Management Studies, May-June 2018, Vol. 6, No. 3, 177-187
doi: 10.17265/2328-2185/2018.03.003

A Socio-Technical Perspective on the Design of IT Architectures: The Lowlands Lens

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The paper aims at developing a more comprehensive design theory for designing effective IT architectures based on organizational design principles. It builds on the sociotechnical systems design theory (STS-D) for the design of work, workplaces, and organizations as developed in the Lowlands (The Netherlands and Belgium). Traditional sociotechnical approaches study the effects of the technical system on the social system and try to jointly optimize both systems by end-users' participation. The Lowlands STS-D approach focuses on creating organizational conditions for developing humane and productive organizations. Organizations are considered as social systems. Technical systems need to support the effective functioning of work and control of work within that social system. Therefore, the division of labour is central in the Lowlands STS-D approach. It is articulated in designing the execution tasks (production structure) and control tasks (control structure). Furthermore, it claims that the design of IT architecture follows after organizational design of the production and control structure. This boils down to the design of provisioning of information needed at workplaces and between workplaces. To understand the Lowlands approach for designing IT architecture, called archipelago, we will first in-depth explain its organizational design principles and sequence, and its application for designing IT architecture, which is becoming ever more feasible with new technologies. Furthermore, with this paper we attempt to bridge the different languages used by organizational and IT designers as they should jointly work on the same outcome: humane and productive organizations.

Keywords: sociotechnical design, IT architecture, humane and innovative organisations

Introduction

Given growing global competition and the predicted shortages in the labour market, organisations, nowadays, face the dual challenge of creating workplaces that are, on the one hand, more productive, flexible, and innovative, and on the other hand, healthy places to work. There seems to be a need for workplace innovation to transform traditionally monolithic bureaucratic organisations into modern organisations that meet these challenges (Oeij, Žiauberytė-Jakštienė, Dhondt, Corral, Totterdill, & Preenen, 2015). Bureaucratic

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organisations are defined by and embedded in their structures, support systems, decision making systems, facilities and IT systems. Bureaucracies are, due to their focus on maximising the division of labour and central control of the work processes, designed for stable environments and mass production. Hence, they are not well-suited to respond to the need to be agile in a dynamic environment with ever changing customer demands. Therefore, to realise new ways of organising through workplace innovation, an integrated approach to systemic change including IT systems in the organisation is needed. In this paper, we regard sociotechnical systems design (STS-D) as design approach that focuses mainly on the design of the core work process and its control.

We will first discuss the Lowlands STS-D theory as a base for the design of the core work processes, that is, the primary process and its control. It focuses on creating organizational conditions for developing humane and productive organizations. Organizations are considered as social systems. Technical systems need to support the effective functioning of work and control of work within that social system. Therefore, the division of labour of executing and control tasks is central in the Lowlands STS-D approach. This differs from traditional sociotechnical approaches, which study the effects of the technical system on the social system and try to jointly optimize both systems by end-users' participation.

The paper is structured as follows. First, we will describe Lowlands STS-D theory, followed by a presentation of its design principles and the design sequence. Second, we will discuss the consequences for designing IT architecture in this STS-D approach. Finally, we will end with some concluding thoughts.

Lowlands STS-D Theory

An organisation's core work process is the primary process of an organisation, such as, making goods or providing services. How these goods or services are produced, i.e. how the core work processes are organised, largely determines the extent to which the organisation's products or services create added value for customers. Hence, orchestrating an organisation's shift towards workplace innovation-related goals—performance and quality of work—typically requires a redesign of the core work process. In this respect, STS-D theory provides a valuable framework, given that core work processes are rooted in a dynamic systems—theoretical perspective of work and organisation (Kuipers, Van Amelsvoort, & Kramer, 2010; De Sitter, 1994; De Sitter, Den Hertog, & Dankbaar, 1997). The design of the core work processes determines the needed degree of (central) coordination and the possibilities for self-organising capabilities at the operational core. A maximum division of labour creates the need for central coordination and hierarchical control whereas a minimum division of labour creates conditions for self-organisation and horizontal coordination (i.e., more job autonomy). Given that organisations are complex social systems, a systemic view as offered by STS-D is helpful in redesigning organisations when required by changing economic circumstances. Bureaucracies have difficulties in coping with economic changes, while flexible, flow-based organisations are better equipped to handle change and turbulence (Kuipers et al., 2010).

