Beyond Nolan's Nine-stage Model
Evolution and Value of the Information System of a Technical Office in a Furniture Factory

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Abstract: This paper reviews the evolution of information systems. Nolan's Model has been reviewed and a new Smart Era seems to be arising. The model has been used to analyse the development stages of a technical office's information system in a furniture factory. The necessarily changing business model in the company throughout the ages has been analysed from the perspective of the contribution of the technical office's information system to its main business process.

1 INTRODUCTION

Companies are constantly changing due to the strong competitiveness of the markets. Transformations in their organizational structures, in their business models, in their facilities or in simple or complex business processes have required in many cases the addition of information systems involved in each case. Companies have been incorporating new technologies, making greater use of them and performing different styles of management over time in order to maximize the value of investment in information systems (IS). Although this evolution of the information systems in the company has not always produced the expected results (Nijland, 2004) or has not used adequate tools and methodologies to successfully measure the IT value (van Wingerden, D., 2008).

This paper reviews the Information System evolution in organizations based on Nolan's nine-stage model (Nolan, 1992) (Mutsaers, 1998) to pass through three different Eras.

A case study of the evolution of the IS of a Technical Office in a furniture factory is presented. The fundamental role of these information systems covers from design to manufacturing, in order to achieve new products, efficient production and/or a flexible factory.

The paper is structured as follows; section two deal with the value of the IS for organizations and section three reviews the evolution of IS. Section four presents a new scenario that is emerging in a disruptive way: Industry 4.0. The case of the evolution of the IS in a technical office in a furniture Factory is included in section five. Finally, the conclusions are presented.

2 INFORMATION SYSTEM VALUE FOR ORGANIZATIONS

Renkema and Berghout (1997) define value as the sum of financial and non-financial consequences.
Benefits refer to all positive consequences of an IS investment and sacrifices to all negative consequences. Lucas (1999) includes in the Information Technology (IT) value all financial, non-financial, direct, indirect, tangible and intangible contributions from investments in IT, i.e. he takes into account financially quantifiable contributions but also other contributions perceptible by the user in the result of the processes to calculate the value of the IS.

So, IT benefits are indirect (Figure 1).

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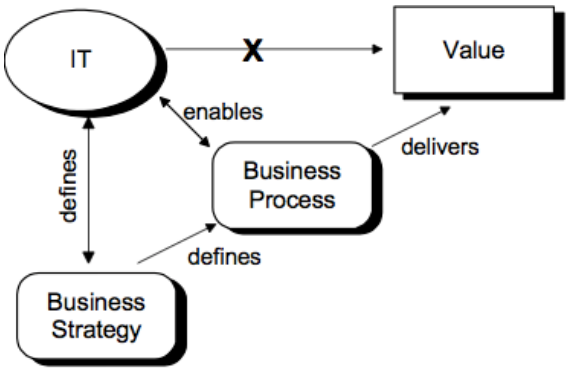

Figure 1: Explanation of the IT productivity paradox (Wigand, 1998 ; referenced by Teubner, 2005).

Henderson & Venkatraman (1993) in their "Strategic Alignment Model" present the influence of information systems on business and a proper alignment with business.

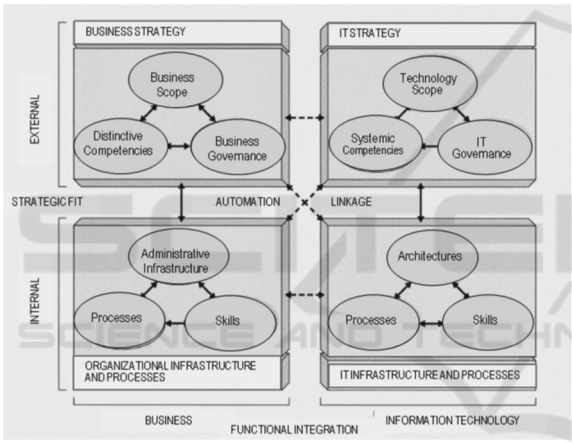

Figure 2: Strategic Alignment Model (Henderson and Venkatraman, 1993).

The Strategic Alignment Model (SAM) makes a distinction between the external perspective of IT (IT strategy) and the internal focus of IT (IT infrastructure and process). It is composed of four quadrants that consist of three components each. These 12 components define what each quadrant is as far as alignment is concerned. All the components working together determine the extent of alignment for the company being assessed (Henderson and Venkatraman, 1993; Papp, 2001; Sakka et al., 2010).

