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Integrated vs. add-on: A multidimensional conceptualisation of technology obsolescence

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ABSTRACT

In the past two decades, technology obsolescence has become an increasingly common feature of the global economy, often precipitated by new technological breakthroughs and innovations. Although a number of companies persist with obsolete technologies until disaster strikes, our understanding of the dynamics of technology obsolescence and why some firms persist with obsolete technologies remains largely underexplored. This conceptual paper seeks to fills these gaps in our understanding by developing a four-domain framework to explicate the dynamics of technologies' obsolescence, which takes into account the components in determining different types of obsolescence. The framework articulates two types of life-cycle match and two types of life-cycle mismatch. The article also contributes to the literature by delineating an integrated framework of firm-specific and market-based factors which account for some firms' persistence with obsolete technologies. Amassing and utilising the latest information to update their technologies can help firms enhance their competitiveness. The wider implications of the analysis for public policy and directions for future research are examined.

1. Introduction

Historically, it has often taken product recalls, tragedies and monumental losses to bring to the fore the existence of obsolete technologies within companies and industries (Gidadhubli, 2000; Gupta and Wilemon, 1990; Luo, 2008; Shein, 2011; The Economist, 2014; see also Hora et al., 2011). In a world of increasing global integration and competition, technological breakthroughs and innovations have destroyed the competences of many firms as well as accelerated the demise of old technologies in both industrialised and industrialising nations (Adner, 2002; Afuah, 2009; Amankwah-Amoah, 2015a, 2016c; Fawcett and Waller, 2014; Pourakbar et al., 2012a, 2012b; Schilling, 2013).

Reflecting on these varying realities, some scholars have emphasised that the adoption of modern technology can help to minimise errors and defects, reduce costs, improve efficiency and innovativeness, and above all deliver sustainable competitive advantage (Afuah, 2009; Powell and Dent-Micallef, 1997). Buoyed by technological advancements, many firms have sought to improve their competitiveness by eliminating obsolete technologies, routines and processes (Bartels et al., 2012). In spite of this, some companies persist with using obsolete technologies (see also Cooper, 2004). Such persistence may stem from high switching cost, but our understanding of the wider issue remains underexplored (see Bartels et al., 2012).

Recent streams of scholarly works have emphasised that the obsolescence problem is "*going to get worse, not better*" during the 21st century (Bradley and Guerrero, 2009; Pourakbar et al., 2012b; Sandborn, 2007a). Indeed, around 3% of the global pool of electronic components becomes obsolete every month (Sandborn, 2007b). In spite of the growing body of research on obsolescence and the potential benefits of discarding obsolete technologies (Feng et al., 2007), there remains limited understanding of the dynamics of technology obsolescence and why some firms persist with an obsolete technology (see Bartels et al., 2012; Sandborn, 2007b).

Against this backdrop, the main objective of this paper is to explicate the dynamics of technology obsolescence. Our secondary objective is to examine why some firms persist with obsolete technologies. The issue of technology obsolescence is particularly important given that undetected obsolete technologies can lead to errors and product recalls, and thereby undermining the reputation and competitiveness of the focal firm (Luo, 2008). The study offers several contributions to technology, operations management and strategy research.

First, although the existing streams of research have reinvigorated our understanding of technology obsolescence (Rivera and Lallmahomed, 2016; Sandborn, 2007a, 2015; Torresen and Lovland, 2007), a shortcoming is the relative lack of a comprehensive conceptual model to account for the dynamics. The study deepens our understanding of technology obsolescence (Pecht and Humphrey, 2008; Sandborn, 2003) by

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developing a unified framework which encompasses and takes into account the state of the products as well as the components in determining different types of obsolescence. The study further extends prior research by explicating and specifying the different ways in which a product can come to be declared obsolete by the end users.

In addition, although technological development per se has garnered rich streams of academic research (see Afuah, 2009), there remains a lack of clarity about the issue of persistence with outmoded technologies. By delineating firm-specific and market-based factors which account for such persistence, the paper provides in-depth insight into how firms come to reach such decisions.

In developing the multi-dimensional framework, we begin by providing a brief review of the literature on obsolescence. Next, we pull together the multiple streams of research on the subject to develop a four-domain framework to account for the various facets and different types of technology obsolescence. This is followed by explanations of the features of the four quadrants. Finally, the directions for future research and implications are examined.

2. Technology obsolescence: definitions and scope

Technology in this context refers to tools, devices and body of knowledge that mediates between inputs and outputs, and creates new products or services (Rosenberg, 1972; Tushman and Anderson, 1986). Technology can be conceptualised to include methods, techniques, equipment and devices (Dosi, 1984). One line of research has conceptualised products to include software, hardware and firmware, which are all subjected to threats of obsolescence (Bartels et al., 2012).