STS-D theory suggests that, as a result of the division of labour, the organisation is an interacting network of people executing tasks and roles, using (IT) instrumentation, tools, and machines. These tasks and roles are thus allocated to individuals, teams, departments, and business units. Lowlands STS-D makes the distinction between production (executing) and management (control) in the following manner:

(1) the structure of executing activities (the production structure of the core work processes—PS);

(2) the structure of control activities to manage the core work processes (the control structure—CS).

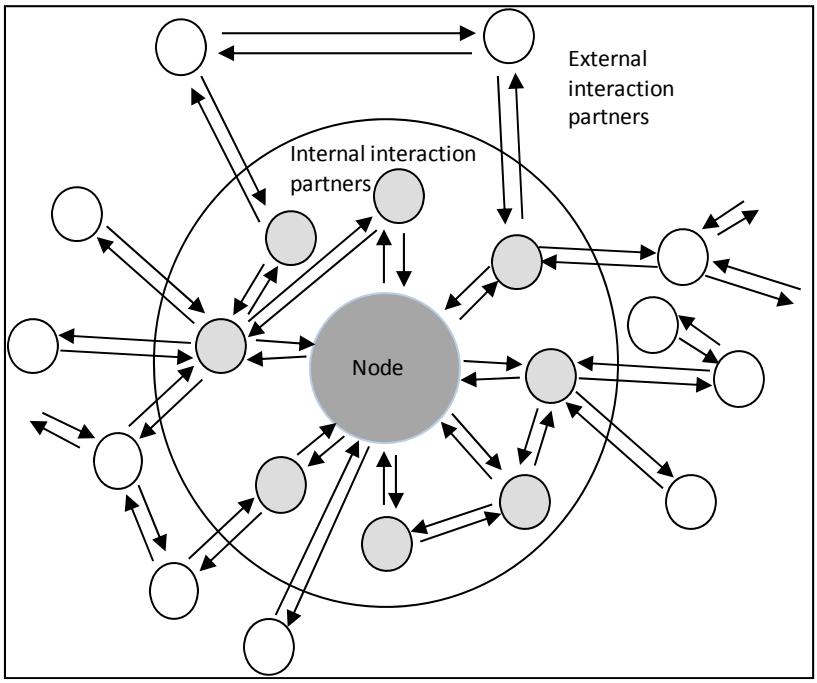

Figure 1. The interaction network with nodes (Kuipers et al., 2010).

In STS-D a role or task is the work that needs to be done, which is often related to the work of other people. All these roles and tasks together constitute the whole of the core work process. In other words, all these roles and tasks together complete the whole task of, for example, a team or an organisation. The notion of whole tasks implies, in theory, that there is no division of labour at all, for example, when a team is making a complete end-product from start to finish. This is, however, almost never the case, and therefore, roles can be seen as nodes interacting with other interdependent nodes to complete the core work process (see Figure 1). A node is a point where several inputs and outputs from different interaction partners come together to do the work.

In STS-D, as an offspring of systems theory, inputs are transformed into outputs as in the input-throughput-output model. The core work processes function in a similar vein at every level, such as at the level of tasks, jobs, teams, departments, and the organisation as a whole. At the nodes, inputs are therefore transformed into outputs or outcomes, meaning that resources are transformed into products, information, or services. Interaction between nodes, for example, the collaboration of individuals in a team, is necessary for a number of reasons, such as, the exchange of information, knowledge creation, planning and/or coordination, and deliberation. Team members are, for example, dependent on each other's task execution. At the nodes, interactions happen with both internal and external interaction partners. In order to ensure productivity either directly or indirectly, these various interactions between nodes need to be established at the right time, between the right jobs, with the right material or information and at the right place. Otherwise, execution of tasks gets delayed or mistakes become a risk. Figure 1 illustrates this point. However, these planned interactions between nodes can suffer from interference due to variance that is not accounted for in the original planning of the production in the core work processes. For instance, in the building and construction industry, different parties have to collaborate to get the job done as they are connected in specific supply-chain models. If one of the parties withholds information or drops out of the project unexpectedly, this will interfere with the other parties' capability to get the job done. In this sense, a node has to cope with two types of variance:

