One hundred reasons socially beneficial technology might not work

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Abstract

Technologies service many human needs. Socially beneficial technologies can also assist in resolving some of the world's most pressing problems: climate change; access to safe drinking water; quality housing; universal health care. Often a technology already exists, awaiting to be applied. In other cases it is within grasp given appropriate prioritisation. This paper considers approximately 100 theories of and approaches to technology innovation and adoption regarding the question, How is the failure of socially beneficial technology explained? Approaches include legal, regulatory, political, philosophical, sociological, usage, psychological, technical, economic, commercial, and marketing. This paper creates a framework of six categories in order to classify and compare the theories. It then proposed further research steps to examine the question.

1. Introduction

Many technological inventions, products and initiatives fail. They may get no further than an idea in an inventor's head, or they may be launched as a product having cost billions of dollars. The Mars Climate Orbiter crashed on Mars due to a programming error [1] after 286 days in flight and more than $300m expenditure. The London Millennium Footbridge took around 18 months to build and was closed after three days for two years' repair due to lateral swaying [2]. When the Iridium satellite phone company filed for bankruptcy in 1999, it had fewer than 20,000 customers for a service that required the launch of 66 satellites costing several billion dollars [3].

In many cases this is assumed to be normal market function, as some products succeed and others fail in a competitive commercial environment. By learning from past experience organisations developing technologies attempt to increase their chance of success.

This paper examines a related question, How is the failure of socially beneficial technology to be explained? It is not attempting to reach a single or multiple explanations, but to gather a list of possible explanations.

The paper describes approximately 100 theoretical approaches to this question. These range from well recognized theories with significant literature and extensive research, to others that are little more than widely held prejudices. Each approach has been selected based on evidence of its influence. The list of approaches results from a purposive selection of technology uptake literature which could be applied to the question. It is not presented as exhaustive, but seeks to provide a representative selection of approaches.

The first section of this paper begins with a description of fields involved in the research, the relevance of the question, and the research method. A summary of the findings is then given in a narrative flow, followed by the Conclusion. The second section comprises six appendices which explain each of the 100 or so approaches. The References section then identifies literature on the 100 or so approaches.

2. Multidisciplinary approach

While no single similar list was identified during the research for this paper, the following 11 fields were identified as each having relevant literature or frameworks:

1. Legal, primarily focused on Intellectual Property [4].
2. Regulatory, particularly jurisdictionally based compliance obligations [5].
3. Political, the will or interest of a government or interest group to drive or prevent the uptake of a particular technology [6].
4. Philosophical, where reasoning is based on belief systems [7].
5. Sociological, focusing on the societal context [8].
6. Usage, particularly the User Centred Design explanations [9].
7. Psychological, focusing on the individual's reaction to the product or service [10].

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8. Technical, based on the engineering concept of ‘fit for purpose’ [11].
9. Commercial, driven by the concept that investments will succeed if they deliver ‘return on investment’ [12].
10. Economic, looking at broader economic issues that prevent technology adoption [13].
11. Marketing, similar to the psychological approach in that it examines the individual’s response to a specific initiative, but from a different theoretical base [14].

Each of these separate areas provides a framework for examining the question, but in each of these there is no uncontested theory or even framework regarding why a socially beneficial technology might not be successful. To give a single example, in the commercial field, Schumpeter suggests that large corporations are most conducive to technology innovation [15], while Porter examining the same question more than half a century later reaches an opposite conclusion [16].

In addition to theories from these fields, this research considered discussion around several technology adoption questions:

- What are the steps in technology adoption [17]?
- What circumstances favor technology innovation?
- What influences the barriers to entry within a particular industry [12]?
- What is the relationship between technology and society? [6]
- Does technology push itself onto society [18] or does society pull its needs from technology development [19]?

The range of areas requires the work to be multidisciplinary, drawing on tools from each of the above fields.

3. Why it matters

An examination of barriers to technology uptake may be considered simply an examination of how the market impacts technology uptake. By introducing the concept of socially beneficial technologies, the question becomes more complex.