Broadly speaking, there are different types of obsolescence. First, there is voluntary and involuntary obsolescence. Involuntary obsolescence occurs irrespective of whether the customer or the manufacturer necessarily wants to alter the product (Bartels et al., 2012). Voluntary occurs when the user or manufacturer allows the technology to die out. It can be attributed to its high inefficiency and high maintenance cost. There is also expected obsolescence, where the focal firm is aware of the time support service is to be discontinued or the machine becomes obsolete. Unexpected obsolescence refers to sudden changes in the position of the original manufacturer, e.g. declared bankrupt or issued with notices of impending closure or end of production. This then forces the focal firm to seek alternative sources of supply.

Paralleling the above body of knowledge, some scholars have defined obsolescence as the degree to which an employee lacks the current knowledge or technological acumen required to deliver expected performance (Amankwah-Amoah, 2015b; Aryee, 1991; Sandborn and Prabhakar, 2015). From an engineering standpoint, the skills of engineers, electronic components and software are all subject to risk of obsolescence (Aryee, 1991; Wallis, 2010). Table 1 provides a sample of definitions of obsolescence used in management, operations and strategy literature. The table also illustrates the multitude of interpretations of the term.

Broadly speaking, obsolescence occurs when a particular technology is considered less effective in addressing its current and future needs/problems of affirm relative to other technologies currently available and/or utilised by other firms (Cooper, 2004). Put differently, technological obsolescence occurs when the functional qualities of a product are inferior relative to newer versions of the same product (Cooper, 2004). It can also occur when devices and software become non-procurable from the original producer/manufacturer/supplier (Bartels et al., 2012). Some of the unique features of obsolete technologies include high failure and error rates, continuous breakdowns and repairs, increasing product recall associated with the technology, and high cost of operations and manpower (see Hitt and Schmidt, 1998). Table 2 summarises a range of technologies/products that have been considered obsolete.

There is also perceived obsolescence. This is where the users or customers of a product are persuaded to replace a functional product and/or its component because it is seen to be no longer fashionable or suitable (Bailey 2013: 366; Zhang et al., 2012). Indeed, the introduction of a new version of a product buttressed by effective advertisement and promotion can persuade users that the old version has lost its appeal and attractiveness, and therefore needed to be replaced (Rivera and Lallmahomed, 2016). Such approach can help to ensure sustained consumption and contribute to the profitability of the producers. One example of planned obsolescence can be traced to the Phoebus cartel (1924–1939) formed to control the light bulbs market by limiting the lifespan of light bulbs to 1000 h (Kessler and Brendel, 2016; Rivera and Lallmahomed, 2016).This distorted market competition.

Technology obsolescence can be viewed as the outcome of a "*mismatch between the life cycles of products and the technologies they incorporate*" (Feldman and Sandborn 2007: 2). Following similar logic, Feng et al. (2007: 1) defined it as a mismatch "*between electronic part*

Table 1
List of "obsolete" products/technologies.

Types	Nature of evolution/modernisation process	Current status
Cassette	• Superseded by the compact disk and other storage devices. It was found to be unreliable and possessed limited ability to store large data.	• Can be purchased from aftermarket sources.
CD players	• Evolved and built in to other technologies.	• In use in underdeveloped markets and countries.
Floppy disk	• It was a cutting-edge technology of the 1980s but has since been found to be inefficient, costly and unreliable, prompting many users to switch.	• Can be purchased from aftermarket sources and used by some government agencies in both developed and developing economies.
Fax machines	• Many users have found e-mails to be much cheaper and more convenient to use relative to fax machines.	• Can be purchased from aftermarket sources.
Telex machine	• Users have shrunk and some countries have not developed the infrastructure to support its operation.	• Can be purchased from aftermarket sources.
Landline telephones	• Many developed countries have leapfrogged to the latest technology and built facilities for mobile networks.	• In decline but still in use.
MP3 players	• Many users have switched to alternatives including using mobile phones.	• In decline but still in use.
CD-ROMs	• Emergence of more reliable and high-capacity storage devices has encouraged many users to switch.	• In decline but still in use.
Typewriter	• Superseded by the PC and keyboard which is more efficient and effective.	• Can be purchased from aftermarket sources.
DVD	• Superseded by streaming services such as Netflix, Hulu, Apple's iTunes Store and Amazon Instant Video. Cloud-based storage options have also emerged and are growing.	• Still in use.
Public phone booth	• Its function has been subsumed by the emergence and development of mobile phones.	• Still in use but usage rate has declined.
VHS	• DVD/Blu-Ray discs emerged with superior quality and multimedia functionality relative to VHS.	• Can be purchased from specialised stores.

Data sources: synthesised from: Amankwah-Amoah, 2016c; Bartels et al., 2012; Grobart, 2012; Pollack, 1990; Smith, 2013; Stonington, 2015.