(1) *external variance*: such as lack of information, communication errors, changing customer demands, incomplete input, conflicting and ambiguous or competing demands;

(2) *internal variance*: human errors, technical disturbance, invalid and inflexible capabilities, shortage of resources.

The key question that arises is how can organisations deal with these types of variance at the nodes in ways that do not disrupt the production process? According to Lowlands STS-D, to deal with such variance, organisations should on the one hand, redesign the division of labour in such a way that the complexity of the interaction network can be reduced, and on the other hand, increase job control possibilities so that variances can be controlled at the source. In this respect, De Sitter et al. (1997) suggested to create simple organisations but make jobs complex, meaning that jobs become rich and varied. In other words, bureaucracies create jobs that are too simple for the complex changes in the environment. Lowlands STS-D creates complex jobs so that inherent "simple" organisations can deal with that complexity in flexible ways (Mohr & Van Amelsvoort, 2016).

The Relation Between the Division of Labour and Productivity

The productivity of an organisation is related to its capability to cope with strict external demands, namely, business and customer demands for variety (product mix), and uncertainty about both short- and long-term planning. Therefore, the capability to meet these external demands, is contingent upon the needed internal variety, namely meeting requirements in relation to efficiency, quality, flexibility, and innovation. Only if organisations can internally vary how they operate, are they able to meet the external requisite variety (Ashby, 1969).

Bureaucratic organisations are based on the principle of maximum division of labour in executing tasks and the control of tasks by rules and procedures, which, in turn, leads to complexity and rigidity (Achterbergh & Vriens, 2009). This maximum division of labour can be counterproductive for a number of reasons. First, bureaucratic organisations tend to be characterized by: 1) simple jobs, i.e., the formation of silos between functional departments, each pursuing fragmented goals and interests; and 2) complex interactions, i.e., long hierarchical communication lines, central decision making, and a large number of rules and meetings. Bureaucracies have many nodes, and are therefore exposed to the risk of much interference in the core work processes when the work cannot be performed as initially planned. Hence, if external pressures on the organisation that threaten the planned process increase, the bureaucratic organisational design will rapidly lead to productivity problems. These problems can be manifested for instance as (Kuipers & Van Amelsvoort, 1990; De Sitter, 1994):

- unreliable and long lead times due to poorly harmonized processes;
- slow response times;
- difficulty in quality assurance due to insufficiently managed processes and poor communication;
- poor cost control because actual (hidden) costs cannot be monitored and (too) much interference occurs;
- slow and blind decision making;
- expensive coordination and control mechanisms;
- lack of employee involvement;
- lack of innovative capability due to poor communication between the business functions, and a lack of initiative.

In general, the traditional, bureaucratic response to these problems is to tighten control by centralisation of decision making and implement more stringent rules and procedures. These measures are counterproductive, because the root cause of these dysfunctions is, in fact, deepened. In contrast, STS-D aims to reduce complexity by minimising the division of labour (see section (3) on "Lowlands STS-D principles").

The Relation Between the Division of Labour and Employee Involvement

The division of labour does not only affect productivity but also the quality of working life. For instance, Karasek's *Job Demand—Job Control* model (Karasek, 1979; Karasek & Theorell, 1990) (see Figure 2) suggests that work organisation, specifically, high control (autonomy) in performing tasks is crucial in transforming job demands from risks and stress drivers into learning opportunities.

