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The importance of history -
Technological development of existing technological systems

By

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Abstract:

The main argument forwarded in this article is that the history of development of a technological system matters because it decides what steps are possible for the next phase of development. The history can be read from the ways in which central resources of the system interface with each other, and with other resources linked to the system. Since this interaction is not random, but instead systematically created by the involved actors, it tends to preclude some lines of development and emphasise others. It is in this way that certain avenues for development open, whereas others close. However, since the nature of development work is uncertainty, we can not know in advance which avenues will open and which will close. This understanding can only be reached when looking back at what has happened so far, by looking at the history of the system and the memory traces which exist within it.

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1: Objectives of the article

Technological development has periodically been a very important subject within economics. According to Olsson (1997, in the preface to the Swedish translation of Rosenberg, 1994), technological development was a central area of research for classical national economists until the late 1800s, such as for example Adam Smith and Charles Babbage (1833). Although side-tracked for a period of about 60 years, due to the dominance of neo-classical national economy tradition, technological development and its effects again became important from the 1950s and onwards (Olsson in Rosenberg, 1997). This resurgence of interest in the effects of technological development has shown up in both macro- and micro-economic analysis.

This paper will take a look at technological development, and we will take as our point of departure the effects of technological development on the firm and its network. However, the aim is not to explain how technological development takes place. Rather, the paper will attempt to develop some useful concepts, which can be applied within the IMP tradition when discussing technological development in general and development of resources and resource capabilities in particular. The connection between technological development and resource development will be made explicit in the theoretical part of the paper.

The empirical case, which will be used to help illustrating and developing these concepts, is the development of alternative uses of a specific technological system, the narrowband-ISDN system in Norway. Originally developed for the telecommunications market and introduced in the beginning of the 1990's, this system has gradually come to be used for other applications as well. In the case, we will look at how the ISDN-system has been used for electronic payments.

2: Theoretical background

The IMP tradition

Technological development is, as the name indicates, a process. Studying processes is a difficult task, and can arguably only be properly done through longitudinal studies. This is one of the main reasons why we will not really undertake such a study in this article. However, we believe that it is possible to suggest some concepts which could be useful in such a study, even though we only have the compressed and limited space of this article in which to do it. We will approach this task by looking at a way to describe a technological system as it exists in a specific point in time, and then look at how concepts can be added to this static picture in order to introduce dynamics.

Words such as technological system and technological development have some commonplace definitions, which allow us to understand the general notion of what we are discussing. However, we need a more precise definition for our use. To develop such a definition, we will turn to the IMP tradition for useful concepts.

In the IMP tradition, there are three concepts which, when used together, are thought to express the depth and complexity of business relationships. These three concepts are resources, activities and actors. They were introduced in a model by Haakanson and Johansson (1992), and were more thoroughly discussed in Haakansson and Snehota (1995). In this book, the idea was also developed that the three concepts mentioned above could be used to analyse different levels of business relationships (see for example fig 2.11, p45 and fig 2.12, p47 in Haakansson and Snehota (1995)).

Technological systems as "resource constellations"

Of these concepts, the resource concept is the most promising when we want to describe a technological system. A technological system can be said to consist of a number of machines, that together with the knowledge of how to operate them and what to do with them, enable those who control them to perform certain tasks. This comes very close to the description of a resource constellation, which is "individual resources that are gathered together to support certain activities". We will argue that for the purposes of this article, it is useful to equate a technological system with a "resource constellation".

Equating a technological system to a "resource constellation" imbues a technological system with some important features. Firstly, it means that the resources, which together make up the technological system, need not necessarily belong to the same companies. This in turn means that managing the properties of a technological system cannot be done purely internally in a company. Instead, it must mean to manage the resource ties between the resources which make up the system, whether these are between two internally controlled resources, or one internally controlled, and one externally controlled resource. Thus managing technological systems must therefore also mean to manage business relationships to companies that control other parts of the resource constellation. This can in some cases mean a tugging war between companies as to which direction further development of the system should take, but it will also mean that companies can work together to develop the system into something that all involved companies can benefit from.

Secondly, we can argue that many of the resources making up a particular technological system will also be part of other technological systems. This follows from our definition of a technological system as a resource constellation, and is an important aspect to consider for deployment of resources, which we will return to later.

Thirdly, we will argue that at the point in time we have chosen as our point of observation, considerable work has already been put into adapting these resources to each other. We will return to this crucial argument a little later also.

Technological development as a change in resource ties

Technological development must then also be related to our definition of a technological system. Since we have just defined a technological system to be a "resource constellation", it seems only prudent to define technological development to be a change in the way that resources are tied together.

However, this introduces two problems, which require some further discussion. First of all, does any change in the way resources are tied together represent technological development? To this we must answer no. For development purposes, we are only interested in qualitative change. That is, when the tie between two resources has been changed as a result of modification or adaptation of one or both of the two resources. Also, we will put forward the requirement that at least one of the two resources that are qualitatively changed, must be a part of the system before the change. Thus, while there is a possibility to add new resources and resource ties to the system, these processes must go on in interaction with existing resources and resource ties.

We do regard the resources, which belong to the system at a specific point in time, to be "flexible", in the sense that they can be modified. However, like Holmen and Pedersen (1999), we will not go into a debate of whether a modification of a resource gives us a new resource or whether it is merely the same resource, which have been changed. We will assume that it is the same resource. Thus, development means to modify some or all of the resources belonging to a technological system, thus giving the system a new set of ties between the resources, and thus also (hopefully) an improved ability to support activities. Often, a particular problem for companies is related to gaining the ability to support some new activities, while at the same time retaining the ability to perform all former activities.

