Diffusion of Wireless Communication Technologies and Technological Lock-in

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***Abstract*—This paper analyses the diffusion of wireless technologies and its contribution to the value proposition of companies. Technological dependency on these key technologies was assessed by investigating emerging lock-in effects. The current situation was assessed with 21 case studies in Swiss Medium Sized Enterprises.**

I. Introduction

Since decades, companies have been deploying wireless technologies in their products and processes, leading to unintended dependencies. These path-dependent evolutions of products and processes may lead to technological lock-in situations for companies, industries or even societies. Especially where increased returns from growing diffusion into networks are observed, lock-in effects are likely to occur [1], [2]. This lowers the ability to switch to solution principles with higher potential. [3]

Public perceived utility of specific technologies is dwindling with increased standards of living [4]. This increases the risk of brisk refusals of technologies with perceived adverse effects, without any rational analysis of utility and dependency [5], [6]. Health risks are often categorically refused and are therefore not negotiable. Regulatory actions assure that these risks are kept low. From a company perspective, these regulations may pose unexpected economical and technological limits [7]. Combined with path dependencies, companies may end up in technology traps [8]. This paper assesses the diffusion of wireless technologies and their evolving lock-in effect for companies. The presented results base on 21 case studies in Swiss Medium Sized Enterprises.

II. Methodology

As little empirical information about lock-in effects in the field of wireless technologies is available, perspectives and theories are yet to be elaborated. Case study research is an appropriate methodology for building theory in such situations [9]. Lock-in effects in this context is still rather a description of a phenomenon than an established field of scientific research.

To comply with the challenges of information retrieval a semi-standardized design was applied. Sensing for information outside anticipated theories and mindsets is facilitated hereby.

The exploration of the diffusion of wireless technologies gives insight in the diversity of technologies applied and possible areas of application. The degree of diffusion shows the severeness of potential technological lock-in effects. The investigation was carried out along four generic dimensions of relevance Fig.1.

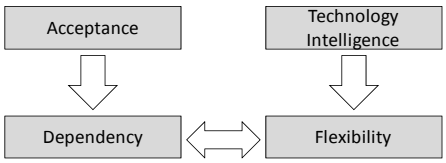

Fig. 1. Framework – Dependency may be balanced with flexibility

- Dependency

The functionality wireless technologies provide to the value proposition of companies is investigated in depth to determine the severeness of a possible lock-in situation.

- Acceptance

Customer attitude determine market success and public opinion may have a strong influence on regulations not only through lobbying activities but mostly through establishing a paradigm of utility and threat perception.

- Flexibility

The mastery of wireless technologies facilitates timely, supplier-independent adaption of technologies to comply with new regulations or changing customer preferences. Dependency occurring in internal support processes is becoming a major risk potential for many companies.

- Technology intelligence

If an important technology is not backed up with a technological equivalent substitute and has to be abandoned, it's of utmost importance to foresee such fateful coincidence as early as possible. Therefore intelligence is needed for technologies, markets and public perception.

III. Results

The series of interviews includes companies using wireless technologies in their processes or products. Large process applications have been studied in detail, since lock-in situations are expected to be more severe in such environment.

Thus, for our sample we focused on organizations heavily prone to acceptance (e.g. hospitals), dependency and flexibility (e.g. large infrastructure providers).

A. Dependency

Wireless technologies have been applied for years. A vast set of technologies and applications has evolved since. The amount of products and processes relying at least partially on wireless technologies is tremendous and still growing. But dependency evolves through more and more applications. The main drivers are:

- Functionality
- Security
- Efficiency
- Comfort

Since efficiency of processes, security and comfort are perceived as add-ons, most companies observed believe that abandonment of wireless technologies wouldn't pose a big problem. Earlier, wireless technologies were in fact at the periphery of products' functionality, but today they are very often at the centre of the functionality of products or processes. Change happened in small steps. Some companies are not aware of the fact that there is no feasible wired substitution for GPS in fleet management or theft protection of cars. GSM-R installations are at the centre of today's railway infrastructure allowing for travelling speeds above 160km/h. Cold chain control in logistics is impossible without wireless technologies. Today's reality shows high technological dependency on wireless technologies that is hidden and a far cry from hyped topics such as ubiquitous computing and mobile internet access or mobile television.

Many companies report that wired or paper based solutions would theoretically be re-introducible accepting a tremendous loss in efficiency (Fig.2). A regionally ban of wireless technologies could of course lead to a complete loss of competitiveness for freely tradable goods in such a scenario.