If one video cassette recording technology (Beta) has technically superior features to another (VHS) but loses a marketing battle, relatively little

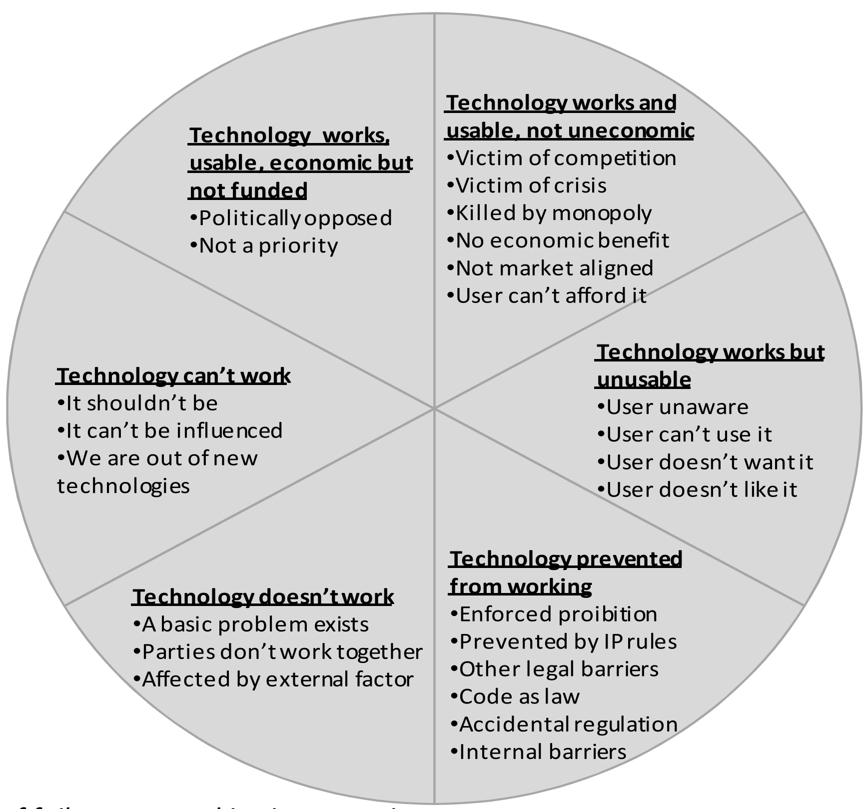

Figure 1. *Causes of failure grouped in six categories.*

is lost to the broader community. However, if a low cost treatment for a debilitating eye disease fails in the face of superior marketing from a higher cost treatment servicing a small fraction of the low cost alternative, then this is a net negative for society. This is an example of the possible divergence between the usefulness of a technology and the commercial benefit from technology: maximising commercial benefit does not necessarily maximize the usefulness of a technology.

More widely, socially beneficial technologies can assist in addressing some of the world's most pressing problems: climate change; access to safe drinking water; quality housing; universal health care. Often a technology already exists, awaiting to be applied. In other cases it is within grasp given appropriate prioritisation. This point will be examined in further detail in future research. While it is not the purpose of the current paper, it provides context for this paper.

4. Approach

The purpose of this paper is to lay the basis for further research into the question, How is the failure of socially beneficially technology to be explained? Faced with a wealth of theories on the subject, the aim is to establish an approach for reviewing and comparing these theories.

For the purpose of this paper, 'socially beneficial' is broadly defined to include any technology whose primary purpose is societal rather than commercial gain. This definition is sufficient for the purpose of this paper, but insufficient for a general discussion of the question. For example, as currently structured this definition could include technology developed in a national or sectional interest, which may or may not be considered socially beneficial in a global context.

As a first step, I undertook a purposive literature review based on the question. This identified the 11 fields described above. Technology uptake literature in each of these was then searched for explanations of technology failure. In each case the example of failure relates to any technology, not just technology that could be described as socially beneficial.

This produced a list of approximately 100 theories or assertions regarding what leads to technology success or failure. This is a superset of the range found in most technology uptake literature, because it explicitly includes uptake challenges in situations where there is no necessary commercial basis for the technology (eg, provision of health services to people who can't afford for them).

It appears intuitively likely that socially beneficial technologies that are also 'not for profit' will face some barriers that are common to all technologies and some barriers that are different to 'for profit' technologies, with such points as 'if there is no promise of profit why would any investors be interested'. Nevertheless, for the purposes of this paper I have deliberately refrained from starting along this path for the following reason: the requirements of adequately defining 'socially beneficial technology' are not trivial; nor is creating a defensible test for the efficacy of any of these more than 100 theories. Both of these need to be completed before an examination of the theories themselves. Rather than taking tentative steps which would tend to detract from a discussion of the range of theories, this paper is deliberately limited in its goals. The Conclusion discusses possible next steps.

For these reasons this paper makes no judgment regarding the efficacy of any of these theories, nor suggests a preferred set of theories. Some of the theories are complementary, as multiple theories could fit the evidence of a specific case. Others are mutually exclusive. Some appear to have no merit, but are widely held. From a societal perspective readers may find some repugnant.

