant from the inventors and engineers. In the case of the sugar mill, the eventual users – the workforces – were indeed the last to be considered in the development of new approaches, and this pattern is evident in many of the technologies discussed in this book.[56] Sometimes this translated into a fundamental, if unexpected, commercial disadvantage, as in South Africa for John Fowler & Co., where they lost significant sums of money establishing a model farm to demonstrate their steam ploughs, which were technically challenging to operate.[57] However, the efforts in communicating detailed design configurations reveal the working practices of engineers and the relationships that emerged between companies to facilitate manufacture. The result was the creation of many of the structures and relationships that helped form and sustain the

British World more broadly. Engineers responded to specific technical demands, and information on product performance in operation via sustained feedback loops was highly valued. The importance of empirical data and experimentation are also apparent in the extensive engineers' notebooks that document incremental improvements in many components and processes. Finally, the close collaboration across companies illustrates the importance of supply chains and partnerships to complete large industrial projects.[58]

Many of these practices were concerned with realising the ideas and goals identified at the earlier stages of the design process and demanded material interaction; the sharing of drawings, demonstrators and prototypes; the formation of workshop facilities and operation; and the transportation and installation of goods. All of these – some of which established protocols that long outlasted the technologies they were designed to support into existence – shaped communication in the final stage of our framework.

Notes

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9. Museum of English Rural Life [hereafter MERL], John Fowler & Co., TR FOW, AD2/1, 'Administration book,' ff. 1–32.
10. Mitchell Library [hereafter ML], Sir William Arrol & Co. collection, TD208/67/1, Minute book, ff. 246, 21 August 1901.
11. These details are taken from a typed volume, 'Administration of the steam plough works' [nd but c. 1960], ff. 1–32, MERL, John Fowler & Co., TR FOW, AD2/1, 'Administration book.'
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13. University of Glasgow Archive Service, [hereafter UoGAS], Archives of William Douglas Weir (1st Viscount Weir), GB 0248, DC 096, Notebooks & diaries (1888–1953); Letterbooks & general correspondence (1899–1959); J. & G. Weir Company papers (1904–1962).
14. For similar examples, see UoGAS, Smith Mirrlees (and associated companies), GB248, UDG118/1/6/1, Drawing register, 1859–1898 (effectively Smith Mirrlees' data content management system); UGD118/2/8/1 Roller books 1904–1942; UGD118/4/4/23, Sketch book, 1896–1910.
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16. Arrol & Co., *Bridges, structural steel work*, p. 24. (Sir William Arrol & Co 1909)
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CHAPTER 6

Conclusion: An Empire Connected?

Abstract This conclusion brings the four sections of the methodological framework together in order to discuss the legacies of design collaboration across the empire. We align our findings with postcolonial models that highlight the fluidity of the colonial world and forms of interaction within it. In addressing our initial research questions, we summarise firstly how imperial and British elites played prominent roles in technological initiatives, and secondly the tangible and traceable networks of communication that were the legacy of design activity. We conclude by considering the applicability of our findings beyond the British Empire, and the broader lessons regarding assumptions of knowledge and the circularity of communication networks during this period.

Keywords Circularity · Conduit · Communication networks · Design process · Colonial knowledge · Imperial elites

An anonymous diarist in Jamaica in the early 1820s made this private observation on the agricultural practices he found in place there: 'I am of opinion that much manual labour might be saved in this country if the Plough was introduced in place of the Spade, the majority of the Planters here are Scotchmen, and too much wedded to prejudice and old customs.'[1]

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This simple and somewhat obvious statement touches on many of the themes covered in this book: the confidence in technology to overcome economic, social and cultural blockages on 'progress'; the assumptions of colonial knowledge – both internally in Britain and across the empire – and, lastly, the nature of the communication of those ideas, technologies and designs.

Throughout *Design, Technology and Communication*, we have attempted to demonstrate across a range of technologies and industries the polyvalent nature of the communication of design, as informed by assumptions of colonial knowledge such as that displayed in the Jamaican diary.[2] What did British industries learn from the colonial context and how and by what means was this knowledge communicated and adapted? By developing a four-stage framework – identification, specification, conceptualisation and production – we have tried to illustrate the circularity of communication, both within and across the British World. Although the opportunities resulting from the empire in the form of large and diverse markets could engender complacency in some British industries, overall, the picture is rather more complex. We have shown here that many innovations – particularly incremental adaptations – were developed to meet the needs of challenging, critical markets in the face of fierce competition.[3]

As such, this work is part of a relatively new shift in the literature of technology and colonialism, which moves away from the diffusionist and transfer models, towards a postcolonial framework which highlights the fluidity of the colonial world and the circuits of interaction within it.[4] In our case, this revolves around design and innovation and the communication required to facilitate this. We have explored the way in which the colonies could be both drivers for and sites of technological innovation, development and experimentation, and not simply dumping grounds for mature or obsolete products and designs. We have sought to contribute to these debates by focusing not on the workings or impact of the technologies themselves, but on how and why they were designed and the ways in which design acted as a conduit for communication during the long nineteenth century.[5]