The four quadrants are (Henderson and Venkatraman, 1993):

- Business strategy at the external level of the business domain. It is structured by three components: business scope, business competencies and business governance.
- Organisational infrastructure and processes that form the internal level of the business area. This domain is composed of three components: administrative infrastructure, skills and business processes.
- IT strategy at the external level of the IT domain. It is structured by three components: technology scope, systemic competencies and IT governance.
- IT infrastructure and processes that form the internal level of the IT area. Likewise, it is formed by three components: IT architecture, IT skills and IT processes.

Nevertheless, as indicated above, the value is materialized through the business processes. Teubner (2005) represents it as shown in the following figure:

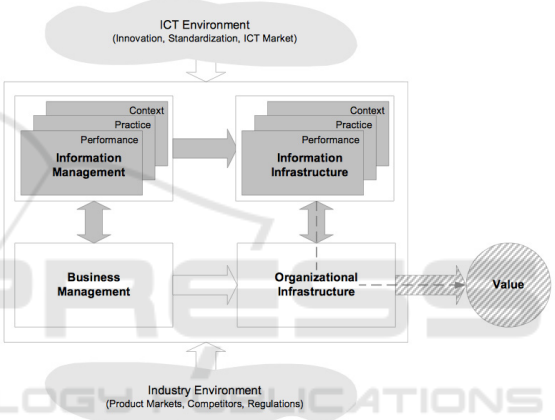

Figure 3: IT Productivity Framework – IT21 (Teubner, 2005).

A correct evolution in the ICT Environment aligned with the Industry Environment has brought value to the organization.

3 EVOLUTION OF THE INFORMATION SYSTEM IN THE ORGANIZATION

As technology advances, so does the role it plays in organizations.

Thorp (1998) presents the evolution of information systems with only three stages:

- Automation of Work. The emphasis is placed on operational efficiency, not on doing things differently.
- Information Management. IT was increasingly applied to provide information to support

improved decision making, to move it "closer to the customer" and to support new service and product design. Benefits moved beyond operational efficiency to operational and tactical effectiveness.

- Business Transformation. As more and more computing power is distributed, and as advanced communications capabilities continue to erase the constraints of time and distance, the very nature of businesses, and even entire industries, are being redefined. Benefits have moved beyond operational and tactical effectiveness to strategic effectiveness and positioning.

Nolan (1992) presents the evolution in three "Eras" with three stages in each Era (Mutsaers, 1998).

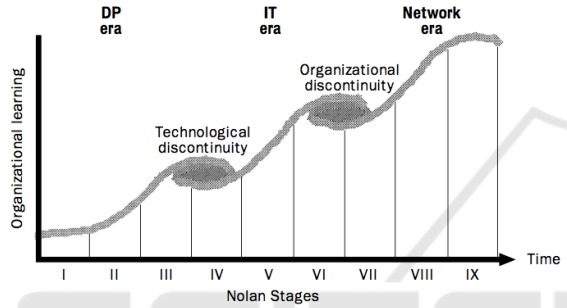

Figure 4: Nolan Stages (Mutsaers, 1998).

Data Processing (DP) Era : Management of the organization begins to pay attention to the phenomenon of automation.

Stages 1. Initiation: an organization becomes acquainted with automation. 2. Contagion: There is an increase in the need for other sorts of systems. 3. Control: Owing to the spread of automation throughout the organization and the failures encountered in this, there exists a need for control of the automation activities and emerging costs.

Information Technology (IT) Era: A breaking point appears because of a technological discontinuity. The business environment has changed enormously. In the IT era, companies are typically process-oriented, and separate business units are organised according to markets, product-lines or geographic areas.

This era includes the stages: 4. Integration: Companies use IT to enable new methods of doing business. Integration of applications and different technological platforms are key. Old systems must be replaced to facilitate integration. 5. Architecture: New system development activities are focused on achieving highly-strategic business objectives, such as integration with suppliers and customers. As a consequence, the involvement of top-management is increasing rapidly. 6. Demassing: Business unit management assumes full responsibility for the business strategy and the related deployment of IT. This leads to a shift in the application of IT, from a technological phenomenon, driven by IT experts, to a strategy-driven management resource.