The high degree of diffusion of wireless technologies is facilitated by four major drivers:

- Standardization
- Mass production
- Efficiency
- Law

Standardization and mass production go hand in hand and allow for low prices which in turn increase volume again, relying on standardization of interfaces. Standardization is an enabler of diffusion itself. It not only allows for mass production, but moreover, companies can equip their products with wireless interfaces since interoperability is granted in the end users' setting of application. Many applications show enormous potential for process efficiency, leading to substantially reduced costs. As an example, RFID-tags may reduce costs in logistics, as compared to two-dimensional bar codes, no direct line of sight is needed. Specific applications are forced by law, such as air traffic communication or train radio.

As a consequence of ubiquity of wireless technology there is an increased demand for service availability. This cannot only be fulfilled by service level agreements; availability needs to be designed into the products; a systemic perspective is therefore needed.

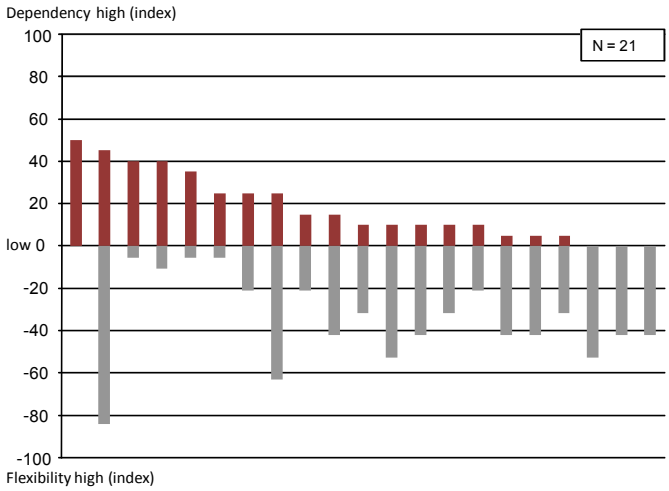

Fig. 2. Degree of Dependency and Flexibility (Normalized index showing both dimensions separately, bars representing companies)

B. Acceptance

In our sample of companies acceptance of wireless technologies observed was generally good (Fig.3). Sounding the all-clear is yet premature; to big is the variety of factors determining the current setting.

Reported complaints about wireless technologies mostly stem from suppliers of end-users, especially for consumables and commodities. Retailers carry the burden of customer complaints. In the area of business to business transactions, acceptance issues are hardly observed, as the potential in functionality and efficiency outweighs potential adverse effects. Further, managers taking these decisions are not "exposed" to their own wireless technologies applications in their internal processes and products. In retail business exposure is direct and customer complaints have an immediate impact. We observed a wave of sensibility to wireless technologies in general, in addition to all complaint about mobile telecommunication antennas. Transparency about radiation is requested by more and more customers, SAR-figures (Specific Absorption Rate) introduced 2001 by handset manufacturers are a must. In the past, radiation was a nasty side effect, but today it opens up a new field of product differentiation. Companies like Swissvoice or Siemens started developing and promoting low radiation products.

As with customers' complaints the setting for customer-, staff- and industry- associations is similar. Whereas among customer associations deteriorating acceptance due to negative side effects by radiation is widely observable, similar occurrences are reported by companies in their staff-associations as well. The setting-up of wireless technologies such as GSM-antennas and W-Lan-infrastructure repeatedly provokes negative reactions. Meanwhile, industry associations don't witness such issues.

Information about acceptance issues or radiation concerns is barely transferred upstream in supply chains. Thus, even if retail customers might complain, this information does not

appear on the radar of the suppliers. Such issues are brought forward only to sellers of "ready-to-use"-products, component suppliers are barely confronted with them. Hence, absence of observed acceptance issues is partly due to interrupted information flows in the supply chains.

The distinction of areas of application into products and processes shows differences in the nature of acceptance issues on another dimension: Whereas wireless technologies used for end-products witness radiation as of topmost concern, applications in business processes often are confronted with security and privacy concerns. Companies fear for instance that classified process information may get tapped more easily if transmitted wireless. Also, stability and reliability of transmission is often questioned. As security, privacy and radiation is difficult to control at an individual level, reputation of service providers gets more important.

Most companies in our sample rely on wireless technologies balancing utility and potential negative side effects. Companies using wireless technologies in their internal process only, are in a more comfortable situation explaining their need for wireless technologies. This phenomenon is observable comparing public transport companies with mobile telecommunication providers. Both are using a wide array of wireless technologies. Using wireless technologies in processes instead of servicing them directly to customers may reduce visibility and perception by the public.