In this model, job demands are seen as stressors such as work overload, unpredictable demands, time pressure, role ambiguity, interference (problems), and emotional and physical demands. Job control is the combination of autonomy, decision latitude, instrumental support from colleagues, constructive performance feedback, craftsmanship, flexible resources, leaders' appreciation and support, accurate information, and communication. In this respect, there is evidence that high job demand and low job control are important predictors of psychological stress and illness. In addition, De Sitter (1994) claims that job control leads to involvement and motivation, which translates into positive effects on indicators such as absenteeism, turnover, and stress. Moreover, there is evidence that a combination of high job demand and high job control in the form of active work is a predictor of an innovative organisation (De Sitter, 1994).

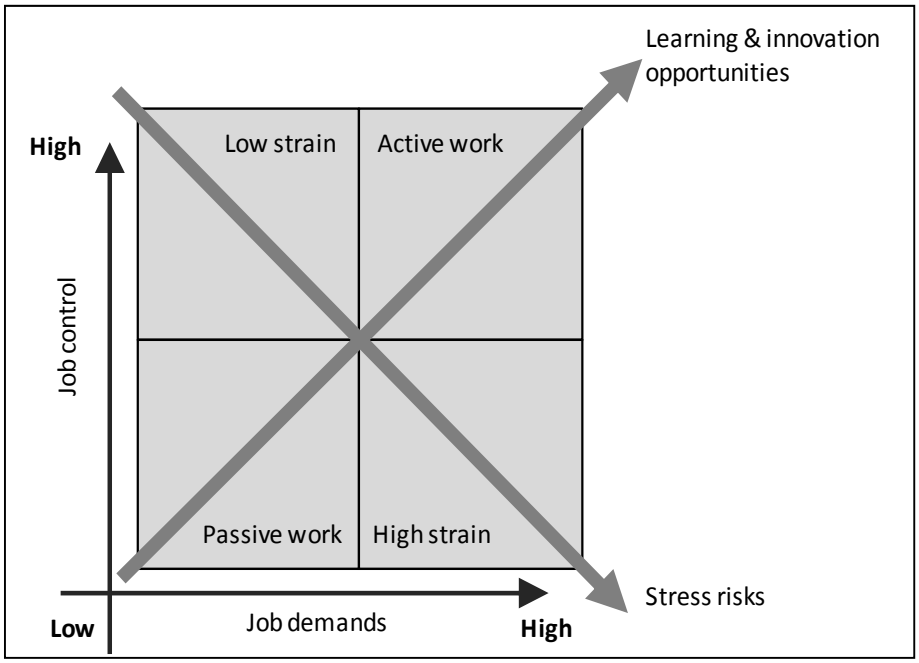

Figure 2. The job demand—job control model of Karasek (Karasek, 1979; Karasek & Theorell, 1990).

In sum, job control is an important predictor for employee involvement and, as such, a precursor to workplace innovation. Indeed, STS-D proposes that, by increasing job control, employees are stimulated to learn, better equipped to deal with interference and, thereby, better prepared to respond to challenges arising from job demands. This increased level of job control does not only affect employee involvement but also serve

the organisation by affording the possibility to better mobilise the use and development of human talent (De Sitter, 1994), and thereby enable the goals of workplace innovation.

Lowlands STS-D Design Principles

As previously stated, we take the STS-D perspective as a base for designing the structure of an organisation which has to deal with dynamic demands. To reduce the shortcoming of bureaucracies, a three-step design sequence for reorganising the core work processes is developed (De Sitter, Vermeulen, Van Amelsvoort, Van Geffen, & Vertroost, 1986; De Sitter, 1994). First, one designs the production structure, second the control structure, and third the information structure.

Design Sequence

Within Lowlands STS-D, there is a specific sequence for the design of organisations (De Sitter et al., 1986):

(1) *The design of the production structure, or how an organisation produces its goods or services*. If we assume that strategic positioning, such as the need for flexibility, innovation and healthy work, has been carried out, one needs to first design the core work process. This is done by focusing on the overall picture and then on the details (i.e., first on the whole, then on the parts). Based on the different customer families one starts with creating the different (business) units, then the different departments within these units, and finally, ends with the design of the work teams and jobs.