Network Era: The increasing pressure from the business organisation for ever-more tailor-made functionality from information systems makes it necessary to create an applications portfolio that is both flexible and stable at the same time.

This Era includes the stages: 7. Functional Infraestructure: The focus was on integration of systems; now the name of the game is integration of flexible modules of functionality and network connectivity. 8. Tailored Growth: When the functional infrastructure is in place, including server-type of information systems, the focus will shift to the expansion of the functional support for users. 9. Rapid Reaction: The expansion stage is now over and the main activity is to adapt the functionality as the highly dynamic business teams change.

The transition from the DP to the IT Era is accompanied by a Technological discontinuity. From the IT to the network Era an Organisational discontinuity occurs. However, a new discontinuity arises for IS related to new technologies such as big data, cloud computing, wireless sensor networks or the Internet of things. In addition, this set of new proposals has been "tagged" for the industry as Industry 4.0.

4 INDUSTRY 4.0

The production system will have a new development with a higher level of automation of the production lines due to the new intelligent systems, with the ability to learn and make their own decisions. In the Industry 4.0, sensors, machines, workpieces and IT systems will be connected along the value chain beyond a single company (Rüßmann et al., 2015). Industry 4.0 promotes, among other things, autonomous decision-making, interoperability, agility, flexibility, efficiency and cost reductions. This is the reason by which many companies are aiming to implement the technologies and concepts related to "Industry 4.0". However, current research about "Industry 4.0" is diverse, limited and clearly insufficient regarding its implementation in operational levels of the production processes Herman et al. (2015) defines Industry 4.0 as a

collective term for technologies and concepts of value chain organization". This new paradigm seems to mark the future roadmap, leading to the fourth industrial revolution (Erol et al., 2016).

According to Gilchrist (2016), the Industrial Internet (Industry 4.0) is a coming together of several key technologies in order to produce a system greater than the sum of its parts. The Industrial Internet provides a way to get better visibility and insight into the company's operations and assets through integration of machine sensors, middleware, software, and backend cloud compute and storage systems. Therefore, it provides a method of transforming business operational processes by using as feedback the results gained from interrogating large data sets through advanced analytics. Four Main Characteristics of Industry 4.0 are: i) 1. Vertical integration of smart production systems ii) Horizontal integration through global value chain networks iii)Through-engineering across the entire value chain and iv) Acceleration of manufacturing.

Perez et al. (2017) identified eight main different features of the term "Industry 4.0": Virtualization, Interoperability, Automatization, Real-time availability, Flexibility, Service Orientation and Energy efficiency. These features are being supported by these technologies/concepts: Cyber-Physical Systems (CPS), Internet of Things/Services (IoT/IoS), Smart Data and Smart Factory.

The value of Industry 4.0 has been approached by Schuh (2014) not only on its impact on production processes but also on indirect departments by deriving individual activities which lead to a growth in productivity and therefore competitiveness.

All this leads us to think that it seems necessary to define a new Era beyond those already defined by Nolan. That new Era could be called the Smart Era and should be associated with the new functionalities, technologies and concepts exposed previously.

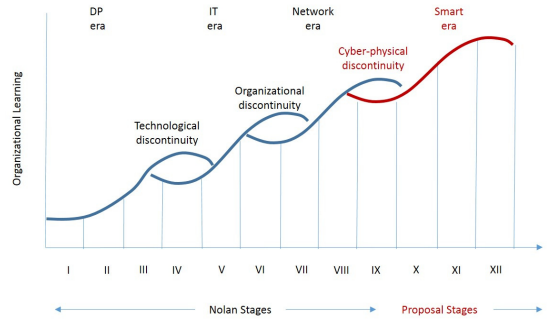

Figure 5: Extended Nolan Model.

5 CASE STUDY: NOLAN'S ERAS IN THE INFORMATION SYSTEM OF A TECHNICAL OFFICE IN A FURNITURE FACTORY

5.1 Context

5.1.1 Furniture Sector

The furniture market has traditionally been very cyclical and is sensitive to the economic conjuncture. Indeed, the furniture industry has been one of the most severely hit by the recent economic downturn in Europe. After a peak in 2007, total industry production has decreased by more than 14% and total sector employment decreased by 20% between 2007 and 2011. This has accelerated an underlying restructuring process common to other low-tech industries (such as clothing and textiles). Nowadays one strength in this sector is "the advance in furniture production technology" and an opportunity is " the growing demand for high technology and knowledge intensive jobs" so information systems and information technology are crucial in this new environment. (EU commission, 2014).

