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Exploring loose coupling in system interaction

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Abstract. The concept of loose coupling is used in various disciplines, such as organisation science, computer science, information systems and geography, but its definition and application is elusive. In this paper we investigate the roots and meanings of the concept, and ask two research questions: (i) How is the concept of loose coupling used within streams of IS research? And (ii) how can we apply the concept to design the system interaction within the field of IS? Our method is a systematic review of the literature, where we identify the definitions and uses, conduct a cross-disciplinary meta-analysis, and deduct a framework for analysing and using the principle of loose coupling. We then discuss implications for the dynamics of information infrastructures. We offer two contributions. First, we provide a comprehensive overview of the loose coupling research, and gives rich insight into uses of the concept. Second, we propose a framework where we synthesize the insights.

Keywords: Loose coupling, modularity, innovation

1 Introduction

The principle of loose coupling is well known in computer science; in programming it is often defined as a low degree of interdependence between routines or modules [1]. The point is that when two components are loosely coupled changes in one of them does not affect the other. The reverse argument is high cohesion, which means that the methods of a module belong together.

Interestingly, the term is also used in several other disciplines, such as organisation science, and information systems. At a general level it is used to characterize the degree of integration versus autonomy of systems, but at a more detailed level the definitions and uses vary significantly. For instance, loose coupling often serve as a vehicle to analyze difficult conceptual problems [2]. But much of the work does not examine the concepts "underlying structure, themes and implications" [2: 203].

Loose coupling is often regarded as a solution to complex cooperation between different systems, both in organizational [7] and technological projects [10]. Loosely coupled systems maintain autonomy, while they also limit the effect of errors and risks [9]. On the other hand, tighter coupling mechanisms are often seen as a necessary technique in providing the systems with the necessary information. Especially in the health sector where information correctness is absolutely necessary and the security and privacy issues are of outmost importance, there is a need to protect certain technological solutions from uncontrolled intrusion.

Our research context is information infrastructures, i.e. large and interconnected socio-technical systems. An increasing requirement for technological portfolios is the reusability of components, tools, architectures and systems in order to be competitive in the market. The literature on information infrastructures [26] take this into account. But the concepts of installed base, bootstrapping and cultivation are more occupied with existing systems and their utility than modularity, layers and patterns as software enablers for loose coupling. The existence of heterogeneous networks on a national level [30] or in knowledge organizations [20]; evolving modular ecosystems connected through a common base [29, 31], or system transition from physical to digital products [16, 18], all brings with them a necessity to understand possible interconnections between organizational or system modules.

Based on this, we claim there is a need to take a step back, to investigate the concept and its uses within many different fields in order to rediscover its rich insights, and to provide a systematic categorization of its contribution. Our interest in this paper is thus, i) to have a broad investigation of the different fields where it have been used and how, ii) what kind of problems the concepts are addressing.
Our research questions are:

- How is the concept of loose coupling used within streams of IS research?

- How can we apply the concept to understand the system interaction within IS?

Our contribution is twofold. First we explore and structure the ways loose coupling is used within streams of IS research, second we add to the literature by investigating principles for coupling between system modules. We do this by establishing a framework for analyzing the concepts in relation to the challenges in system design and management.

2. Method

We chose a literature review as our research approach, as we wished to explore how the concept was used. The process is described in table 1.

2.1 Data Collection and Analysis

Table 1: Data collection and analysis

Step	Description	Output
1	Search in Google Scholar using "loose coupling" and "information systems research"	1080 articles
2	Select relevant articles based on inclusion and exclusion criteria	100+ articles, 21 chosen
3	Systematize findings according to streams of research	Table 2
4	Identify relations and key insights in the literature based on research stream	Table 3-7
5	Framework for principles of loose coupling	Section 4