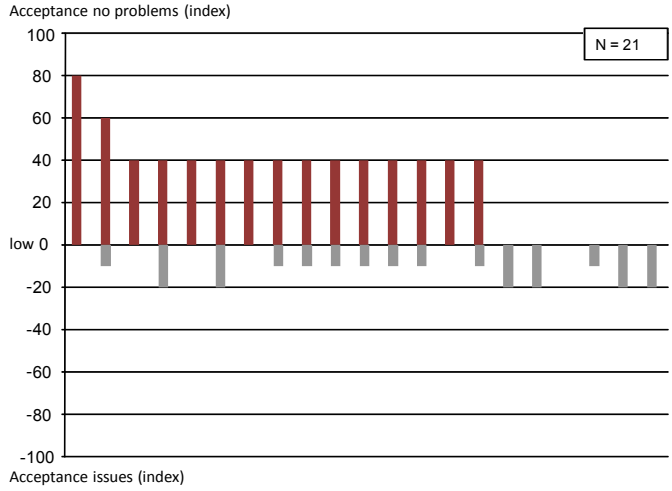

Fig. 3. Acceptance and issues indications (Normalized index showing both dimensions separately, bars representing companies)

Whereas general acceptance of wireless technologies was generally good, GSM-antennas on the companies' sites showed a different picture: Half of the 8 installations observed on the sites wouldn't be installed anymore. Resistance to GSM-antennas is omnipresent, reputational risks for companies along with long and cumbersome internal discussions were among the reasons companies gave when explaining why they would not set up antennas again on their premises.

C. *Flexibility*

As technological flexibility is a viable response to "absence of evidence of harmlessness", the degree of freedom in terms of internal knowledge available and time needed to change technologies is of particular interest.

Standardization pushed diffusion and dependency as well. This reduces value added within companies and wireless technologies evidence more and more black-box characteristics: Components and even whole wireless communication modules are completely sourced externally. Interestingly, flexibility perception among these companies was found to be highest, as their substitution scenario encompasses primarily the time needed for replacement of such communication modules. Typically time ranges of some months are given (Fig.4). But in case of major frequencies- or signal-modulation- changes, prior to production new standards of wireless interfaces need to be negotiated within industry. This procedure may take several years, as today the case with the development of the IEEE standard 802.11n shows. In the case of a big scale substitution of wireless technologies, production capacity could be a bottleneck, as due to standardization huge populations of products or modules would need to be substituted simultaneously. The time-frame needed for adaption discloses the severity of lock-in effects in terms of how much effort and time is required for adaptation.

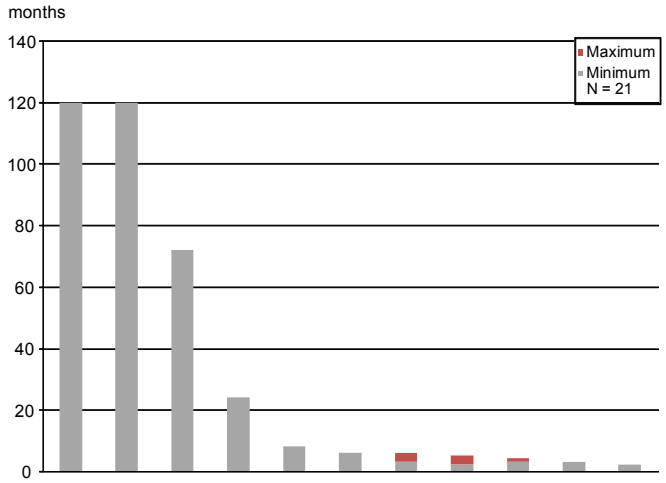

Fig. 4. Time needed by companies for substitution (Normalized index showing both dimensions separately, bars representing companies)

Wireless technologies are applied by companies in products and services who have barely internal knowledge about these technologies, but chose to use it, as modules are available at low cost, with reasonable band widths and with standard interfaces facilitating ease of integration into their products. More than 50% of the observed companies rely on external knowledge although they built up internal competence as well (Fig.5).

Apart from the application of standardized technologies, several companies in our sample develop highly specialized wireless technologies in order to suit their very particular interests; often such technologies operate at technological or even physical limits. These companies face advantages in

terms of internal competence and thereof technological flexibility. Though altering highly specialized systems is time consuming too, because all activities need to be mastered without considerable economies of scale. In such kind of situations time demand of several years for adaption is observed.