In order to do this, we did not examine the origins of revolutionary new technologies such as steam power and instead looked to later incremental and adaptive technologies and their adaptation for new environments and requirements. In this way, we argue that the activity of design itself acted as a conduit for intra-imperial communication in this period – that is, as a conduit for communication within and across the different contexts of Britain, its empire, and beyond.[6] We have tried to understand and demonstrate how both the technologies themselves and the processes of communication behind their development actually worked; how ideas were practically communicated and how this changed over time and space. We did this by asking two fundamental questions. What was the nature of design in the British Empire with regard to location, stakeholders, motivation and format? And what do both the opportunities and restrictions posed by the imperial context tell us about how design functioned as a conduit for communication?

As we have outlined, the geographies of motivation were varied and complex, but we would make two key interventions on this fundamental point. Firstly, in terms of the less tangible networks of communication in place within and across Britain and the empire, design was a bidirectional conduit. Its practical, goal-orientated nature meant that it took a range of forms, but we found the most important factors in initiating and establishing linkages were economic and financial.[7] These included the financial and capacity priorities of the companies and engineers, the economic structures and vagaries of an increasingly global marketplace, the demands and opportunities posed by free trade and tariff reform, and the increasingly competitive and demanding markets of the dominions.[8] Secondly, we have demonstrated the range of responses and interactions the design process necessitated between companies and engineers – the traceable networks of communication that formed, and the methods and protocols that were their legacies. Why and where engineers and entrepreneurs travelled to in the imperial world, how they identified or were contracted to meet potential design opportunities, and then how they went about that work on a day-to-day basis has been a key concern.[9] By uncovering and unpacking the surviving archival record of their correspondence, drawings, patents and experimentation logs, we have been able to identify an important circuit of imperial communication.[10] Of course, the exception that proves the rule in this case is the large body of evidence of extra-imperial activities of companies and engineers under examination. Business boomed for companies in nineteenth-century Britain, but often more so in non-imperial territories, not least European countries and the Americas. A glance at the order books for the agricultural machinery manufacturers John Fowler & Co. and Ransomes, Sims & Jefferies Ltd, or the locomotive manufacturers Sharp, Stewart & Co. and the North British Locomotive Company, clearly demonstrates the importance of these markets to business.[11] Communication was not simply limited to and between Britain and its empire, therefore; and many of the design innovations explored in this text were also applied, adapted and circulated to the wider British World, complicating the geographies of innovation.

Additionally, we have considered the nature and structure of the communication of design: its various forms and how these changed over time and location. Communication in our period, often across immense geographical distances, was necessarily constrained by technology, and despite the rise of the telegraph, most of this took the form of letters and drawings.[12] Much of both the concept and detailed design stages would have been carried out verbally, but we have tried to reconstruct in this book these processes as carefully as possible. We have been aided by the fact that we have generally looked at incremental technologies rather than those which were more disruptive or revolutionary; as such, the basic technological parameters were nearly always already in place and only adaptations were being made.

Crucial to our argument and approach has been the analysis of the different stages of the design process: identification, specification, conceptualisation and production. As the first stage, we examined the principle of identification of both design and market opportunities in Britain and the imperial context. In order to understand the drivers for new or adapted designs we defined the markets and opportunities present. As we have made clear, however, the possession of the formal and informal empire did not assure the straightforward presentation and initiation of design collaboration. Indeed, there were as many obstacles to communication as there were opportunities, demonstrated by the importance of business outwith the imperial context to many of our case study companies.[13] The second stage was specification, whereby the requirements of the imperial context were more closely mapped out according to the specific user and/or customer requirements.[14] A significant part of this stage of the design process was the impact of competition on design. This included the highly influential contracting competitions various imperial authorities operated, principally to build major infrastructures such as bridges and railways.[15] As such, much of the specification for these designs was already outlined, and engineers and companies had to respond directly to these. In the third stage of conceptualisation, engineers developed and evaluated their initial concepts for new designs or adaptations of existing technologies. This included patterns of design generation, the role of collaboration at individual or institutional level and a discussion as to whether patents acted as a form of communication in this specific context. The fourth stage of production combined detail design, manufacture and distribution in the delivery of completed design solutions. This included the processes by which concepts were converted into working prototypes and tested, the establishing of production processes, identification of labour skills and the transfer, or distribution, of the technology.