Our literature review was "concept-centric" [27]. In the first step we searched for articles in Google Scholar using "loose coupling" and "information systems research". This returned 1080 articles. In step 2 we selected relevant articles; inclusion criteria were that the article had to treat the concept theoretically or empirically, and that the concept was central either as a theoretical or empirical contribution. This was operationalized by entering each article, and search on "loose coupling". Exclusion criteria were thus that loose coupling was only peripherally dealt with. In addition, we used "backward referencing" [27] as the reference lists in the articles lead us to core literature on the subject from other research areas, but then from an "information systems" relevance. This gave us 100+ articles. All the articles were read until we saw a recurring pattern where the concept was used but not in new ways. In addition, there is relevance between "loose coupling" "modularity" and "hierarchical layers". The concept of modularity is in its depth about how systems or organizations are organized in modules or units. Loose coupling is related to modularity in that it is occupied with the connections between the modules. The relation between "coupling" and "modularity" led us to explore referred articles which used coupling concepts implicitly, but in new ways. Examples are "agility" or "adaptation" between components, which also address our research interest. The result of this process was 21 articles.

In step 3 the 21 articles was read thoroughly and categorized into a conceptual classification [17] of 5 research streams, based on following criteria:
1. The journal, book or the conference the article was published
2. The type of challenges the article addressed
3. The unit of analysis or the object of study the article was dealing with

The 21 articles were organized into a table, and the three criteria were applied to each one of them, leading us to the five research streams. In step 4 we deduced key principles from the texts, in order to enable "new ways of thinking about the topic" [17:363]. These key principles were in step 5 synthesized into a framework consisting of three main categories. The categories were established going back to the articles to identify some common technological or organizational reality they referred to.

3 A review of the research on loose coupling

The concepts of tight and loose coupling are used in IS to outline units or modules of organizations and technology are connected. Tight coupling is in some aspects preferable because of the enabled effectivity. The example in Latours "Science in action" is the machine. De Bruijn and Lejiten [28] claim that the simple structure of tight coupled systems makes them relatively easy to repair when they fail. On the other hand, according to Tiwana [29] there is a link between the division of authority and the technology. In knowledge organizations like the professional bureaucracies with loose organizational coupling, modular architecture will thus be preferable. Without taking stand in if and when to use loose or tight coupling, we will in this paper look at the concept of loose coupling, and how it is used in the IS literature.

In this part we identify several fields where the concept of loose coupling is used. This is done to enable an overview of a broad range of literature dealing with coupling mechanisms. The 21 articles were categorized into five research streams. A summary is provided in table 2.

Table 2: Key research streams

Stream	Understanding of loose coupling	Key insights	Theo-retical	Empirical	Refer-ences
Computer science	Modules organized in hierarchical layers interact through standardized interfaces.	Benefits of modular programming from 3 perspectives: Managerial, product flexibility and comprehensibility.		6	[3, 4, 5, 6, 21, 22]
Organization theory	Events are connected but preserve their own identity physically or logically separated.	Loose coupling enhances autonomy innovation and change and reduces risk and inefficiency.	3	3	[7, 8, 2, 9, 10, 20]
Industrial management	Loose coupling enables system management	System management knowledge on component and core design; and architectural knowledge, the links between components	3		[11, 12]
IS management	Loose or adaptive coupling enables system restructuration	Adaptive coupling between architecture and business enables restructuration and reorientation of IT portfolio.	1	1	[13, 14, 15]
Digital innovation	Loose coupling between modules enables layered architecture.	Loose coupling between components through standardized interfaces, enables a layered architecture which instigates innovation.	2	2	[16, 17, 18, 19]
TOTAL			**9**	**12**	

3.1 Computer science

Parnas [3] is a much cited contribution, claiming that modularization is a "mechanism for improving the flexibility" of a system [3: 1053]. Decomposition and modularization is related to Herbert Simons work. He argued that most complex systems can be decomposed into stable subassemblies and that these are the crucial elements in any organization or system. Modularization is about breaking the system into definable entities which can be maintained and developed further without affecting the rest of the system. The system modules maintain a high level of integrity internally while the coupling between the modules is flexible and adaptable [3, 4].

Parnas see three key benefits from modular programming: 1) manageable – shortened development time because separate groups work on each module with little need for communication; 2) product flexibility- changes in one module does not affect the others; 3) comprehensibility – the possibility to study one module at a time. The whole system can be better designed when it is better understood, and the system modules should interact through distinct interfaces.