A more in-depth look at resources

To further describe this technological system and some of the peculiarities pertaining to it, we need to go deeper into the resource concept. Many authors have written about resources in the IMP perspective. However, one of the more useful recent papers on this subject is the one written by Holmen & Pedersen (1999). This paper presents a number of important concepts regarding resources, and we will need several of these concepts in order to reach our objectives.

One of the many useful concepts in this article is the concept of "realised versatility". According to Holmen and Pedersen, realised versatility *"...refers to all the different combinations in which a resource have been tried out over time, and the modifications which have been made of that resource"* (1999, p16). This means that each and every individual resource, which together makes up the resource constellation that constitutes a technological system, represents some degree of realised versatility. Since we remember that one of the features of a resource constellation presented above is that the individual resource is always adapted to the other resources, this also means that their adaptation (and modification) for use in that particular technological system is part of this realised versatility. In other words, the realised versatility carries an imprint of the process of technological development that brought the resource constellation into being.

This observation is crucial, because it points to an extremely important feature of a technological system: it's history of coming into being. We will argue that this history is a crucial element in translating between process and structure. The history of a system can be seen as an aggregation of the realised versatility of its component resources. Each individual resource carries *"memory traces of those combinations* *that may have been abandoned and the different configurations the resource has had over time"* (Holmen and Pedersen, p16). It also expresses the current, existing resource ties it is used in. Thus, the realised versatility of each and every resource displays it's past, as well as it's present. And just as each individual resource can do this, we argue that there must also exist such memory traces on the higher levels of aggregation that is in the resource ties and in the resource collections and constellations. For want of a better word, we will, on the resource constellation level, call this phenomenon the system's history. Thus, studying the resources that makes up a technological system should give us a certain insight into its history, and vice versa.

A natural question would be to ask; how complete is this insight? One answer could be that it is not very deep. Certain features of the history can be rather obvious when we look at the technological system, even if we have only scant previous knowledge of the system. For example, looking at some of the safety systems of a car, one can easily guess some of the most common ways of being injured when sitting in a car. Safety belts points to the fact that many have been hurt by being tossed out of the front window, and airbags points to the fact that the driver has often been hurt by being slammed into the wheel. Other parts of the history are obvious, but may not make much sense to us. For example, the QWERTY-paradox (the layout of modern keyboards) can easily be recognised as a memory trace of a former configuration, which was important in a resource tie between keyboards and some other resource. However, many people do not know that the specific resource tie that gave the keyboard (or more precisely, its predecessor, the typewriter keys) its present appearance was the tie to the typewriter mechanism. The need for often used types to be spread as far away from each other as possible, and the need to keep writing speed down in order to avoid mechanical problems, governed the design of the keyboard. These ties do not exist any more, but we still use keyboards that actually are designed to prevent us from writing too fast! However, there are also many of the features of a system's history that are inaccessible to us, unless we happen to have other types of knowledge about the system. In other words, the memory traces are always there in the system's history, but what observation of this history; the resources, their existing ties and their realised versatility can tell us, depends upon what we already know.

How is a resource constellation created?

The next point we will argue is that the system has reached its present state because of a process of purposeful experimentation, and not (in general) as a result of random processes, nor as a result of a predestined path. At this point in time, we will need to introduce actors (Haakansson and Snehota, 1995, chapter 5) in order to get a grip on how this process happens. It will be our view that actors represent the guiding hand behind these processes of experimentation.

First off, we will argue that any actor has a certain amount of knowledge about the history of a system that the actor is related to. For several reasons, this knowledge is not complete. Some of these reasons are related to properties of the resource level, such as the immense complexity of the number of resources and resource ties which make up a technological system, and the way in which effects spread out in a network. Other reasons are linked to the actor level, such as human limitations in perception and ability to think about complex situations. Nevertheless, actors do have a more or less limited knowledge of a systems history, and understands more or less of the ties and adaptations that have created the current system. We therefore argue that there must exist an awareness boundary, which delimits the part of the system that an actor has knowledge about. The argument for the existence of this boundary follows the same lines as those argued for by Dubois (1998). Although she primarily writes about activity structures, we believe that her argument is useful and relevant for the resource level as well. For example, she argues that: *"individuals… […]… may be more or less aware of the activities and their interdependence within the end product related activity structure"* (p114). Since technological systems have component parts controlled by different actors, the awareness boundary may stretch into other firms as well. In fact, in some cases, an actor awareness boundary may be limited to only resources, which are actually controlled by others. This point is also in line with Dubois (1998), who argues that: *"In order for the firm to be able to capture efficiency potentials in terms of similarities in the specific part of the activity structure outside the firm, a certain awareness of the other activities and activity chains handled by the supplier is needed"*(p115).

"Realised versatility" is, as we argued above, the embodiment of history in a specific resource. Thus, the system has a history, which is based on the "realised versatility" of all its component resources. An actor may, as we argued, be aware of some or all of the "realised versatility" of a resource. And this, in turn, decides how much of the history of the system the actor can relate to.

The awareness boundary of an actor must thus necessarily be a subset of the history of the system. It is important to realise that it is not necessarily a good thing to have a large area within one's awareness boundary. One reason for this is that a fairly extensive knowledge of a system's history often will lead an actor to become reluctant to try new experiments, since the actor may believe that something similar has been "tried it before and didn't work". Also, higher awareness will almost always mean that the actor can see that an experiment will break some of the complex relationship ties which do exist, and thus create uncertainty about whether the change will be good or bad. However, less knowledge run the risk of wasting time and money on experiments which will not work, and which should not have been tried based on earlier experience, if the actor had had such knowledge. Thus, we will argue that the importance of an actor's awareness boundary is not to make it larger (or smaller), but the fact that it exists.