As well as this proposed framework of the communication of design, two key overarching intellectual themes also emerged. Firstly, the nature of colonial knowledge and its impact on the assumptions behind many of the technologies have been outlined here.[16] Although we can note the obvious point that most British engineers regarded the technologies they were designing or adapting to be superior to native or indigenous technologies, this was often complicated by the realisation that they were tried and tested under local environmental and market conditions. British technologies nearly always had to be adapted in order to compete with these local innovations. The market for ploughing implements clearly illustrates the tension between assumed British superiority of knowledge and the necessity to understand local agricultural requirements.[17] Although ploughing technology, particularly steam ploughing, offered enormous opportunities in terms of expanding the types of land that could be brought into cultivation, and the speed and thoroughness with which it could be managed, there were a number of obstacles to its successful adoption. These included the high capital costs of the machines, their sensitivity to challenging terrain and the expense of their repair or replacement parts. These obstacles meant that in effect, the steam plough only worked successfully in limited areas of both Britain and the empire, and in many cases simple wooden beam ploughs remained the norm for example in many parts of Egypt and India.[18] So, a technology might be an improvement in design or productivity terms, but it would only be a commercial success if it matched the needs and means of the market.

Secondly, and related to the previous point, our work has demonstrated the importance of imperial and British elites – the 'gentlemanly capitalists' to use Cain and Hopkins' terminology – to the successful, or unsuccessful, development and communication of innovation.[19] Much design work in this period, including its testing and evaluation, was time- and cost-intensive, not least because of the large geographical distances over which the empire stretched and the huge variety of environments and markets technologies were expected to work in. For the technologies we have examined, the customers (although not always the users) of technologies were overwhelmingly elite – both British and imperial. Although the users or labourers working with new technologies were nearly always non-elites (agricultural labourers or enslaved labour in the Caribbean, for example), their purchasers almost always were – whether governmental, social or financial, such as the 3rd duke of Sutherland or the Indian princely classes.[20] As such, the adaption and adoption (or rejection) of technologies were usually couched in the language of 'improvement' and we argue that unsuccessful designs were often developed along class and/or racial lines rather than being grounded in colonial needs. We can see evidence of this in the terse comments of Indian civil servants, claiming that aspects of the 'native character' prevented the use of improved technologies and reflected in the frustration aimed at small labourers in the Scottish Highlands when they rejected the steam plough in favour of the traditional foot plough.[21]

Design, Technology and Communication has attempted to demonstrate through the exploration of detailed technological case studies the specific stages, influences and practices in the communication of design and innovation in the long nineteenth century. Although Britain and its empire has been the geographical locus of the book, it is clear that the empire in and of itself did not influence these processes as much as might be initially assumed. Much of the engineering design and production was taking place in Britain in the examples used here, and the communication of ideas, adaptations and evaluation was then extended to the British World – whether into imperial or non-imperial territories. The empire in some cases presented more obstacles than opportunities for new or adapted design, the contracting competitions for industrial systems such as railways or the telegraph notwithstanding. Where the empire does complicate these processes is in the power and influence of British and colonial elites. In a period where the meanings and impacts of technology were shifting rapidly, a constant uncovered in this work is the elite assumption of knowledge and how this was often in tension with local expertise and resource necessary for successful and sustainable design solutions. The direct and tangible nature of the interaction that supported their development has left its traces in infrastructure, trade, business practice and lifestyle. These are the legacy of a deeply collaborative process, undertaken with a range of motivations and results, but which underpinned an empire of communication.

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8. B. Attard and A. Dilley, 'Finance, empire and the British world,' *Journal of Imperial and Commonwealth History*, 41:1 (2013), pp. 1–10. (Attard and Dilley 2013)
9. Andersen, *British engineers and Africa*, pp. 3–5. (Andersen 2011)
10. There are numerous examples, but symbolised here by Museum of English Rural Life, [hereafter MERL], John Fowler & Co., TR FOW, ET, 1/1 'Book of facts: Drawing Office,' c. 1853–1877.
11. See for example, records of John Fowler & Co.'s partnerships in MERL, TR FOW, AD/7 (Cuba); AD7/30 (Hawaii); and those of Ransomes, Sims & Jefferies Ltd: TR RAN, AD7/47 (Peru and Columbia).
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14. For example, in sugar production technologies: A. H. Adamson, *Sugar without slaves: the political economy of British Guiana, 1838–1904* (London, 1972), pp. 6, 9, 171–2 (Adamson 1972); M. Craton and J. Walvin, *A Jamaican plantation: the history of Worthy Park, 1690–1970* (London, 1970), pp. 156, 219–22. (Craton and Walvin 1970)
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18. Both of these ploughs were marketed as having features suitable for their specific colonial contexts, for example, light, sandy soil and simple structures which could be easily repaired without specific parts: MERL, Ransomes, Sims and Jefferies Ltd, TR 5RAN, SP3/1; for John Fowler & Co., see MERL, TR FOW, Publicity records, PI/A4, A6 – advertisements and catalogues; MERL, Ransomes, Sims & Jefferies Ltd., TR RAN, AD7/63, Letters from India and Ceylon, ff. 26, 25 November 1875; see also British Library, India Office, Public Works Department, L/PWD/3/22, files 189; 201 (1875), for similar debates over irrigation equipment and S. Bhattacharya, 'Cultural and social constraints on technological innovation and economic development: some case studies,' *Indian Economic and Social History Review*, 3:3 (1966), pp. 251, 255. (Bhattacharya 1966)
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