Yourdon and Constantines' [22] ideas developed in the late 1960s, focused on the art of designing components and the interrelationship between the components in a best possible way. Their "best practices" aims at achieving efficiency, maintainability, modifiability, generality, flexibility, and utility. The modularity in system design avoids monolithic systems where each piece is so highly interrelated that they behave like a single piece.

Designing loosely coupled systems, systems where one can maintain or study any one module without having to know very much about any other modules in the system, we avoid monoliths.

These insights are used also later in object-oriented programming languages and in the patterns literature. In Gamma et al [21] loose coupling are important in keeping specific operations isolated within modules, while the interaction between modules is provided and maintained through distinct interfaces. They do this explicitly through encouraging a set of "patterns" with practical suggestions on how to design software. The use of patterns lowers the degree of dependency, facilitates cooperation, change and reuse of the software architecture.

Larman [4] claims that "coupling is a measure of how strongly one element is connected to, has knowledge of, or relies on other elements. An element with low coupling is not dependent on too many other elements"[4: 229]. The modules are designed in hierarchical layers, and the pattern of "low coupling" is established in order to standardize interaction between components. This is also the main focus of "Unified modeling language" (UML). In Booch et al [6], "loose coupling" between the classes and objects in the hierarchy is central. Loose coupling is also important in web-programming where it allows service consumers to interact with a service provider even when the latter is not available. In such systems design, clients are not affected when services suffer from temporary downtime [5]. The perspective of inheritance within UML and OOAD indicates that there is something "deeper" you can build new modules upon.

Table 3: Computer science

Understanding of loose coupling	Key Insights	Reference
Interacting modules with internal cohesion organized in hierarchical layers.	Modular programming makes systems easier to manage, more flexible, efficient, maintainable, and modifiable.	[3, 22]
Loose coupling in interaction between service consumers and service providers, to avoid temporary downtime.	Importance of loose coupling in integration and web technologies.	[5]
Low coupling gives lower maintenance dependencies, low change impact and higher opportunities for reuse.	The importance of layers and patterns in obtaining loose coupling in OOAD	[4, 6, 21]

3.2 Organization theory

Glassman [8] uses loose coupling to describe interaction in organs and cells as well as organizations, and is particularly interested in how independent units do not affect or infect the whole system when doing something. Moreover, Glassman claims that a way to maintain loose coupling is by having a subsystem which is more tightly coupled to the variables in question [8]. The internal persistence within systems enables loose coupling between systems, and a dynamic flexibility between organizational or bodily units.

Weick [7] extends Glassmans view, concentrating on aspects of loose coupling in educational organizations. He offers insight into seven aspects on loose coupling: risk reduction; its role as a sensitizing device, and in localized adaptation where any one element can adjust to and modify a local and unique contingency without affecting the whole system. Further it enables innovation, novelty, is more efficient to run, cheaper to improve, and requires less coordination. Weick primarily portrays the autonomous effect of loose coupling and how risk, or inefficiency is lowered.

Weick and Ortons [2] literature analysis establishes five organizational outcomes of loose coupling. First they see persistence as an outcome of loose coupling in that it creates "strong" units which make change difficult for management. This could be seen as a problem from a managerial point of view. Second buffering enables an indirect relation between modules or units which sometimes could prove to be good – in that errors, risk or harm is not spread –sometimes wrong – in that important alarms or messages does not reach the loosely coupled element. The third concept is adaptability to change through collective judgment and dissent. We understand them as the importance of having something in common in order to be individualistic which is about agreeing on global rules in order to enable local freedom. The fourth and fifth concept are satisfaction, which is about inspiring motivation, safety and mastery of tasks and reducing conflict through smaller teams; and effectiveness which is about the combination of tight and loose coupling through global and local aspects of training, education and common variables.

For Perrow [9] loose coupling reduces risk in that errors are not spread as the risk is isolated at module or unit level where the participants have deeper knowledge of the system and are able to react to its eventual failure. Second he claims that tightly connected systems when exposed to errors may both react strangely, its behavior is

the outcome of unexplainable side-effects, and that the error messages the system gives makes it very difficult to find the cause of the error.