The next step in our argumentation will be that based on their awareness boundary, actors make decisions about both the deployment of resources to a system, and the focus for further development effort. The first part of the argument is that actors align resources with other resources in order to exploit the connections they know about in an economical way. This alignment process is the process that we will call deployment.

We will argue that deployment of resources cannot be optimised, in the sense that we can compute the "value" of the resource in each possible combination and then align the resources in a way that maximises their total value. There are several reasons for this. One is that the actors doing the deployment never have a full view of the system(s) the deployments will serve. As argued above, they will have to do with their limited knowledge of those parts of the system which are inside their awareness boundary. Secondly, optimisation is impossible because of the number of actors involved in the deployment. Often, these actors see different parts of the system.

Thus, when the deployment of one specific resource is discussed, they will tend to suggest different ways of tying the resource to other resources. Third, since the individual resources often belong to several systems, there will have to be trade-offs considered about how (and how much) a resource should be available to a given system. Certain uses may also be mutually incompatible, or the use of a resource in one system may require a modification, which cannot be later reversed. Finally, resources are heterogeneous, so their value is not fixed, but depends upon the combination(s) they are used in (Haakansson and Snehota, 1995, chapter 4). As a result of all the above factors, deployment will never represent a stable, optimal solution, but instead be a working compromise between several actors' awareness of the resource's capabilities. Nevertheless, actors will use their knowledge of the systems history to deploy the resources in the best way they can, where best means getting as much out of the resource as possible.

Actually, the fact that the deployment never is (or can be) optimal is the very same reason that innovation and development is an ongoing process. Any actor looking at a system can always find resource ties, which could be modified or changed in ways that could improve the economics of the deployment. We will argue that this holds true no matter how large or small the awareness boundary of the actor is. Thus, development is in fact DEPENDENT upon the fact that the performance of systems cannot be optimised, but rather, that it can always be improved upon.

We are not the first to propose that actors deploy the resources according to their knowledge of them and their history. Penrose argues in her book (1959) along similar lines. For example, she claims that the heart of the productive activities in a firm is "productive opportunity", which according to her *"…comprises all of the productive possibilities that its entrepreneurs see and can take advantage of"* (1959, p31). Later in the same chapter, she goes on to note that *"It is clear that this opportunity will be restricted to the extent to which a firm does not see opportunities for expansion, is unwilling to act upon them or is unable to respond to them"* (id, p32). The ideas here are very similar to those we propose, but there are also differences.

Penrose do propose that external resources are important (as for example on top of page 31, where she claims that: *"…its purpose is to organize the use of its "own" resources together with resources acquired from outside the firm…"*). However, her main focus is nevertheless that of the development of internal resources, that is, those resources that are controlled by the firm. We, however, are dealing with technological systems whose resources are spread among several actors. Thus, we must take into account that an actor may very well be as interested in resources controlled by another actor, as he is in those controlled by himself. This would for example be the case when a resource tie exists, which is perceived to be important to his own business. Although we do concede that an actor's possibility of influencing the use of a resource that it does not control is somewhat smaller, we will argue that it is by no means zero. Thus, there can in some instances be of paramount importance to work with other actors in order to change resource ties within their control. Also, there are many resource ties, which ties resources controlled by two different actors. Here, the chance of influencing is probably larger, but still not as large as it is within the control boundary of an actor.

Another difference is that Penrose tries to explain the growth of a firm, whereas we want to explain (or at least discuss) development. However, we believe that Penrose has captured an important factor in explaining development in exactly the way she relates the productive opportunities to the productive activities, and this is the factor that we wish to base our argument on.

Finally, we also propose that actors do not treat all resources and resource ties within their awareness boundary equally. Instead, they have focal areas within the awareness boundary (this may be one or more individual resources and/or resource ties), which are currently of primary interest to the actor. Whereas other resources and resource ties are regarded as temporarily “fixed” (that is, the actor currently believes that these resources or resource ties are performing adequately), resources within the focal area are currently being experimented with, to see if existing ties can be improved, and/or whether new ties can be established which will improve the use of the resource (in a qualitative way).

This means that there are certain resources or resource ties, which are of particular interest to the actor at a certain point in time. This may be because the resource or the resource tie(s) represent a problem, or an opportunity, or it may be that another actor has proposed to do something about the resource and resource tie(s), or it may simply be an area where the actor believes that it is possible to do something to improve existing performance or develop new products or services. As can be seen, there are many possible ways in which a resource can end up within an actor’s focal area. The main proposition is that it is within these focal areas, that development is taking place.

In particular, we believe that when the focal areas of several independent actors overlap, chances are that the actors will both spot some potential for development (that is, a modification of a resource or resource tie) AND that they will manage to combine their efforts to do something about the situation. This in contrast to a situation where only one actor has spotted some possibilities for development. In those cases, the actor is often unable to change the situation since the resources, which need to undergo modification in order to bring about the development, are considered temporarily “fixed” by other actors. This follows from the way that focal areas are defined above. Also in this argument can we find support from Dubois (1998), who argues that: *“Rather, overlapping awareness boundaries are needed for firms to create better solutions. Through interaction they can combine their respective knowledge of how a certain product is produced, refined and consumed”* (p115).