I also don't suggest that simply because a technology fails to be adopted for one of the causes listed here this is necessarily bad. In particular, just because a technology is developed for socially beneficial purposes doesn't make it socially beneficial. Some technologies have unintended consequences [20] which made their rejection socially beneficial, such as Thalidomide [21].

In order to compare theories from the 11 fields I regrouped the approximately 100 approaches into a framework of six categories each having several subcategories (Fig. 1). While there is still a visible connection to some of the 11 fields, this was done in order to move the research beyond a simplistic field versus field approach, for example, a societal versus commercial approach.

5. Findings: The framework

Descriptions of each cause theory with an example and supporting references is located in Appendices A to F. Following is a summary of the theories in a narrative flow.

5.1. Technology can't work (Appendix A)

In this category are theories which deny the value of attempting to control technology, in the following subcategories.

- Technology shouldn't be: it isn't meant to be; it is unreasonable; it is uncontrollable; technology development per se is a negative; a particular technology is a detour; any attempt to implement socially beneficial technology will lead to a tragedy of the commons.
- Technology can't be influenced: it is autonomous; technology development can only occur in the right circumstances.
- We are running out of new technologies: there is an end of creativity; there are no new frontiers; technologies just can't come into existence.

5.2 A technology doesn't work (Appendix B)

In this category are those explanations based on an inadequacy in relation to the technology itself.

- There is a basic problem with specific technology: it isn't fit for purpose; it has unanticipated consequences; there is a lack of planning; there is a failure of project management.
- Parties that need to work together for a technology's success don't: there is a lack of cooperation; the technology is too simple; the necessary infrastructure is closed; standards poisoning occurs; technologists are not appropriately engaged.
- External factors affect technology: It has a closed design; the rush to market is too fast for the development of effective standards; the technology suffers the effect of marketing.

5.3 A technology is prevented from working (Appendix C)

In this category are cases where a technology could work if some prohibiting circumstance were not present.

- Enforced prohibition: It isn't legal; it suffers censorship; there is a threat of arrest; there are negative court rulings; required content is privatized; the technology is subject to military secrecy; the technology is seen as a military threat; military sabotage occurs.
- Prevented by Intellectual Property rules: Necessary patents are not available; copyright is not held; it is prevented by patent control; patents are used as investment rather than for productive development; there is a threat of dispute; the cost of engaging with the patent system is prohibitive; there is conflict of laws; clear intellectual property rules don't exist.
- Other legally enforceable barriers: Taxation; hardware controls; a requirement for escrow; consumer legislation; control of limited resources.
- Code as law thesis: There are limits on media devices; control through code.
- Accidental regulation: Wrong regulation; red tape; the technology is too different for regulators to consider; governments reject international standards.
- Internal organisational barriers: Internal sabotage; tradition; hierarchy; inflexibility; bureaucracy; silo mentality; a Not Invented Here attitude; isolation of the decision-maker; appropriate reward structures.

5.4 A technology works but is unusable (Appendix D)

In this category are cases where a user is unable to achieve a benefit from the technology.

- The intended user doesn't know about it: The technology is not offered; the consumer is unaware; access to information is blocked; the technology is not understood; there is a lack of informed debate.
- The intended user can't use it: It is inherently unusable; it is poorly designed; it is unfriendly; it needs user engagement; it is built for technologists.
- The intended user doesn't want or need to use it: It is not wanted; it is not interested; it is alienating; the need is already met; it is over-hyped.
- The intended user doesn't like or trust it: Because of technophobia; because it is unpleasant; because it is too strange; because the intended user lacks confidence in technology.

5.5 A technology works and is usable but uneconomic (Appendix E)

In this category are theories where technology appears to provide a benefit, but fails to meet commercial requirements of Return on Investment (ROI).

- Victim of competition: Market forces defeat the technology; others hold greater commercial promise; there are commercial wars; a vendor sabotages standards; the

technology is undermined by vaporware; it loses a competitive race; it fails to 'cross the chasm'; it suffers from marketing failure.
- Victim of crisis: The technology is affected by the Global Financial Crisis; it is affected by a regional or national economic crisis; it is a victim of overcapacity.
- Killed by monopoly: The technology becomes a victim of monopoly interests; the manufacturer decides not to provide ongoing support; the technology threatens economic interests; the technology is overwhelmed by an existing monopoly.
- No visible economic benefit: The technology provides no ROI; it holds no competitive advantage; the investor's purpose is commercial benefit, not user benefit; other non-beneficial technologies are more profitable.
- Not market aligned: The technology doesn't suit economic needs; it is defeated by a technology divide; it doesn't fit a planned release strategy; other necessary supporting technology is not available; distribution of less beneficial technologies is preferred for market reasons.
- Customer can't afford it: The technology is inherently too expensive; a 'green premium' makes it more expensive than alternatives.