(2) *The design of the control structure, or how the core work process and supporting processes are managed*. The second step is a redistribution of control capabilities through the design of the management structure. This control structure is designed in reverse order, in other words, from the parts to the whole (i.e., bottom-up and not top-down). That is, first one determines what can be controlled at the (lowest organisational) local level (i.e., team and job level), subsequently what can be organized at the level of a larger organisational operating unit (above that level), and finally what needs to be controlled at the (highest) organisational level. Next, the consultation and decision-making structure can be further elaborated in detail. The principle here is that emerging problems require autonomy to solve them at the level where those problems occur. This implies that the task of managing the core work processes should as much as possible migrate to the lowest organisational level.

(3) *The design of the information structure (and other support systems).* Thirdly, the various (technical and support) systems are embedded in the new organisational architecture (see next paragraph). These systems include IT and support systems. Here the rule is that these systems should support and not control the production and control structure. An important addendum to this basic rule is, however, that especially with knowledge work, more and more production (and control) occur within the context of IT. Therefore, a modern adaptation of the Lowlands STS-Design sequence takes information and IT aspects into account when designing the production and control structures—thus, a Pi-Ci-IT model.

We now turn from the sequence of steps to the design rules. Here, again we touch upon the design of the production structure, control structure, and information structure, but now in more detail, as the design goes from a crude design to a fine-grained design. This consists of four steps, namely parallelisation, segmentation, local control, and support systems. The STS-D approach avoids the shortcoming of bureaucracies because it results in a far more flexible design that enables a proper response to change and turbulence. We discuss this design approach in the following from both a strategic and an operational point of view.

Design as a Strategic Issue

Now that we have explained the general design sequence of STS-D, we address its strategic relevance first. In the next section, we discuss how these strategic choices can result in an operationally robust design. Robust means that interferences in the core work process are minimised. According to the open-system principle, the design of organisations needs to be strategic and should include all stakeholder perspectives. This is in stark contrast to the focus on shareholder value alone often witnessed in traditional organisations (Achterbergh & Vriens, 2009). From a STS-D perspective, in line with the open-system principle, diagnosing, designing, and changing organisations need to be done by taking into account environmental conditions and strategic business choices. These strategic choices, in turn, impose requirements on the organisation and dictate the desired direction (see also Adler & Docherty, 1998). Moreover, it is highly recommended that the design is drafted in co-creation with the different stakeholders. Indeed, the best guarantee for success is to fetch the whole system into the room (Weisbord, 2004). This points to the importance of employee involvement, a hallmark of workplace innovation.

Robust Organisation Design

Apart from strategic choices, we need robust organisations which can cope with the demands of flexibility and innovation in a dynamic world. Hence, from the STS-D perspective, robust organisation design is based on the following three principles (Kuipers et al., 2010; De Sitter et al., 1997).

Principle 1: *Reduce complexity in the division of labour in the core work processes (PS) by focusing on customer order families*. Reducing complexity can be achieved by the introduction of parallel processing (i.e., factory in a factory). Parallel processes: a) afford a better business focus; and (b) create the conditions for decentralized control (see also principle 2). Parallelisation is defined as creating parallel streams of orders based on different customer families (e.g., markets, type of product). According to this principle, the design of the core work processes is based on the type of customers and their different demands and different processes. This implies identifying customer families (orders) that show homogeneity in terms of business demands, and, therefore, impose identical constraints on the manner in which the production process must be carried out. Each value stream is directly connected with a specific market, and therefore, with that market's dynamics. Thus, value streams are not affected by the dynamics of other markets. Identifying these customer families involves finding criteria to divide customers into relatively homogeneous subsets with different strategic demands. For example, a construction company builds tangible products. However, renovating a house or building a hospital represents completely different core work processes with different strategic demands and different information needs. Hence, a miniature organisation can be formed around these subsets of customer orders (i.e., one for house renovations and another one for commercial buildings) that each complete the process from a to z for this group of customer orders. In other words, the whole task is performed by a relatively self-organising group (i.e., autonomous work teams). We refer to the process as parallelisation. In other words, parallel order streams are created, with each being maximally interdependent within the stream, but minimally dependent across streams. This implies the design of whole tasks and the creation of self-organising groups, units, and communities of work which are smaller in scale. Segmentation of the core work processes can help to reduce process complexity and create teams of eight-10 people. Segmentation is defined as cutting the flows of orders into parts, in such a way that a whole task of activities with high interdependency is created (i.e., De Sitter's complex jobs at team level).