Summary of theoretical background

To sum up the theoretical background, we will argue that development of a technological system is dependent upon the current deployment of resources in the system, as well as the awareness boundaries of the actors involved with the system (or, more precisely, which control a part of the system), and the focal areas they currently have. Another important argument is that the system cannot be optimised, which in turn means that there are always opportunities for improvement, and thus always a dynamic situation.

We will now proceed to have a look at a case, in order to see if we can identify the concepts argued for above, and whether we can recognise some of the effects we have predicted.

3: Case: The connection between the telephone system and the electronic payment system

The telephone system in Norway, and the introduction of the ISDN system:

In the early 1990's, Telenor decided to introduce Integrated Services Digital Network (ISDN) services into the Norwegian market. ISDN is an international standard for telecommunication. The standard was developed, and agreed upon, by all major countries, and was introduced as a fully digitised alternative to analogous telephones (also known as the plain old telephone system, or just POTS). Before ISDN, status in most developed countries was that the switch offices, as well as main trunk lines between switch offices, operated on a digital basis. Likewise, most of the larger users, such as large businesses and organisations, had digital connections to their local switch office. However, local connections between a consumer or a small business and the local switch office were done analogous. Signals from these sources were converted into digital signals in the switch office, and then routed through the digital trunk lines, to be converted back into analogous signals at the local switch office of the receiver.

Technically, ISDN provides the customers with two separate, digital channels for data transmission known as the B-channels. These channels can be used for normal speech transmission, but can also be used for data transmission from a computer, or for fax services or Internet access. The channels are separate, so that two transmissions can be run simultaneously. This allows for a customer to be for example logged onto Internet, and still have access to normal phone services. The ISDN-connection also provides the customer with a D-channel. This channel has only limited capacity (16kb/s, compared to 64kb/s for the B-channels) and was designed as a signalling channel, handling "administrative traffic" for the two B-channels. The main part of the administrative traffic is the task of establishing and maintaining a connection between two telephones, but since the D-channel is separate from the B-channels, it can be used even when both B-channels are in use. Thus, if a customer is using the Internet and making a phone call at the same time (both B-channels are in use), it is still possible for the D-channel to screen incoming calls and display the number of the incoming call to the person using the phone. This could for example allow the person to end his or her call, and accept the incoming call instead.

Although analogous connections are perfectly capable of handling normal telephone traffic, a fully digitised system (based on ISDN) had certain advantages to the customers and the service provider alike. For the customers, ISDN would allow better possibilities for the simultaneous use of several pieces of equipment (of particular interest for small businesses). Also, the ISDN gives private customer better access to data networks than an analogous system, which needs modems to convert data from digital to analogous transmission before they go into the analogous telephone system (only to be converted back into digital at the nearest local switch office…). Finally, the D-channel allows a number of extra telephone services pertaining to telephone "management" to be developed. An example is mentioned above, where ISDN allows a person to see the number of an incoming call.

For the service provider, it is beneficial that ISDN is fully digitised. Since the trunk lines between switch offices are digitised, local switch offices need equipment in other to convert from analogous to digital transmission, and back. This equipment would not be needed if all users had ISDN (or other digital-based connections).

As mentioned above, ISDN was introduced in the early 90's in Norway. Telenor was persistent in wanting its customers to switch to ISDN, and analogous connections were changed into ISDN connections at an impressive rate. At the present, Norway and Germany have the highest ISDN penetration in the word. However, even though the Telecom provider has made it possible for almost everyone to have access to ISDN, analogous modems are still in use in a large scale, especially for Internet connections from homes and small businesses.

The electronic payment system in Norway

The online electronic payment services system (EFTPOS) in Norway was developed in the mid 80's. At the beginning (1985 to 1993), all EFTPOS traffic were done through analogous modems to PADs in Telenor's network, or by using the X.28 protocol to Fellesdata. In the early 90's, a system of direct lines were established by the banks.

Electronic payments offer many advantages for consumers, retailers and banks alike. Consumers can avoid acquiring and carrying large sums of cash, retailers can also reduce their use of cash and banks can reduce their administrative costs and can also reduce the number of branch offices, which has to be staffed. The electronic payment services system was in this way advantageous to all parts involved. However, even though it was advantageous, it was not easy to implement. This was due to three factors. Firstly, the system required a large up-front investment in the form of equipment, electronic cards and infrastructure. Secondly, although technology existed, it was in no way a well-defined body of knowledge. Thus, development work needed to be financed, and as always with development, the end results were uncertain and as such the work carried a substantial economic risk. Thirdly, all parties were concerned with security.

Although there were some attempts to develop proprietary systems, it quickly became clear to the involved parties that the initial investment was too large for one single bank or groups of banks. Also, it was thought that the usefulness of the system would be larger if there was one uniform system, instead of several proprietary systems. Thus, all the Norwegian banks grouped together and established BBS (the payment centre of the banks). BBS was charged with the task of developing a well-functioning system and with building the necessary infrastructure on behalf of the banks. BBS would charge the banks for this service, and the banks were then free to set fees to their customers based on the cost they incurred. This would allow the banks some freedom in which services they chose to offer, and at what fees.

The key to a successful implementation was thought to be coverage. The electronic payment system needed coverage all over Norway, and in all types of stores and shops. The original concept would use the X.25 data network as a basis. Proprietary X.25-connected cables were laid down to IBK-centres, from where smaller, asynchronous lines would lead to the actual stores and shops. Each store would then have one or more electronic card terminals, where cards could be used for payment. In the other end, BBS had its own machines to handle the incoming data and check PIN codes and balance on the accounts. This online system covered the larger shops, and shops in concentrated areas, and functioned fairly well. Approximately 20.000 terminals were installed in this system.