5.6 A technology works, is usable and economic, but not funded (Appendix F)

In this category are theories regarding technologies that meet all usage and commercial criteria but are still not progressed.

- Politically opposed: The technology threatens political interests; it is not aligned to political interests and therefore receives insufficient investment; it is not one of the 'picked winners'; there is active opposition to it; its usage is stigmatized; it doesn't reinforce a political imperative.
- Not a priority: Government investment is drawn to other things such as military spending; the technology receives insufficient government assistance; there is no government purchase; it is not prioritised.

6. Conclusion, limits and further work

This paper has shown that there are a significant number of theories that could address the question, How is the failure of socially beneficial technology to be explained? While some of these theories could be applied to any technology, others are of specific relevance to technology not primarily developed for commercial gain.

The framework of six categories introduced in this paper has been shown to provide a means of grouping the list of theories, for classification and comparison purposes.

One limit of this research relates to the purposive selection of literature in assembling the list of around 100 theories. While not yet tested, this result is falsifiable, for example by the identification of a large body of additional theories or the addition of several other research fields that show this work to be unrepresentative of the range of theories for failure of technology uptake.

Subsequent research will look at how to apply the approximately 100 theories to scenarios where socially beneficial technology both failed and succeeded, in order to test the explanatory power of these theories. Further research will also provide more detailed comparison of this framework and of frameworks used to examine the questions listed in the Introduction regarding technology adoption, innovation, barriers to entry, the relationship between technology and society, and technology push versus society pull. The further research will also review the usefulness of the framework of six categories in analyzing a large set of theories.

Appendices

Appendix A. Technology can't work

In this category are theories which deny the value of attempting to control technology.

A.1. Technology shouldn't be

Not meant to be: Humans shouldn't develop technology, because this is the province of a god or gods. Human confidence in technology is blind hope [22]. Some schools of modern conservatism places prohibitions on classes of technology such as stem cell research [23].

Unreasonable: Modern technology while not demonic is essentially mysterious, placing unreasonable demands on nature [24].

Technology determinism: Technology is the single most important source of change in society, so if a technology is unsuccessful, it was not meant to be [6].

Technology development a negative (Luddism): While technology development is possible, its general effect in changing productive capacity is negative, therefore it should be actively opposed [25]

Specific technology is a detour: For Negroponte the (originally analog) facsimile machine in the 1970s was 'a serious blemish on the information landscape' [26].

Tragedy of commons: The generosity of a benevolent inventor introducing a new technology is all for nothing, because human nature will corrupt any technology occurring outside the market and lead to an effect which is opposite to the goal of the inventor [27].

A.2. Technology can't be influenced

Autonomous technology: There is no inherent purpose to technology. Rather than meeting needs, advancing political (including military) goals, creating/meeting consumption demand, or delivering any other comprehendible purpose, technology has become autonomous. It is 'out of control'. This may be a positive development, as we approach a technology singularity [28]. It may be dystopian [29]. Or it may have no identifiable meaning [6].

Technology development needs to occur in the right circumstances: Goethe's late 18th century discovery of the shortcomings of a purely physics-based approach to color perception could have changed the history of color reproduction, but it took until 1957 for his views to be validated [30].

A.3. Technology can't happen

End of creativity: The declining per capita rate of fundamental new inventions since the early 20th century reflects the phenomenon that we have already developed most technologies that we can, and there is now a closing range of discoveries available for human creativity to discover [31].

End of frontiers: Technical creativity relies on freedom from restrictions and the ability to release unfettered thought. In the early 20th century California became a centre of film production in part because of its distance from the US East Coast and the enforcers of the New Jersey-based Motion Picture Patents Company [32]. Today there is virtually nowhere on earth beyond the reach of intellectual property laws.

Can't come into existence: The economic environment from the 1980s saw a significant reduction in government spending on basic research in the sciences and technology. At the time it was pointed out that there was no investment of the sort that earlier had led to the creation of the Internet [33].

Appendix B. Technology doesn't work

In this category are those explanations based on an inadequacy in relation to the technology itself.

B.1. Basic problem with the technology itself

Not fit for purpose: The technology fails to meet a critical requirement of its purpose, and is therefore of no value [11]. An example is a bridge that collapses due to unexpected engineering properties.

Unanticipated consequences: Production or use of the technology creates one or more negative outcomes that render the technology worthless or predominantly harmful [20].

Lack of planning: The technology has hidden or unappreciated defects that require significant rework, such as the Y2K bug [34].