5.1.2 Technical Offices in Furniture Industries

Technical offices in the furniture industry sector (and indeed its Information Systems) are functionally interrelated to the commercial and purchasing departments, and mainly to the production area.

In addition, as part of an organization that is immersed in an unstable and changing sector environment, its activity needs to be able to adapt to new business models, new markets and forms of production, new technologies and machinery, new products and customers; so that the organization can maintain high levels of productivity and profitability to stay in this competitive market.

Decisions about new product production and the required changes (or incorporation) in infrastructure are important not only for a possible growth of its market share, but also for the continuity of the business, because an important part of the success depends on a suitable implementation of these decisions. In this sense, continuous develop of its information system and a successful investment in

new IT solutions are also crucial to optimize this area of the company.

In this case study, the factory manufactures bathroom furniture and the technical office is in charge of different services to: i) ensure a proper use of the resources and information systems of the factory used for production. ii) ensure the security and reliability of the systems, iii) capture orders, design products, define technical information, produce computer files for CNC (Computer Numeric Control) machines and optimize production.

The quality strategy of this technical office is summarized in the following sentence: " providing our internal users with services and data that satisfy their needs and expectations, designing, implementing and executing reliable processes". The main areas under this technical office are shown in the following figure:

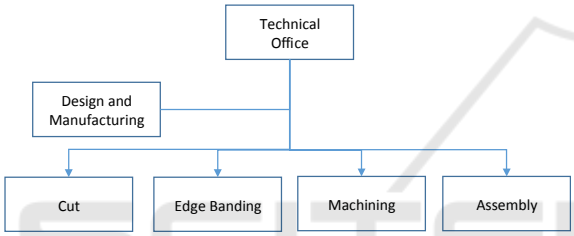

Figure 6: Main areas under this technical office.

5.2 Value Provided by the Technical Office's Information System

As discussed above, it is difficult to attribute the financial performance of the productivity for the IS in the technical office because this performance is also a consequence (and subject to the influence) of other factors, such as the management of the production or other CEO decisions. The IS of the technical office, by itself, cannot be evaluated in isolation but it can be evaluated in combination with other processes within the context of the production area.

The evolution over the years of the IS in this technical office has involved an increase in investment in hardware, software and user training. As IS for the technical office have become more advanced, the level of exigency in the use of it, generally associated with its inherent high technology, has also been more sophisticated. Thus, over the last few years, the ways in which these IS can add value to the organizations have risen to become essential to increase the benefit of the organization.

5.3 Evolution of the Information System

The three Eras defined by Nolan are presented in relation to the evolution of the technical office in the company studied. The Parts Processing Era, the Batch Manufacturing Era and the Mass Customization Era are shown respectively associated with the DP Era, IT Era and Network Era.

5.3.1 Part Processing Era - Data Process Era

This era started with the first years of existence of the factory. This was a period in which, once acquired the means of production that allow the automation of processes, the unique objective was improving the *efficiency* that this production automation entails. This did not imply changes in the traditional functional hierarchy of the organization.

1st Stage: Initiation. At this stage, the focus was on reducing costs and improving ratios and scale factors thanks to the automation of the production processes supported by the technical office. It had a merely operational point of view.

2nd Stage: Contagion. The operation of Information Systems focused on the satisfaction of the users because of the reliability of the work processes associated with the information received. The top management of the company had, at this stage, little control over the investment made not only at the production machinery level, but also in the hardware, software, and training of technical office personnel. Investments in highly specific IS were not formally justified.

3rd Stage: Control. It is inevitable that failures will occur during the contagion stage. Errors made by the technical office related to data automation posed an undesirable risk. Due to the IS costs, senior management, through the administrative departments, wanted to exercise greater control over investments in IS. The Information Systems plan became one of the control instruments used.

5.3.2 Batch Manufacturing Era - Information Technology Era

A technological discontinuity appears with the new software for the optimization of cutting boards, imbrication of pieces for their milling and a generation of programs of CNC. Internally, the new focus of the Technical Office is oriented towards the

effectiveness (once the stage of mere automation had been passed).