However, this system could not be used for the smaller shops, and neither could it be used for shops, which were located far away from an IBK-centre. Smaller shops did not have the number of transactions necessary to justify the cost of a reserved line connection, and the cost of an IBK-centre was so high that it needed to be connected to several shops in order to make it cost effective. Thus, an alternative solution had to be found for these two groups, and the solution became to continue to use the established infrastructure in the telecom area (Plain Old Telephone system, or POTS).

The telephone system was not very well suited to the task. Firstly, it operated with analogous speech, not with digital links. Thus, a modem had to be installed between the electronic card terminal and the telephone jack to allow communication with the telephone system's local switchboards, and to allow the digital data of the terminal to be translated into "analogous speech". Also, on the Telenor side, PADs (packet assembler/ disassembler) had to be installed to convert the analogous speech back into digital data and feed them back into the X.25-network. Another problem was that the telephone system required separate lines for each item, if they were to be used simultaneously. Thus, a shop was forced to have separate telephone lines for telephones, for fax machines and now for each of its electronic payment terminals. A third problem was that due to the rather tedious technical process needed to establish a digital connection between modem and PAD, a waiting time of about 14 seconds was necessary between call and confirmation. Except for these problems, the solution was cheap and functional, and satisfactory for the involved parties. Approximately 30.000 terminals are now installed in this part of the system, and the number is still growing, since the stores, which are still being added to the electronic payment system, are usually small.

Thus, the electronic payment system consisted of two separate parts. One part based on the all-digital X.25-data network with proprietary lines to each terminal for those with a high demand, and another part based on modems connected by the analogous telephone system to PADs, which fed the calls back into the X.25-data network. Two different operators serviced these parts. Kommune-Data served the X.25-network (although the actual trunk lines were owned by Telenor), and Telenor took responsibility for the traffic on the telephone system between modems and PADs.

Developments in the interface between the electronic payment system and the telephone system

As we can read above, there has always been an interface between the electronic payment system and the telephone system. The analogous telephone system was used in the electronic payment system from the very start, and was used later to handle the smaller businesses and those geographically dispersed. Changing to ISDN confronted the user with very few problems. All that was needed was to switch the terminal over to the ISDN, and use an available B-channel in the same way that the terminal had formerly used the analogous connection. This meant, however, that there was no digital connection between ISDN and the terminal, even though both systems operate on digital signals. Instead, digital signals from the terminal were converted into analogous speech by the modem, only to be converted back into digital signals when it was fed through the ISDN telephone. Strangely enough; it took almost four years before equipment were developed which could handle the electronic payment terminal-ISDN interface in a purely digital manner (thus eliminating the need for a modem and two conversions of the data).

It seems only natural that if it is good to use analogous telephone lines in order to link small businesses to the electronic payment system, it must be even better to use digital telephone lines for the same purpose. This, however, did not appear to be true in this case. So why did it take so long before a digital interface occurred between these two systems? We do not know the full answer to this, but from our interviews, we can suggest some factors.

Firstly, even though both the electronic terminal and the ISDN network are digital, there is still a need for specialised equipment in order to communicate between them. Such equipment had been designed and developed in order to handle the terminal-POTS digital-analogous interface, but no equipment existed for the terminal-ISDN interface. Development costs for such equipment are large, and thus developers are reluctant to start on such work unless they think there will be a demand for it.

The users of the electronic payment systems (the businesses) are generally not particularly interested in the type of carrying technology used for their electronic payments. Instead, they prefer to view the system as a “black box”, and are oriented towards two other factors; performance and price. Performance in the electronic payment system was generally thought to be good enough among the users, and although there were some discussions on the price of the service, the price was also thought to be reasonable. Thus, there were little pressure from the users for a change in carrier technology (from analogous to digital connections). Instead, users were reluctant to spend money on changing their equipment. Do not fix things that are not broken, was the general view. Because of this, users were in this instance not pushing for a change of technology, and were definitely not interested in investing in the development of new equipment.

Secondly, there was also a need for several supporting technologies, in order to use the ISDN-system for electronic payments. The D-channel of the ISDN-system has a capacity of 16kb/s. Although this was not too bad for a 1992-standard, it didn’t take many years before the D-channel was regarded as slow, and unfit for data transmission because of it’s low capacity. Of course, this was never thought to be a problem, since the construction called for actual transmission of data to be handled by the two B-channels, and not the D-channel. The purpose of the D-channel was to handle signal traffic, which meant that the capacity could be very limited, and still sufficient.

However, this view of the capacity of the D-channel changed. The reason for this was that users discovered a number of data communication tasks, which were not very demanding in capacity. Electronic payment services are one of these. An average payment transaction consists of approximately 200 bits. In essence only a short burst of numbers is being transferred. Also, while the B-channels are circuit-switched (meaning that a connection has to be established and a line through to the destination has to be reserved, no matter how much the traffic is used), the D-channel (as well as the X.25 data network) is packet-switched. In essence, this means that the D-channel is always online, and that no connection needs to be established, since each "packet" of data is sent out with a header containing an address. Thus, if a company sends a large number of short transmissions, packet-switching technology is superior, whereas if the need is for a small number of long transmissions (a telephone call, sending of a fax or transferral of large data files), circuit-switching technology may be better. Of course, this also depends upon the price structure offered by the carrier. And as we already said, electronic payment services represent (for most of the users) a large number of burst transmissions.