Failure of project management: While the technology can work under some circumstances, its complexity, scaling characteristics, or some other property lead to a propensity for projects to fail [35].

B.2. Parties that need to work together for its success don't

Lack of cooperation: The technology is fully effective, but lack of cooperation between parties involved in its introduction or use results in failure of technology to achieve its goal. This could include unwillingness to cooperate between various users of the technology, such as the early instruction from Marconi that its land-based operators refuse to answer calls from ships using non-Marconi equipment [8], or confusion regarding measurement standards such as the US/British Mars mission crash [1].

Too simple: While the technology is fully effective, its simplicity is an affront to technologists who would prefer to introduce a more complex and technically challenging solution. This is found in the technological criticisms of Appropriate Technology, the suggestion that the best technology for a given circumstance will be determined by specific circumstances rather than by the current state of the art. See for example the Discussion tab at the Wikipedia Appropriate Technology page [36].

Closed infrastructure: Technology cannot be implemented because it depends on an open infrastructure, such as a high-speed peer-to-peer communication network rather than an asymmetric network that in effect provides broadcast or multi-cast functionality with a limited back channel [37].

Standards poisoning: A standardised platform for innovation exists and provides the opportunity for innovation. This is then 'poisoned' by a leading industry player or industry forum to maintain industry barriers to entry. Wireless Application Protocol was designed to be incompatible with TCP/IP in order to create a gatekeeper role for telecommunications companies [38].

Technologists not appropriately engaged: Despite a government imperative to implement a reforestation program in Cuba in the early 1960s, simple technical mistakes reduced its effectiveness [39].

B.3. External factors affect technology

Closed design: Technology innovation cannot be implemented because of infrastructure monopolisation where the monopoly provider's interest in innovation is limited, such as prior to deregulation of the US telecommunications environment in the 1980s [40].

Rush to market too fast for standards: The rush to market threatens new standards that don't have time to address early teething problems including security [41].

Effect of Marketing: Technology innovation is distorted by the requirements of product marketing [42].

Appendix C. Technology is prevented from working

In this category are cases where a technology could work if some prohibiting circumstance was not present.

C.1. Enforced prohibition

Not legal: The most appropriate technology is illegal, due to reasons unrelated to the technology itself. The production of hemp fibre for clothing is prohibited in the US due to association with a related but separate drug-bearing plant [43].

Censorship: Publication of research into the effectiveness of Intellectual Property protection measures is illegal under the US Digital Millennium Copyright Act [4].

Threat of arrest: The arrest of a Russian citizen visiting the US to address a conference on the security of copy protection systems provided a strong disincentive to research in cryptography [44].

Negative rulings: A court rules that a particular use of technology is in breach of law, such as the Napster defeat in its commercial MP3 offering [45].

Privatised content: Traditional media content was created prior to the Internet, and media companies that own rights to a particular sound recording or printed book have now asserted that this includes rights to this intellectual property in a new media context. This has been described as a property grab [4].

Defence secrecy: National defence organisations may lay claim to a technology for an extended period of time, indefinitely preventing its use or knowledge of its existence. The CDMA (spread spectrum) technology was patented in 1942, then spent some decades behind a veil of military secrecy. Finally in the late 1990s we saw its use in Global Positioning (GPS) and 3rd generation mobile telephony (3G) [46].

Military threat: Throughout the Cold War an alliance of several counties established the Coordinating Committee on Multilateral Export Controls (CoCom), an embargo list of military and dual use technology including cryptography. The effect of this was to limit technology development in the US in dual use technologies as export opportunities for the technologies was artificially constrained [47].

Military sabotage: Reed describes a major explosion in a Siberian gas pipeline due to CIA sabotage of pump control software obtained through a Canadian computer company [48].

C.2. Prevented by Intellectual Property rules

Patents: No single company has sufficient patents necessary to create a workable technology. After WWI three US companies between them held the patents necessary to create a radio transmitter or receiver, and between 1912 and 1926 there were 20 significant patent disputes between two of these companies, General Electric and AT&T [49].

Copyright: A technology provides effective service, eg the video cassette recorder, but its use opposed. For Jack Valenti, 'the VCR is to the American film producer and the American public as the Boston strangler is to the woman home alone' [50].

Patent control: Key patents for major technology are held monopolistically. Prior to WWI, the Seldon Motor Vehicle Company held the US patent for the car, a control which was finally defeated in court in 1911 [51].

Patents as investment: A company may invest in patents with no intention of developing or implementing a technology. For large technology companies, the holding of defensive patents ensures future negotiating strength in any new technology development in related fields, even if the company itself is doing no work in those fields [52]. In a separate process known as "patent trolling" a company may purchase patents for the sole purpose of demanding payment from others engaged in technology innovation [53].