Step 4: *Integration*. The adoption of a new business model in the company under study implied, firstly, the acquisition of a new manufacturing line to include intermediate stock of parts produced in optimal batches, and secondly, an important integration of existing applications into the new production process. Information Systems were acquired to achieve the objectives and not only to reduce costs.

5th Stage: *Architecture*. The data, so far dispersed in different applications were considered at this stage as a critical resource. It is crucial to develop a corporate data production architecture fully integrated with the rest of the organization. Production management increasingly involving Information Systems, were increasingly integrated with the production processes.

6th Stage: *Demassing*. The Technical Office assumed greater control of the company's production processes and the IS related with the technical office activities.

5.3.3 Mass Customization Era – Network Era

The increasing pressure for competence and the market conditions due to the economic crisis in the last years have forced a new change in the organization: Mass Customization. Specifically, the technical office faced the challenge of a mass customization production according to customer preferences. The technical office was managed as a vital *strategic* resource for the company.

7th Stage: *Functional infrastructure*. The interconnection with other business units of the organization was strengthened. In particular, the connection with the commercial area information system was improved.

8th Stage: *Tailored* Growth . The new context implied a demand of request. Users of new applications implanted by the technical office to support the organizational changes required new functionalities.

9th Stage: *Rapid reaction*. The new functionalities available are used to adapt quickly to the new business context: the new customized demand of the clients, and the changed production system. The technical office, equipped with flexible and configurable information systems, can create and adapt orders, make launches to production with different criteria, according to the guidelines imposed by the organization.

5.3.4 Smart Era

New technologies are knocking at the door of technical offices. In the case of this company in the furniture sector i) the creation of prediction models using information collected plant WSN and exploiting the information using big data, ii) Intelligent use of RFID technologies iii) Advanced CAD / CAM systems.

These new technologies offer new insights and value to the company. We can talk about a new Era and new stages in near future. These stages can be incorporated into Nolan's model. The following table summarises the three Eras defined by Nolan and their relation to the evolution of the technical office in the company studied. The new Smart Era and the new stages proposed have also been incorporated.

6 CONCLUSIONS

Organizations have invested progressively in improving their information systems. The result of such investments (as value for the organization) is difficult to identify due to the influence of other aspects in the organization. In addition, another handicap is that this value is materialized indirectly through the organizational infrastructure and specifically by its business processes.

Despite these difficulties, organizations have continued to invest in information systems and these systems have evolved over time.

Nolan's 9-stage model is a classic in describing such evolution. The 9 stages are grouped in three Eras: Data Processing Era, Information Technology Era, and finally, the Network Era. However, a new discontinuity point seems to be arising with the arrival of new proposals like big data, cloud computing, the internet of things or the general term Industry 4.0. This new era could be named the Smart Era.

We have analysed these aspects for a technical office in a furniture Factory.

The value of the investments in information systems in this office cannot be evaluated in isolation, since this is mainly conditioned by the influence of the productive area.

The evolution of the Information System of the Technical Office has been associated with changes in its production context, in particular *Part Processing – Data Processing Era*, *Batch Manufacturing - Information Technology Era*, and *Mass Customization – Network Era*

Table 1: Beyond Nolan's nine-stage Model.

	PRODUCTION SYSTEM EVOLUTION AND STAGES IN THE CASE STUDY			
INFORMATION SYSTEMS EVOLUTION	Production system	Objective	Stage	Description of the stage meaning at the company
Data Processing Era	Part Processing	Efficiency	1	Focus on reducing costs and improving ratios and scale factors
			2	Little control over the investment
			3	Information systems became as a control instrument
Information Technology Era	Batch Manufacturing	Effectiveness	4	New business model IS help to achieve the objectives
			5	Data considered as a critical resource
			6	The technical office increase the control over the production system and the information system
Network Era	Mass Customization	Strategic alignment	7	Technical office Increase collaboration with other areas of the company
			8	Request of work to manage new requirements
			9	Quick response to needs
Smart Era	Intelligent Manufacturing	Visibility, transparency and intelligence	10	Seamless communication between IS and business (all the areas and partners in the company)
			11	*Self*-competences (including self-estimation, self-assessment and self- adaptation)
			12	Accurately and immediate decisions

This evolution has been key i) to automating manufacturing processes; ii) for the optimal management of the information from the tactical point of view (efficacy and efficiency of the processes); and iii) to transform the business adapting it to the new business models of the company. In addition a wave of new technological proposals are arriving as precursor of a new Smart Era.

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