Ciborra [10] is particularly interested in the autonomy of loosely coupled systems. Using the case of an internet tool developed within a medical firm, without intervention from the central management, he claim to demonstrate both the autonomous "nature" of internet and intranet, and the inherent potential for innovation in loosely coupled departments. Based on this he suggests releasement, instead of top down and loose coupling rather than alignment to make infrastructural growth [10].

Berente and Yoo[20] uses loose coupling as a device to describe how employees at NASA adapted to a corporate enterprise system by using alternative templates that met their needs. Loose coupling is here used as a tool to enable situated practices to coexist with tightly integrated and standardized enterprise systems.

The potential conflicts of institutional logics in large enterprises are solved taking local needs into account. The temporal, procedural, material and interpretive aspects highlight the need human agency has to flexibly customize system functionality to its own requirements.

In summary the organizational literature gives insight into the practical organizational benefits of autonomy and freedom at work. Loose coupling enables innovation, efficiency and makes change easier. Loose coupling is also an important mechanism in balancing the local and the global. The authors in this area acknowledge to a lesser degree the technical, architectural and governmental "downside" of parallel systems running more or less independently of the official one.

Table 4: Organizational theory

Understanding of loose coupling	Key Insights	Reference
Events are connected but do also preserve their own identity as physical or logical separateness.	7 aspects of loose coupling in organizations: risk reduction, sensitizing device, localized adaption, innovation, efficiency, easy to improve	[7]
Loose coupling among systems contributes to stability by allowing persistent behavior of the system on the face of certain inputs.	The degree of coupling depends on the variables they share. One way to obtain loose coupling is by having tighter coupling on a lower level.	[8]
Relation between dependence (tight coupling) and interdependence (loose coupling) in organizations.	Five organizational outcomes of loose coupling, their effects, techniques and consequences.	[2]
Loose coupling reduce, isolate and make risk more manageable.	Loose coupling keeps the risk at module or unit level where the participants have deeper knowledge of the system and are able to react when needed.	[9]
Loose coupling enables decentralized autonomy and innovation.	Innovation is obtained through liberty of organizational units, and by the use of generative technologies like web.	[10]
Loose coupling enables dealing with implementation of information systems which is not adapted to all practices	Forms of loose coupling in ERP implementation, that highlights human agency: Temporal, procedural, material and interpretive	[20]

3.3 Industrial management

Loose coupling and modularity is also central in the stream we define as industrial management. Sanchez and Mahoney [12]claims that modularity and loose coupling is a necessity in order to reduce cost and enable more adaptive coordination within modern technology organizations. The strategic flexibility is necessary in a fast changing market, and modularity in product and organization design enable a new strategic approach. They emphasize the importance of learning processes and that these have to be organized in parallel with the firms' product creation processes. Henderson and Clark [11] claim that it is important to go from seeing the system as an embedded whole, to a view of the system and the product as a set of components. This requires two types of knowledge, knowledge of the core design implementation of the components, and the architectural knowledge which is about how the components are linked together [11].This insight is related to the distinction between radical and incremental innovation. Incremental innovation makes it possible to continue as before with little change, but with some improvement in the products. Radical innovation makes it necessary to look at the architectural components in a new way in that it establishes a new dominant design. The conflict between existing

knowledge and enforced change occurs because the knowledge of existing markets and requirements sometimes make change difficult. The internal knowledge processes are in the change process.

Table 5: Industrial Management

Understanding of loose coupling	Key Insights	Reference
Loose coupling enables (better) system management, adaptive coordination and strategic flexibility	System management requires knowledge on component design and how the components are linked together. Learning processes are vital.	[11, 12]

3.4 Information systems management

The management literature is often dominated by centralization and increasing shareholder values [15] through business process reengineering [23], and by commodification of ICT tools [24]. To adapt to this firms must re-arrange their IT portfolio from "from monolithic, stable architectures into hybrid, best-of-breed, adaptive platforms." [13: 107]. To obtain this the platforms organizing logics has to be re-appropriated based on three building blocks: IT capabilities, relational architectures, and integration architectures. This enables relational governance which will substitute monolithic management models [13].