Thus, the introduction of ISDN opened a window of opportunity for the electronic payment system; the D-channel. Here was a channel, which was always online, which had sufficient free capacity and more than enough to handle the transaction needs of the electronic payment system. Using the D-channel would also free capacity from the B-channels, and allow the user to connect them to other pieces of equipment. And best of all, the D-channel was available for many users, since it had already been installed as part of the ISDN-package.

However, as the D-channel was never meant to be used as a data transmission channel, it was not originally connected to the data networks in any way. Thus, using the D-channel for data transmission could not happen before Telenor had realised a packet-switching network service, which incorporated the D-channel.

All of the above meant that before a digital-digital electronic terminal-ISDN interface could become a reality, technology had to be developed in order to handle this interface. And the users had made it very clear that they were NOT going to spearhead such a development effort. At least not if the only reason for doing so, was to enable a change in the carrier technology.

Telenor pushed very hard for a transferral from the analogous system to the ISDN-system. With this push also came several accompanying technological sub-systems, and among these was a packet-switched data transmission service based on the D-channel. This service, the ISDN-Pak, was introduced in 1995, and with ISDN-Pak, the major supporting system for a digital-digital interface between the electronic payment system and the ISDN-system was put in place. The year after, in 1996, Telenor agreed upon a development contract with a supplier in order to develop the necessary equipment for the interface. The product was introduced by Telenor in 1997 and was branded as the MIA-service.

The MIA-boxes allowed communication between electronic terminals and the ISDN D-channel. It adapted transmission speed and software. Also, the MIA-box was programmable from a remote service centre run by Telenor. This had the advantage of making Telenor able to handle upgrading without having to equip the customer with a new box, and also made it possible to use the same MIA-box for a number of different applications, according to customer's needs. The original box made by the supplier was even multi-channeled, allowing a number of devices to be linked to it at the same time (for example, one MIA-box could handle up to 4 electronic terminals). In order to make business, the supplier introduced the product on the European market. Due to the fact that few Telecom providers had a D-channel service available at that time, sales were low and the supplier decided to withdraw the product from the market. Telenor found a new supplier in Phillips, but this box had only one channel, so users would need one MIA-box for each terminal.

The MIA-box and the D-channel connection became popular with users who used the electronic payment terminals of the BBS's service, and also found use as a network solution for gas station chains owned by the oil companies. To date, almost 9.000 MIA-boxes have been installed, and approximately 500 of these belong to the elder multi-channeled type.

4: Analysis

The online electronic payment system as a resource constellation

We argued in the theoretical part that it should be possible to view a technological system as a resource constellation. The first task in the analytical part is to show that this is a reasonable description of the online electronic payment system.

The online electronic payment system came into existence around 1992, and can be said to consist of four interacting sub-systems; the magnetic strip cards, the payment terminals, the online communications network (and its carrying technologies) and the transaction treatment systems. Each of these subsystems can in turn be said to consist of a number of physical resources (primarily different types of equipment), the knowledge of how these resources are used and how they work together (or, in our concepts, what the nature of the resource ties between them are).

Our empirical case goes into detail on the third of these subsystems, and we will use this as an illustration. From the beginning, there were two important carrying technologies, data networks (particularly X.25) and the analogous telephone system. During the period since the start of the online payment system was established, two more technologies have been utilised; the digital telephone system (the ISDN B-channel) and the digital telephone signalling system (the ISDN D-channel). For each of these carrying technologies, they have had to develop hardware and software that could handle the interface to the terminals and to the transaction treatment systems. In appendix 1 I have tried to summarise some of the important resources used in this sub-system.

One important feature of resource constellations was thought to be the occurrence of resources which are also used in other systems. Among the resources used in the online payment system, several are (so far) proprietary. The prime example of a proprietary resource in this system is the electronic payment terminal, whose only uses are within the electronic payment system. However, most other resources ARE used in other systems. For example, the telephone systems (both the analogous and the digital) are used as central carrying technologies, but also have significant other uses, for example in the telephone system, the fax system and in data transmission. In fact, the traffic on the telephone system generated by the online payment system is a very small part of the total traffic on the telephone system.

Since this is the case, we would expect that any adaptations necessary in order for the online electronic payment system to utilise the telephone system, would have to be added to the equipment used for electronic payments. Indeed, this is exactly what has happened, as the electronic payment system has added modems (and later MIA-boxes) in the user-end and PADs in the transaction treatment end in order to be able to change data to and from a format, which can be transferred on the telephone system. Which other systems the individual resources are used in, is also indicated in table 1.

System development and “realised versatility” of its resources

The system has undergone continuous development, which have mainly resulted in more diversity in the number of technologies used, and the number of possible configurations, which will support the same basic activity (to effectuate an electronic payment). This has also been summarised in table 1. The increased diversity is not a surprise, but rather is in line with the suggestion made by Holmen and Pedersen (1999) that the “realised versatility” of a resource will increase over time. A nice example of a resource who has had its “realised versatility” increased, is the ISDN D-channel. The addition of the packet-switching data transmission network ISDN-Pak, which uses the D-channel as carrying technology, has meant that a whole new field of applications are opened up where the D-channel can be used. Low volume data transmission is one of these applications, and the electronic payment system is among the first systems to use this application (requiring the MIA-box as user interface between terminals and ISDN-Pak). However, other systems are working with ways to utilise the same application, and it is likely that for example online games such as “Tipping”, “V7” and “Lotto” are following soon as users of ISDN-Pak. Other applications are also possible. In the Netherlands, the D-channel is used for surveillance purposes (utilising the fact that the D-channel is always online) and it is likely that such an application can also be utilised in Norway. Each of these uses require adaptations in the technology which links the D-channel to the application, thus increasing the “realised versatility” of the D-channel.