Threat of dispute: A company may avoid innovation in a particular field due to the prospect of patent disputes. One disputed radio patent was filed in 1913 and finally resolved by the US Supreme Court in 1934 [49].

Cost of patent system: A small company may be forced to sell an innovation due to the prospect of being unable to defend an invention in court action.

Jurisdiction extension: The international character of the Internet facilitates legal jurisdiction shopping or 'conflict of laws' [54]. An innovative company may be subject to legal action in any jurisdiction in the world, not just the jurisdiction in which it has developed the innovation.

Lacks clear IP rules: The creation of new technologies unforeseen by legislators creates unclear IP situations, including a fragmentation of ownership of gene DNA sequences [55].

C.3. Other legal barriers

Taxation: While a technology may be provided freely for use, legal measures may be taken to enforce a monetary value on it, as with Poland's attempt to tax free software as if it was commercial software [56].

Hardware control: The establishment of monitoring and control functionality in all computer hardware has been proposed in US legislation and discussed by Vinge [57].

Requirement for escrow: Technology innovation in cryptography has depended on the right to secret cross-border transmissions established in 1865 with the creation of the International Telegraphy Union [58]. This right has been subject to a series of government reviews in the late 20th century.

Consumer legislation: Rules for the stated purpose of ensuring product quality may be applied to limiting innovation. For example, the requirement that plants breed true to type for many generations before they can be sold creates a significant barrier to entry for anyone working with non-mainstream plant breeds [59].

Control of limited resources: Nominal technology limitations, such as limited available bandwidth for radio or television broadcast, provides the basis for limiting publisher access to electronic media which didn't exist for print media [5].

C.4. Code as law

Limits on media devices: Content owners may create technical barriers to the use of a device, such as limits to the ability to play music on PCs, or regional video play controls that prevent DVDs purchased in one geography from being played in another [4].

A tool of control: Lessig also argues that left to itself cyberspace will become a perfect tool of control [4].

C.5. Accidental regulation

Wrong regulation: Technology innovation may be blocked by unnecessary regulation [60].

Red tape: Rules designed to establish product safety may significantly increase the cost of pharmaceuticals and reduce innovation in smaller opportunity markets [61].

Different: A low carbon technically sufficient construction material, such as packed earth or mud brick building construction, may be outside the standard parameters for construction approval (eg http://www.abcb.gov.au/) or building insurance, and therefore blocked from use.

Government rejection of standards: Rejection of standards which could create the basis for technology innovation through ensuring a large compatible user community, such as the US government failure to allocate agreed bandwidth to 3G telephony, perpetuating incompatibility of mobile telephones between the US and Europe [62].

C.6. Internal organisational barriers

Sabotage: Attempts by the Nazi regime to develop nuclear technology were sabotaged by an agreement between key German physicists [63].

Tradition: An enterprise may have excess confidence in the correctness of its technology capability, leading it to miss or dismiss as trivial key changes in technology use, known as 'disruptive technology' [64].

Hierarchy: A company may have a culture which privileges a particular technology, such as photocopiers at Xerox [9]. To get around this culture and create innovative technologies in 1943 engineer Clarence "Kelly" Johnson created the Skunk Works at Lockheed Martin [65].

Inflexibility: Information technology corporate structures may fail to meet business unit technology demand, evidenced in the appearance of Shadow IT, where non-IT business units secretly or openly sponsor technology development outside of the enterprise standard approach [66].

Bureaucracy: The technology development path may be out of line with the requirements for innovation. US forces in Iraq developed vehicle shielding in response to their opponents' ability to innovate with new anti-vehicle mines. While the US military estimates that insurgents modify their tactics in less than a month, in the past 35 years average US weapons system development time has increased from 11 to 14 years [67].

Silo mentality: An organisation may significantly delay implementation of new technology due to internal organizational barriers [68].

Not invented here: An organisation may refuse to allow the implementation of technology where the organization has a tradition of developing this type of technology in-house [69].

Decision-maker isolated: Decision-makers may become culturally isolated, as recognised by the General Electric program to provide 20s mentors to all key senior executives during the Dotcom boom [70].

Reward structures: Reward structures may prevent behaviour necessary to achieve innovation [71].

Appendix D. Technology works but is unusable

In this category are cases where a user is unable to achieve a benefit from the technology.

D.1. I don't know about it

Technology not offered: A superior technology may be unavailable in the marketplace, such as the quiet gas fridge in contrast to the noisy electric fridge [72].