The platform logic [14], however, enables a changed focus on governance structures (i.e., choice of centralized, decentralized, or federal forms) and sourcing structures (i.e., insourcing, outsourcing), toward more complex structures that are reflective of contemporary practice. This makes it essential that IT infrastructures and application functionalities as well as architectural and domain professionals are interconnected through both tight and adaptive coupling mechanisms. The integration of internal knowledge and knowledge on the market enables entrepreneurial action based on "strategic foresight and systemic insight" [14:250] and is obtained through combining IT and business resources.

Ciborra [15] argues against these strategies, claiming that it is not through strategic alignment new corporate infrastructures are created. IIs sometimes grow by autonomy and chance [10], because IIs are deeply sunken into the installed base of organizational processes, standards and practices [25]. The embeddedness makes it difficult to see where it starts and ends; there are no absolute boundaries [15]. Ciborra advocates a strategy where a lot of freedom is given to different groups within the organization, while the management theory on the other hand requires central command and control through a combination of adaptive and tight coupling.

The literature gives insight into the struggle between freedom and governance, between decentralization and centralization. It is a complex and very challenging task, both internally and externally to align the digital strategy with the knowledge on ICT and business in a firm.

Table 6: Information systems management

Understanding of loose coupling	Key Insights	Reference
Loose coupling enables dynamics through local action and decentralized autonomy.	Establishing, diffusing and cultivating information infrastructures is a relational undertaking	[15]
Loose coupling between modules and its role as a way to enable innovation and agility in strategical shift	Agility, continual innovation, and competitive action are core elements of strategic thinking.	[14]
Adaptive coupling as a way to enable restructuring and reorientation of IT portfolio.	Adaptive coupling between architecture and business as a way to enable restructuring and reorientation of IT portfolio.	[13]

3.5 Digital innovation

The stream "digital innovation" combines insights from computer science and organizational studies. Tilson et al [19] looking at the intellectual climate caused by new technologies like mobile smartphones, are mainly interested in the digital infrastructures, and how they differ from physical infrastructures. The paradoxical result of these technologies is that they at the same cause "both tighter and looser organizational control at the individual level" [19: 754]. The digital modeling of processes makes a fragmented portfolio, where decomposed system modularity requires management change from command and control to coordinate and connect.

The flexible portfolio challenges the existing control regimes, and creates individual and traditional self-organizing social assemblages that represent new forms of organizing [19].

While [19] look at the digital technologies ability to change the organizations through digital thinking, Yoo, et al [16] focus on architectural dilemmas. They claim that modular architecture which incorporates four loosely coupled layers of devices, networks and services extends the architecture of physical products [16].

Henfridsson et al., [18] gives practical insight into what this literature tries to motivate. In their work on Infotainment in cars they describe how a big car producer went from using in-house technology to enable use of products available in the commodity market. They claim that the main thing – even though organizational tensions may make this difficult - is to shift from a narrow focus on the physical aspects, to exploit the logical design possibilities in modern software [18]. To enable a more lasting survival, the authors give three advices. First, the attempt to close capability gaps involves an increasing distribution of control and coordination of the innovation process. This provides an avenue for understanding modularity as hierarchy and network at the same time. Third, the modularity of digitized artifacts exhibits multiple ontologies, a combination of digital and physical perspectives.

There is a relation between the easily reprogrammed modularized technology, the products it enables, and the learning process in the reorientation from physical to digital manufacture [18, 19].

Table 7: Digital innovation

Understanding of loose coupling	Key Insights	Reference
Modular design enables loose coupling and interdependence within, and independence across, product components.	Decoupling hardware and software enables digital thinking, i.e. use of patterns to develop digital products.	[18]
Loose coupling between modules as a way to enable layered architecture.	Loose coupling between components using standardized interfaces, enables a layered architecture which motivate innovation.	[16]
Mobile technology simultaneously loosens and tightens organizations' ability to exert control.	The effects on change and control generated by the transition from physical to digital infrastructures.	[19]