Principle 2: *Increase the local (job and team) control capability by decentralization: self-organization and a healthy control structure*. In an effective hierarchy designed to deal with turbulence, the different levels of control (i.e. layers of the organisation) have added value in terms of operational and strategic control. That is, flexible and innovative organisations are structured in such a way that they can react fast both at an operational and at a strategic level. To achieve operational control, work teams are self-organised at the operational level. Operational control is the combination of internal control (job autonomy, i.e., decision-making authority, technological variation possibilities, flexible access to means) and external control (coordination, team members' support, recognition, feedback, and influence). According to Ashby's law of requisite variety, control capability at a node (in this case, the self-organised team) is necessary in order to resolve interference at the place where it occurs and to prevent or reduce quality problems, delivery time deviations, or productivity losses (Ashby, 1969). To achieve strategic control related to the specific market a value stream is connected, different (business) units are set in place. Strategic control is necessary to reduce frequent interference among self-organising units within and between value streams and to explore innovations. Moreover, in dynamic situations, both operational and strategic controls imply learning. The preconditions for control and learning are: participation in goal setting and purpose definition as well as effective feedback mechanisms for inspiration and learning, as in the Job Demand—Job Control model (Karasek, 1979; Karasek & Theorell, 1990).

Principle 3: *Design congruent infrastructure (technology and facilities) and HR systems: minimum critical specification* (Cherns, 1987). Because the units in the organisation have different business demands they will also have different support demands. A supporting HR system, for example, should differ between teams of technically-skilled employees operating on the shop floor and administrative teams skilled in financial issues working in the office. Therefore, the design of the different support systems and technology should follow the first two principles mentioned above. Moreover, their design should be based on diversity instead of "one size fits all" and should be focused on providing support instead of controlling. (See next paragraph for a discussion of the design IT architecture).

IT Architecture Approach to STS-D: Archipelago Thinking

Although information technology (IT) systems play an important role in organisations, IT has never played a major role in designing organisations from a STS-D perspective in the Lowlands. The focus was primarily on designing the production and control structure. Nevertheless, the robust organisation design principles of the Lowlands (see previous section) provide useful guidance for designing IT architectures—what we refer to as "archipelago thinking".

Overall, it is important to take the design of IT architectures more seriously, as IT systems profoundly determine organisational design choices. After all, IT creates the technical context within which many organisations are operating and, hence, they also affect the social work system (Bednar & Welch, 2016).

In Lowlands STS-D, IT systems are primarily regarded as support systems, hence, in the design sequence, this implies: "first organise, then automate". The introduction of traditional enterprise IT systems, for example, such as enterprise resource planning (ERP), has had negative effects on organisational agility, productivity and organisational and employee health in organizations which have to deal in dynamic conditions (Govers, 2003). This is largely due to the fact that they aim for standardization and take a "one size fits all" approach, whereby, all business functions are integrated into one core work process and in one IT system. However, in most organisations, a number of simultaneous processes take place that vary in terms of inputs/outputs, process steps

and information needs. Moreover, due to this attempt at standardization, ERPs can lead to a neglect of customer demands as well as decreased job control. Let it be clear, that there is nothing wrong with standardization. An over-use of process standardization can, however, create complex work processes and procedures which create rigidity in dynamic realities—as dynamics trigger a continuous need for change. Contrary to this practice, the Lowlands STS-D principles suggest that archipelago enterprise computerization (Govers & Südmeier, 2016), when taking into account the necessary variety in work processes, is more suitable in workplaces aiming for humane and productive goals.