Consumer unaware: A more useful technology may lack the marketing spend and be unknown to consumers [73].

Access to information is blocked: Internet content control software may prevent young people from accessing information, such as on birth control and safe sex technologies [74].

Not understood: Technology features, such as highly effective security, may be presented in a complex way that makes them incomprehensive to a non-technical audience, such as cryptography key length [75].

Lack of informed debate: Public debate of technology may move from debate informed by science to an emotion based debate, such as on the recycling of water for human consumption [76].

D.2 I can't use it

Unusable: A technology may be very difficult to use, such as the requirement for complex passwords to protect security combined with the requirement not to write down the password near its place of use [77].

Poorly designed: Useful items may be designed without the user in mind [9].

Unhelpful: While technologists may assert that technologies overcome the failings of people, a study of technology use shows the opposite to be true [78].

Technology needs user engagement: While a user may expect a technology to 'just work', the technology is dependent on the user, such as for regular maintenance [79].

Technologies built for technologists: Usability as a field has identified the problem that technologists test many of their technologies, seeing themselves as typical users [80].

D.3. I don't want or need to use it

Not wanted: Apparently desirable technology, such as housing, is provided but subsequently damaged or destroyed by occupants [81].

Uninterested: A community sector may object to prioritization of a particular technology, eg Gil Scott Heron's 1969 lyrics, 'A rat done bit my sister Nell (with Whitey on the moon)' (http://www.gilscottheron.com/lywhitey.html).

Alienating: An apparently useful technology feature may not attract interest. In a wider sense, engineering itself may be presented in a way which fails to equally attract both men and women [82].

Need already met: Much technology investment is devoted to identifying substitutes to existing technologies that already meet a need, either in order to reduce cost of production, or to allow a company specialising in one field to move into an alternative and economically desirable field [12].

Over-hyped: A technology may provide an adequate service but have been over-promoted; resulting disappointment may lead to the technology's failure [83].

D.4. I don't like or trust it

Technophobia: Even where benefits greatly outweigh any negative impact, an effective technology such as childhood disease immunisation may face opposition due to fear of the technology [84].

Unpleasant: Environmentally friendly or other positive technologies may be considered to be unpleasant [76].

Too strange: In order to overcome the strangeness of the early radio, effectively a box of electrical parts, early radio design, particularly those designed by Gordon Russell, emphasised continuity between existing domestic furniture and the radio receiver [85].

Lack of confidence in technology: For functions that a user places heavy trust on, such as on-line banking, a lack of trust or confidence will delay or prevent technology adoption [86].

Appendix E. Technology works and is usable but uneconomic

In this category are theories where technology appears to provide a benefit, but fails to meet commercial requirements of Return on Investment (ROI).

E.1. Victim of competition

Market forces: For Schumpeter, technical efficiency is not a characteristic of the market. Instead old and inefficient systems may prevail if these are more profitable [13].

Others hold greater commercial promise: Individual investors may have no interest in socially beneficial technology [87].

Commercial wars: Technologies with positive characteristics, such as from the Free Software movement, may be the victim of commercial wars. After embattled software developer Corel received a significant investment from Microsoft, it ceased its investment in software for the Linux operating system [88].

Vendor sabotage of standards: While the introduction of standards generally assists the development of reliable and serviceable technology, companies with a dominant market position may see themselves having an interest in maintaining proprietary standards, such as Microsoft's 1995 plan to 'embrace and extend' Internet standards [89].

Vaporware: Where a market leader is faced with a competitor offering new functionality or some other improvement, a widespread practice is to announce that the market leader is about to release the same new feature, resulting in delays in purchasing and destruction of value for the innovator [90].

Lost competitive race: When technologies lose the competitive race, the result will be the destruction of significant productive capacity such as the replacement of Beta with VHS in the video recording market [91].

Crossing the chasm: Where significant investment is involved, and widespread commercial uptake required, technology uptake experiences a critical moment when the real benefits of the product can be appreciated regardless of the marketing hype, and at this point many products fail [92].

Marketing failure: Regardless of the technology, poor user targeting, poor packaging, or an apathetic audience may kill the product uptake as completely as any other problem [14].

E.2. Victim of crisis

Global Financial Crisis: Each economic crises, most recently the Dotcom Crash and the Global Financial Crisis, saw the ruin of many companies and destruction of significant productive capacity. Many of these technologies were simply in the wrong place at the wrong time [93].

Regional or national economic crises: The Asian economic crisis of 1998 saw a significant impact on Malaysia's ambitious technology plans that were expected to play an important role in assisting national development [94].

Overcapacity: In addition to crisis-driven destruction, key individual technology companies such as Cisco may experience a crisis of overcapacity, regardless of their planning abilities [95].