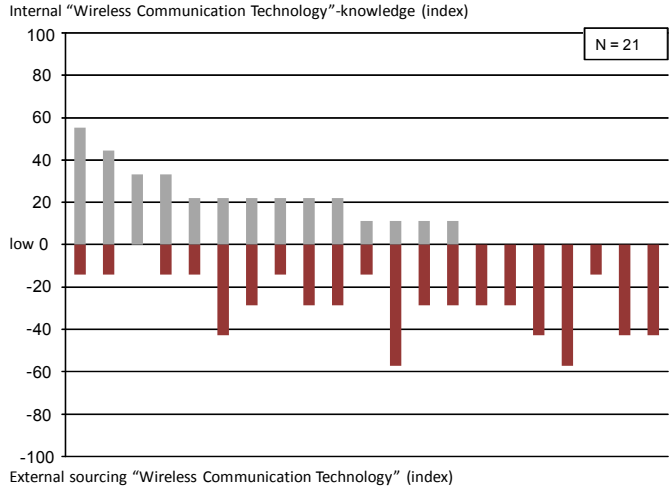

Fig. 5. Internal knowledge and external sourcing of wireless technologies (Normalized index showing both dimensions separately, bars representing companies)

D. Technology Intelligence

Technology and market intelligence support maneuvering if acceptance of technologies is prone to failure, substitution is questionable and if dependency on specific technologies is high. However, due to the standardized products, companies find themselves in the situation using opaque "black-box"-technologies. If companies don't know exactly what technology they use, they don't know what to look for and intelligence is hardly possible. As soon as wireless technology is standardized, it does not get the attention it used to, as these technologies neither pose particular problems nor are at the center of differentiation. In these cases the technology-owner is located outside the companies. Thus, wireless technologies are not at the center of R&D-activities, attention to them is low; often no one is assigned responsible inside companies for their surveillance. Communication with customers and actively managing the perception of these new technologies is rarely found, even though a new trend is observable with companies marketing low-radiation products, such as AVM, Siemens or Swissvoice do.

Another pitfall occurs when companies "delegate" technological intelligence solely to engineers, as their perspective is technology oriented and does seldom incorporate "stake-holder"-perspectives. These situations may even be worse than consciously not supervising technologies; as such constellation lead to fallacy of security.

Only few companies deliberately planned using wireless technologies, most companies increased their dependency unconciously by extending their portfolio of technologies and products – the lock-in situation evolved unnoticed.

IV. DISCUSSION

The results show often unconsciously grown usage and dependency on wireless technologies. Concurrently acceptance within companies is high and negative reactions limited to the end-user level of products. Due to long standardization times and ubiquitous usage the substitution of technologies is difficult or even illusory. This situation is aggravated through low activity in technology intelligence.

The depicted effects need to be further analyzed regarding amplitude within company and significance within industry.

V. CONCLUSION

The issue of a technological lock-in is far from settled, as dependency on wireless technologies is high, and acceptance issues were found mainly in terms of security and privacy for end-users and reliability for business applications. "Black-box"-usage further weakens knowledge about wireless technologies. Technological development may lead to new challenges and solutions, as first publications on terahertz communications illustrated. Thus technological development needs to be observed and public perception actively managed.

REFERENCES

[1] A.W. Brian, *Competing Technologies, increasing Returns, and Lock-in by historical events* in Economic Journal, vol. 99, issue 394, pp.116-131, March 1989.

[2] G.C. Unruh, *Understanding carbon lock-in* in Energy Policy, vol. 28, issue 12, pp.817-831, October 2000.

[3] N. Gandal, D. Salant, L. Waverman, *Standards in wireless telephone networks* in Telecommunications Policy, vol. 27, pp.325-332, June 2003.

[4] H.M. Kepplinger, *Künstliche Horizonte: Folgen, Darstellung und Akzeptanz von Technik in der Bundesrepublik*, Frankfurt etc., Campus Verlag, 1989.

[5] K. E. WEICK, *Sensemaking in organizations*, Thousand Oaks, Sage, 1995.

[6] P. A. Shimpi, *Integrating corporate risk management*, New York, Texere, 2001.

[7] J. Hoyt, H. Sherman, *Strategic groups, exit barriers and strategy decision constraints in high-tech companies* in The Journal of High Technology Management Research, vol.15, pp.237-247, August 2004.

[8] J. Diamond, *Collapse: How societies choose to fail or succeed*, London, Penguin Books, 2006.

[9] K.M. Eisenhardt, *Building Theories from Case Study Research* in Academy of Management Review, vol.14, issue 4, pp.532-550, October 1989.