The ordering principles of De Sitter (1994) and Galbraith (1995) ground the outlook for archipelago computerization that suits STS designed organizations and workplaces. This design principle for designing organizations and work places offers guidance for designing computerization as well. Translated to computerization, it boils down to the following design order:

(1) Reduce information needs via complexity reduction by creating independent primary process flows.

(2) Increase information provisioning by creating the requisite information variety for each primary process flow.

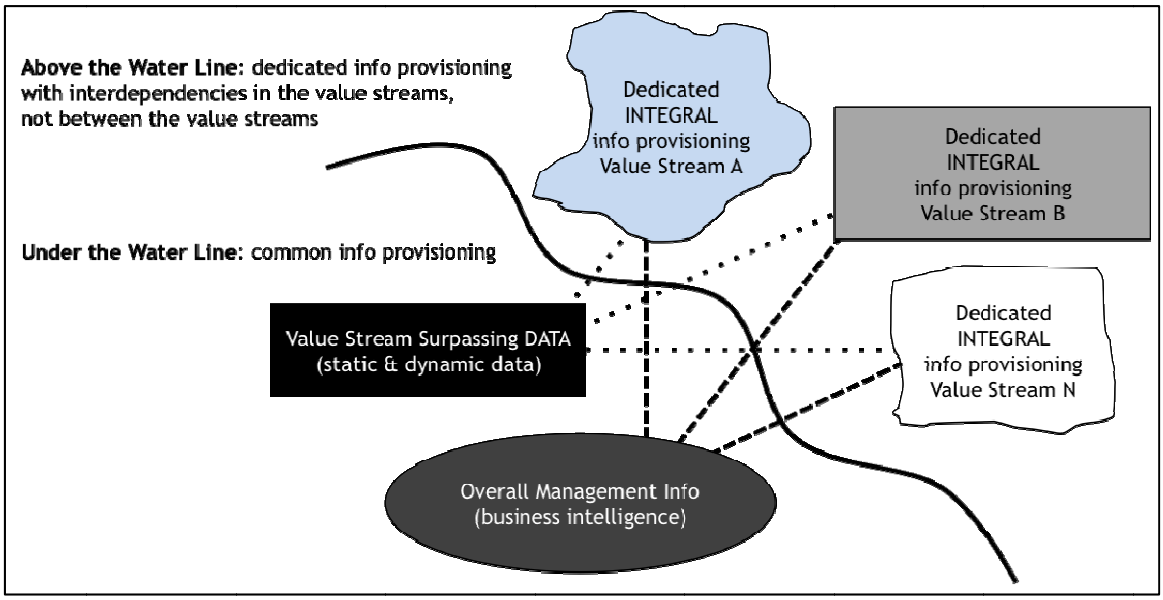

Figure 3. Archipelago IT architecture (Govers & Südmeier, 2016).

Information needs can structurally be reduced by complexity reduction. For this, De Sitter (1994) offers an effective design framework for the diversification of primary processes. It reduces the complexity of relations with the environment and reduces the internal interdependencies. Looking for independent parallel market or production flows (streams) is the first step. Within these streams looking for segments of strongly coherent activity, is step 2. Both steps applied by designing computerization imply that each stream gets, ideal typically, its own computerization to deal with the variety and dynamics of that stream. Basic data, like customer info, are computerized and connected "under the water line" to provide overall management information; a data warehouse architecture can be used for this. "Above the water line" each process stream has its own options and progress of primary and supporting processes. Like an archipelago, islands are connected under the water line, and are disconnected above the water line. In practice an archipelago computerization (see Figure 3) can,

for instance, consist of five parallel, independent enterprise systems instead of having an all-embracing one. Moreover, the development of "enterprise apps" and other new information technologies make this "variety" approach all the more feasible.