Memory traces and the system history

In our theoretical discussion, we forwarded the concept of memory traces: Memory traces are the remnants of former ties in an individual resource, and they are dependent upon increasing “realised versatility” in a resource. As the versatility increases, the resource will by definition be tied to an increasing number of other resources. This means that the resource will be adapted in order to handle the new ties. Sometimes, the old and the new tie cam exist simultaneously. At other times however, one or more old ties must be broken, in order for the new tie to be established. When an old tie is broken in such a manner, the resources will often retain some of their adaptations, which were made for this tie. These remaining adaptations are the memory traces of what used to be.

An example from the case is the speed with which the terminals communicate. The terminals were designed in 1992, and were built (software AND hardware) for using modems with a speed of transmission set at 2,6kb/s. However, transmission speeds of modems have increased quite a lot. Thus, a modern modem usually transmits at a speed of 56,6kb/s or even faster. When a modem “speaks” to another piece of equipment, it must first establish a transmission speed. A 56,6kb/s modem would start with assuming that the receiving equipment also “speaks” at 56,6kb/s. Since the terminal does not, the modem will, upon receiving no understandable answer from the terminal, reduce its transmission speed to the next treshold (32,2kb/s) and try again. In this manner, the modem will reduce its transmission speed gradually (through all the former standard transmission speeds used by modems) until it finally reaches 2,6kb/s. This process takes time (several seconds pr. speed attempted), and time is unfortunately not something that the equipment has a lot of. The reason for this is that modems are designed to assume that if contact with a piece of equipment is not achieved within 20-30s, the piece of equipment is to be regarded as not functioning, and the modem will give up contacting it. Thus, when the difference in transmission speed between modem and terminal is too large, the modem will simply give up communicating with the terminal! This means that when installing a modern modem to an electronic payment terminal, the modem must be programmed to start communication with the terminal at a speed of 2,6kb/s. We should realise that this is not a technical problem, since a speed of 2,6kb/s is more than sufficient for the transmission of the short payment transactions. It is, however, a memory trace, a feature of a resource (the electronic payment terminal), which is based upon a tie with a resource (a 2,6kb/s modem) that no longer exists.

Even the very limited material I have collected for this case shows several such small histories. Thus, we can assume that memory traces are prevalent in technological systems, and that they can be used in order to describe the history of the system itself.

Resource fixity

When we take one specific point in time as a starting point, and examine a particular technological system at that point in time, we will be able to describe the resources used in that system, and the ties between them. As has been argued for in the theoretical part, this description represents the current deployment of the resources. We argued, however, that reaching this deployment situation was not a process of chance. It was a deliberate process of aligning and adapting resources to each other with a specific goal in mind. Thus, their current place in the resource constellation is a result of adaptations done in the resource ties that together make up the technological system. This place is normally dependent upon modifications being done to the resource, or the way it is used and thought of. Thus, a resource increases its realised versatility when it is adapted into a new system. Most likely it is also modified, as is the case with a standard modem used in the online payment system, since it needs to be specifically programmed to handle the “low” transmission speed of the electronic payment terminals.

An interesting question then arises; does this adaptation process mean that the resource in question is now "fixed" in the new system? Does adaptation to a system fix the resource, so that it can no longer be used in other systems? We will argue that this is not the case. According to our basic theoretical assumptions about resources, they are heterogeneous and can always be used in combination with other resources and their use is seldom limited by their use in other connections (except perhaps in a strictly quantitative sense).

However, that they CAN be used is not like saying that they always WILL be used. In our view, the actors involved in development process of the system may for example have decided that the resource performs adequately in its current deployment. Their focal areas may be at other areas of the systems. As such, we would not expect the use of the resource to be changed if it is not in someone's focal area. Also, it is possible for actors to determine that a specific resource tie must remain unchanged, and that other resources must be adapted to the resources in this tie, if they are to be used together. The electronic payment terminal is a good example of this. This resource has not been changed in the fifteen years that have passed since it was designed. This is not due to a lack of possibilities, or a lack of ideas as to how to change it. Rather, it is the result of a decision made by the actors involved (primarily BBS) to keep this resource unchanged, and instead to align other resources (like the modems) to its present configuration. The reason for keeping the resource the way it is, is said to be the costs involved in retrofitting the approx. 53.000 terminals which are already in operation.

In this way, the existing structure deploys resources together with specific other resources in ties and constellations of resources. The ties and constellations are constructed purposefully in a development process, and with the specific intention of making certain activities possible. The ties of an individual resource can be to other resources within the firm, or to resources in other firms. The development process, which made these activities possible, lends a certain weight to the current deployment. We can think of this weight as an important factor in deciding the next step in the process. In particular, high investment in the physical components of the system tends to mean greater weight.

The possibility of a resource to be tied to other resources in one manner or another is always there. Furthermore, we will argue with support in the heterogeneity assumption that there is not one single way of tying two resources together, but actually several. What restricts a resource from being tied to another is thus NEVER the possibilities, but rather:

1) A lack of understanding into the principles by which they can be combined
2) A lack of understanding of the effects of existing ties
3) A lack of opportunity to try out combinations
4) An awareness (acquired through an understanding of the system's history) which precludes that specific resource from the suggested combination

Development processes and their importance to system history

The development process imbues the structure with a history. How strong the weight of the current deployment is in determining the next steps of development depends upon how well aware the current actors are of the history of the development process.