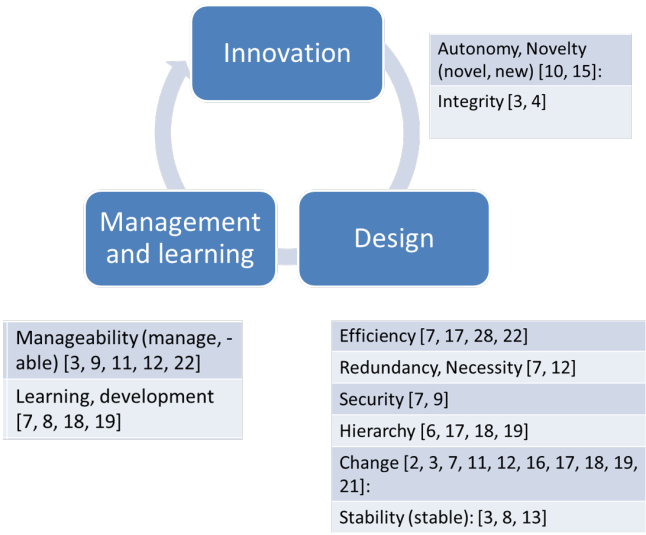
4 Framework for loose coupling in IS

In part 3 we analyzed the literature on loose coupling categorizing it into five research streams. We described how the selected literature used the concept, and its key insights. The key insights consist of theoretical or empirical principles (table 3-7, second row) which in 4.1 are deduced and synthesized into three aspects of organization and system dynamics and interaction.
In 4.2 we propose further research based on the principles in 4.1.

4.1 Key principles of loose coupling

The principles of loose coupling deduced from the articles are categorized into three aspects of organizational and technological reality: Innovation, Design, Management and Learning, shown in Figure 1. Although the insights are derived from different disciplines we argue that this synthesis is consistent and coherent in an IS socio-technical context.

Figure 1: Principles of loose coupling synthesized (with references)



INNOVATION:

Autonomy, *Novelty:* Loose coupling facilitates innovation and novelty in that workers have control of the equipment and resources they need. Examples could be the health sector and universities where knowledge is created in knowledge groups solving complex problems by finding solutions using techniques that not necessarily are bureaucratically defined. Autonomy is in these organizations often an important pre-requisite for obtaining innovation. Universal standardization on work routines, requirements and communication, and tight coupling between units or technology and management requirements may disturb innovation activities. Autonomy enables workers to focus on important local parameters and conditions.

Integrity: Loose coupling gives organizational units as well as technological components integrity. Integrity relates to novelty and autonomy, but is an extension in that it underlines the need for organizational and technological units to keep the internal logic controlled within defined and isolated areas. Examples can range from software objects within a computer system, to big wards for doing heart surgery.

DESIGN:

Efficiency: Loose coupling makes system interaction and system maintenance more efficient. Bureaucratic or global transactions routines enforced through tight coupling may create a routine overload which lowers efficiency. By using loose coupling organizational and technological routines is kept within local units or components. The degree of interaction says something about how tight the coupling must be, and give us the insights on what variables needs to be shared, and how. When only the absolutely necessary standards or routines are globally standardized, system efficiency is improved.

Redundancy, *Necessity*: Separate between the variables needed in local settings and global settings. This is an extension to the comments on efficiency in that it gives insight into a problem related to storing the same variable several places. Organizations and technologies should cooperate and overlap, not doing the same thing twice, but balance their organizational and technological portfolio based on information need. Efficiency is obtained or improved through obtaining joint optimization between global and local parameters, avoiding an extended degree of redundancy.

Security: Avoid connections that make system reactions unexplainable. Perrow [9] demonstrates the difficulties of monolithic system where functionality is wowed together in an intricate whole, and where errors are difficult to find and investigate. These security risks are two folded. First the system reactions are not foreseen, and second the reactions to errors are error messages that are sometimes impossible to understand. To isolate dangerous or highly important units from other parts of the organization, through loose coupling, is thus a way to obtain security, to identify errors faster and to avoid other departments being infected when errors occur.

Hierarchy: The coupling can be between modules on the same level and between different levels. This insight suggests that modules should be organized into layers. Hierarchical layers enable isolation of logics and

knowledge. In software the interfaces towards the user are often positioned at the top, the interfaces towards databases or other systems deeper down, often with business logics in the middle. In organizations reception are often the first thing a client meets. The offices are often positioned elsewhere, sometimes at the top (management) or in the middle, while at the bottom we have the stock, stored documents etc.