Process standardization does still play a role in archipelago thinking as well. Data surpassing value streams are, in other words, shared which can be standardized in common processes. The advantages of technical standardization (like servers, databases, clouds, firewalls, email systems) are, of course, embraced.

A light version of an archipelago system can be, for instance, a menu card structure (Figure 4). Like in a cafeteria, a menu of an enterprise system is built around clear-cut, varied processes. The archipelago design of IT architecture can create the opportunity to provide specific production flow information to the employees and increase job control. This means that you do not have to provide more information than needed, which results in limited complexity for employees.

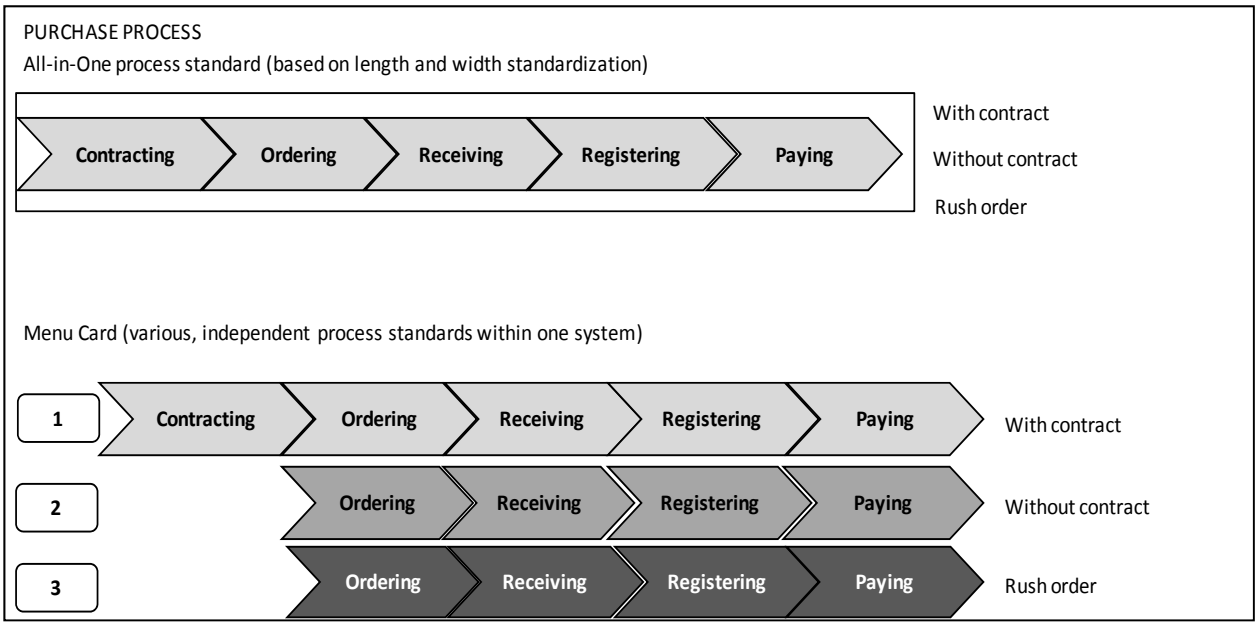

Figure 4. Archipelago light: the menu-card (Govers & Südmeier, 2016).

Conclusion

The Lowlands STS-D theory and practices have played an important role in designing the structure of humane and innovative workplaces in situations with a high variety in market demands. However, for workplace innovation, simply restructuring units, departments, tasks, and roles is not enough. In traditional, bureaucratic organisations, IT systems have hidden conservation mechanisms to keep the bureaucracy in place. Moreover, for workplace innovation, IT systems should be included in designing the workplace. With this paper we aimed at developing a more comprehensive design theory aimed at workplace innovation, by starting from sociotechnical design and by exploring how we can broaden that perspective with such as IT design. And also IT architecture designers can broaden their perspective with the Lowlands STS-D lens. As we primarily focussed on the design process in this paper, we did not discuss the importance of change strategies to achieve a STS design. Of course, change and design strategies should be approached from a mutual enforcing perspective.

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