E.3. Killed by monopoly

Monopoly interests: Technology companies present an image of continuous innovation, which may be at odds with anti-trust findings, such as a 1999 finding against Microsoft [96].

Manufacturer decides not to provide ongoing support: General Motors states that the EV1 electric car was withdrawn from service and each car crushed because the company did not wish to provide long term maintenance [97].

Threatens economic interests: The ability to deliver high quality very low cost health care solutions to impoverished people (http://www.hollows.org.au/) may provoke a response from commercial providers who fear a reduction in profitability.

Overwhelmed by existing monopoly: The 1911 ruling against Standard Oil provides a classical description of monopolistic behavior [98].

E.4. No visible economic benefit

No ROI: If a technology is dependent on commercial investment, it must have the promise of Return on Investment, of paying back its investors and providing them with a profit. Depending on the purpose of the technology, there may be no commercial promise [99].

No competitive advantage: Porter describes the requirement for successful investment in technology being not that the technology provides practical value, but that the company investing in it is able to protect its position if the technology becomes a commercial success. This commercial characteristic discourages investors from investing in a technology with low barriers to entry, such as a lack of ownable Intellectual Property [100].

Technology purpose is commercial benefit, not user benefit: A technology company with a strong commercial position may avoid innovating to improve their product, and limit changes to those that assist in locking customers further in to their products [89].

Greed: Technology which maximises profits for its distribution chain may gain sales at the expense of more suitable technologies [101].

E.5. Not market aligned

Doesn't suit economic needs: Where the response to an environmental or other social challenge is driven by political considerations, the solution may place higher value in other goals such as economic development or corporate profitability than on the original challenge [102].

Technology divide: Technology designed to deliver socially beneficial programs may fail due to the absence of necessary infrastructure elements, including connectivity and training, among the target audience, a 'digital divide' [103].

Doesn't fit release: A feature in a global product that could benefit the population of a country outside the core product market may find that it lacks the commercial importance necessary to have the feature included [104].

Doesn't fit with other technologies: Technologies often depend on other technologies, which may not be available, such as sale of powdered milk to mothers who lacked a source of clean water [105].

Aid and old technologies: Technology migration patterns between developed and developing countries during the 20th century saw delays of several decades, with old technologies often migrating only after less destructive technologies had been developed. This had the effect of preventing many technologies with better environmental and efficiency characteristics from being used where they could achieve the best result [106].

E.6. Customer can't afford it

Customers can't afford it: Even where technologies are critical to life, customers will often be unable to afford them. This occurred with anti-HIV drugs in Africa, prior to the pharmaceutical companies signing agreements allowing the production of low-cost generic versions of these drugs [107].

Adding a green premium: Companies in general will price green products higher than others [108].

Appendix F. Technology works, is usable and economic, but not funded

In this category are theories regarding technologies that meet all usage and commercial criteria but are still not progressed.

F.1. Politically opposed

Threatens political interests: Some technologies are not welcome by political incumbents, such as the printing press in late medieval Europe [109].

Not aligned to political interests: In 2002 one third of US secondary schools were using an abstinence-only sex education approach rather one that provided information on birth control and safe sex technologies [110].

Picking winners: A government may attempt to influence the course of technology development, a practice that is widely debated [111].

Active opposition: Environmentally friendly technologies such as wind farms may be the subject of political opposition, in some cases funded by advocates of less environmentally friendly technology [112].

Usage stigmatised: Socially beneficial technology may be publicly stigmatised. A sentiment which has been attributed to British Prime Minister Margaret Thatcher is that a man who is still catching public transport after 26 is a failure [113].

Doesn't reinforce a political imperative: The return of war veterans to the US at the end of World War Two was followed by government-encouraged campaigns for women to leave the workforce and spend more time in housework, and preferenced technology supporting this [114].

F.2. Not prioritized

Technology investment drawn to other things: Military spending may be considered an alternative to socially beneficial spending such as education (http://education-portal.com/articles/Iraq_War_Spending_vs._Education_Spending.html).

Insufficient government assistance: Widespread technology skills shortages reflect an earlier skills shortage of the 1950s. The subsequent boost to education and training spending in the US was a direct result of the Soviet launch of Sputnik, which shocked the US into improving education funding and standards [115].

No government purchase: Government buyers represent a substantial basis for uptake of new technology [116].

Not prioritized: Environmentally and socially beneficial technologies may lack a voice in existing political structures, and therefore fail to be prioritized, such as occurred in the government funding of so energy production in the 1980s following an earlier response to the 1973 energy crisis [117].

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