Change: Loose coupling makes reuse and reshuffling of components and systems easier. The hierarchical layers of modules or units based on role and task, makes change easier in that parts of the system can be reshuffled without changing everything. Especially in the digital age, with software enabled innovation, the ability to change is important.

Stability: Loose coupling is a device for decentralizing risk and maintaining stability. While loose coupling improves the ability to change, it does also improve the stability in that changes, errors and other foreseen or unforeseen situations only affect the modules or units which are bound to be affected. As Glassman [8] claims, persistence is an important aspect of loose coupling in that there is a system for isolating and maintaining problems that occur.

MANAGEMENT AND LEARNING:

Manageability: Systems decomposed into loosely coupled elements gives a better overview, and is easier to understand. From a management and learning perspective loosely coupled organizations have pros and cons. First, in organizations with tradition for strong management, loose coupling may create decentralized integrity based on factors which managers can see as a threat towards their authority. The management may also prefer universal standardized learning models which make logistics, performance, procedures and production easier to control. On the other hand, in modern organizations, this is also reflected in the technological portfolio, knowledge intensive practices expand the range of complexity which is possible to control by a limited management unit. It is therefore preferable that authority and management is decentralized and based on trust and knowledge monitored only to a certain degree by the central management. Berente and Yoo [20] gives an example of this in that loose coupling makes the amount of success in implementing enterprise systems bigger when different knowledge departments' special technology are loosely coupled to the enterprise system. This can however complicate the activity of governance of the technological portfolio, making the system range unmanageable, which again ruins several of the design principles from our last section (Design). This can be solved by the next principle

Learning and development: should be arranged in parallel. The complex evolution of digital technology makes development and maintenance a learning task, where learning intensive processes has to go hand in hand with the development processes [11,12]. The management thus has to enable the organization to learn how to cope with frequent change, and this is done maintaining autonomy and integrity within the organizational units and technological components.

The dynamics of modern technological reality gives organizational challenges in the continual expectation that technological change is dealt with. In the light of this we propose that Innovation, Design, Management and learning are connected through a reciprocal impact. Innovation is enabled through management of organizational and technological processes leading to design sketches which again causes and requires learning processes.

4.2 Further research

The principles in 4.2 can be developed further within the IS field. We briefly suggest two promising aspects based on our findings: Buffering and patterns.

Buffering may enable efficient use of systems and it may reduce risk. Buffering is a technique used in several technologies, but also in organizations. It regards the rules for interaction between units based on several criteria, like degree of importance. In intensive units interaction is of high importance, while standardized bureaucratic performances can have more "slack". An example is how netshops can use buffering to categorize approaches from the buyer, implemented in a way where the buyer receives feedback based on importance. While synchronous interaction requires immediate response, asynchronous interaction enables a client to use a service even when the service is down

Patterns enable dynamic and efficient interaction between software components, as well as an easier way to switch, change or reuse system components. Software patterns are based on modular thinking where modules or

units are organized into separate parts and integrated through loose coupling. Patterns enable efficiency and integrity, as well as change without affecting the whole system. Use of software patterns and digital resources enables a shift from systems and hierarchies as parts to patterns. A striking example of the possibilities enabled in this shift is described in [17, 18].

5 Conclusion

Loose coupling is much used but not always well understood. Orton and Weick [2] performed a systematical analyzes of the concept, but their interests differs slightly from us in being more oriented towards management effects of loose coupling. Our focus is customized to the field of information systems, and accordingly to a field which focuses on challenges both from the social and technical part of the organization; the practitioner as well as the managerial, and the use as well as the governance.

Based on this point of departure we performed a literature review, and established a framework which sheds light on principles of loose coupling. We claim that the theorization provides three insights. We have synthesized findings in a way that gives a practical understanding of how principles of loose coupling may be used in the field of IS. We also underline that principles have certain pros and cons. Third we construct a template in order to understand the dynamics of loose coupling between several elements within the organization, and between the system and the organization.

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