In other words, the history of the development process affects the next steps in the development process. One effect is that it provides awareness about what has been tested, about abilities of the existing system and about how the different components of the system can be utilised. It may sound surprising that we will argue that this is one of the strongest driving forces for change. A common thought in the literature is that when a system is developed, it is time to recover the cost of development by capitalising on the system. This is done by stopping the investment and reaping the benefits. Unfortunately, this perception builds upon a faulty supposition, the thought that development of a system stops. Instead, development continually takes place as certain ties between resources become more fine-tuned and more efficient, whereas others are cut. It is this continuous process which benefits from the awareness acquired by the actors about the resources and the way they tie together.

History can prevent actors from testing certain ties, since they may know, for example, that these ties have been attempted before and with less than spectacular results. Often, this is a benefit for the company, as this may save time and money, and provide the process with focus on other possible resource combinations, which have not yet been tested. However, it also provides the development process with a set of Do's and Don'ts that may take the appearance and strength of a "path dependent" process. Finally, it will in some cases be detrimental, since it prevents the actors from testing a combination that has been tested before, but at a time where other resources were aligned differently, and thus would not have given the same result as last time. Mercifully, we are often protected from knowing this, as there is no way of knowing what could have been…

Focal areas play an important role in this process. As explained, focal areas are areas within an actor's awareness boundary where the actor sees a potential for development. What is an actor's focal area will change as new solutions are developed and new resource ties are created, but they can also change as a result of the actor "giving up" the area, possibly due to him or her not gaining the necessary support from other actors which could have allowed implementing a change. As an example of how focal areas can change, we can look at Telenor's development of the MIA-box. At one point in time, the focal area was to develop and implement the ISDN as an alternative to the analogous telephone system. When ISDN was introduced, focus changed into different ways of exploiting ISDN. As one result of this (there are others which do not concern this case), ISDN-Pak was developed. Once ISDN-Pak was implemented, focus changed yet again into ways of utilising ISDN-Pak, and the MIA-box for the online payment system was one of these ways. Currently, the focus (in this area) is to think of MIA as a concept, and to adapt it so that it can be used with other platforms (for example and IP-platform).

Thus, the nature of the development is to test combinations of resources based upon what actors are aware of concerning the existing structure (or to be more precise, based upon what parts of the resource constellation lies within the acting actors awareness boundaries. In this way, history is both necessary, and extremely helpful, in giving a development process direction, and thus also very important in deciding what the next attempt to combine will be. History thus gives us considerable insight into the mechanics of gradual innovation.

5: Further research

In this paper, we have tried to argue for the importance of history in development processes. We have tried to show how the actor's awareness of the system's history is important for the continuous development of the system. However, history cannot be the only factor. In particular, the author believes that we need to search for another factor in order to gain better insight into the more radical development processes.

Although we will not explore it in depth in this paper, we will suggest that diversity may be an important factor in more radical developments. By diversity, we will think of differences in the awareness boundaries of several actors who have the same focal area. In other words, actors who have overlapping focal areas, and fairly similar awareness boundaries regarding the history of the system in question, are likely to produce gradual development processes, whereas actors with overlapping focal areas, but different awareness boundaries are likely to produce more radical development processes. However, the chances of success are likely to be larger in the former case than in the latter, since the actors in the latter case must first agree on a fair description of the system and what should (or could) be included in it.

For further research, we thus suggest following this line of inquiry and look at differences in the awareness boundaries of actors and see how this affects the development processes and the development resulting from it.

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Appendix 1: **Overview of individual resources used in the online electronic payment system**

Magnetic strip cards: Developed 1980s. Several variants. Most of them can be used both in online payment systems and in ATMs (automatic teller machines). Also works as ID. Owned by the banks.

Electronic payment terminals: Developed late 1980s. Four variants, but all use the same proprietary software. No current uses outside of the online electronic payment system. Owned by the banks. Serviced by Bravida.

Analogous telephone system: Developed 1870s. Carrying technology for data from online electronic payment terminals. Main use is as conveyor of telephone, telefax and data transmissions. Being replaced by ISDN 1992 onwards. Operated by Telenor.

X.25 data network: Developed 1978. Carrying technology for data from online electronic payment terminals. Main use is for medium-volume data transmissions. Operated by Telenor.

ISDN B-channel system: Developed 1970s. Operative in Norway from 1992 onwards. Main use is as conveyor of telephone, telefax and data transmissions. Operated by Telenor.

ISDN D-channel system: Developed 1970s. Operative in Norway from 1992 onwards. Made available for low-volume data transmission by the instalment of ISDN-Pak in 1998. Operated by Telenor.

Modem: Connects the terminal to the analogous telephone system and the ISDN B-channel system. Numerous variants. Most are standard and have numerous other uses, although once programmed to work as terminal interface, they must be reprogrammed before they can be used for other purposes. Owned by the stores.

MIA-box: Connects the terminal to the ISDN D-channel or B-channel. 2 variants exists in Norway, but there are alternatives. Operative in 1998 (earlier on the B-channel). Bought by the stores from the banks (through BBS).

Reserved data link: Connects the terminal directly to the X.25 network, usually through an IBK. Can be used for other purposes. Owned by the network operator, Telenor

PADs: Connects the analogous telephone system, the ISDN D-channel and the ISDN B-channel to the X.25-network. Allow use of the telephone systems for data transmission. Operated by Telenor.