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The Collaborative Work Concept and the Information Systems Support Perspectives for and from Manufacturing Industry¹

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Most of the discussion and controversy on organisation of work concepts has been referenced to the manufacturing industry along the 20th century: it started with the concept of “scientific management” from Taylor, and continued with the new ideas on the importance of human factors as Mayo pointed out in the 1930s. Immediately after the 2nd World War Friedmann studied the human problems related to new manufacturing technologies and automation. And the late 1950 and 1960s were decades of strong debate on the socio-technics with the research at Tavistock Institute of London and the emergence of national programmes on new forms of work organisation. At the end of the last century the concept of collaborative work was developed together with the definition(s) of information systems and organisational design. However, the interest came from other production activities, like the services. This article analyses the approaches developed on these debates on the collaborative work and information system and its application to the manufacturing industry.

1 Introduction

There are newly emerging disciplines such as Computer Supported Cooperative Work that integrates the concepts of “collaborative work” and “information systems”. In principle, such conceptual relation and the relevant methods deal with the development of information systems to support the strategy towards implementation of cooperative work. This means information sharing, qualifications and competences development, more democratic power relations, higher quality content of jobs, and so forth. However, this article tries to draw the attention to the fact that manufacturing is usually taken as an “old-fashioned” case to discuss the organisational change processes that imply participative

features and complex information and work systems. On the contrary, one can argue that most of the concepts on services design, enterprise architectures or decisional value systems, can also be applied to the manufacturing industries. This becomes particularly apparent as work (re-)structuring appears as a (social) process in the emerging globalised value chains.

The central idea of this concept of collaborative work design and information systems support is that the design of work must be focused on the relationships between the virtual organisation and the social actors. This means an existing complex relation between humans (at operating levels) and equipment (mostly information and communication technologies). In general, the complex working systems are not designed in a sequential process (as in the Tayloristic system). Adding to this issue, the research on individuals-machine interfacing draws on established and emerging theories of individual capabilities or on the various features which give individuals their “capacity to act” (either with others, or with equipment) in a particular situation. Some studies even have a more in depth scope on complex environments (especially with ICT – information and communication technologies) or on resilient situations (risk, quasi-accidents). In this sense, the information systems design must always be integrated in a strategy of work organisation design (at the company level) and depends on the industrial policy at the regional, sectoral or national levels. Such information systems are not autonomous entities or have just a technological dimension.

2 Discussing Concepts

This change on the landscape of manufacturing structure implies a new insight on the concepts that usually are applied to the discussion on this industrial sector. Until today, most studies on organisational changes in industry came mainly from sociology or management sciences. From 1980s several studies from social psychology or political sciences have also emerged on this issue. But, more recently, there is a strong debate over these issues in the fields of computer engineering (more than in social sciences).

2.1 Systemic Innovation and “Living Labs”

Some of the application experiments in the manufacturing industry are still, however, worthy to optimize. In this sense, multidisciplinary basic research must interact with technology and applied research in real environments. Those environments should foster systemic innovation with verification and trials, in so called “living labs”. Such systemic innovation is the one where behavioural innovation takes place with new product and process implementation. Where can one find such “living labs”? Where can innovation environments take place? In reality, most of the experiments and examples came from the manufacturing industry, either in the metal industry (automotive, airplane and space industries), or biotechnology, telecommunications, clothing and fashion, electronics and new renewable energy systems. One can find other sectors and industries as well, but manufacturing in particular can offer sufficient case studies and some best practices on these issues.

At the same time, a large quantity of empirical studies has been published on the topic of relation between organizational models and information system architectures. Most of those studies are concerned with the analysis of how tools and technologies feature in social action and interaction in organizational settings. As Heath and others comment, such “studies serve as a foundation with which to consider how artefacts, ranging from seemingly mundane tools such as pen and paper, through to highly complex systems, feature in the production and co-ordination of social actions and activities” (Heath et al. 2000, p. 306).

This issue is still not very clear, and lacks further theoretical analysis. Thus, although said that “one of the main weaknesses in this area is the lack of appropriate formal modelling methods and theories to define the collaborative, networked organizations paradigm” (Matos, Abreu 2003), there is a clear evidence about the difficulties that computer science experts have about methods and theories on organizations and social behaviours. When these concepts are under discussion in the social sciences, the formal modelling of such relations of concepts is still very limited. This means that the above-mentioned “multidisciplinary basic research”

should be a reality and not just a manifestation of interests or principles.

Heath and others also mentioned that “whilst drawing on analytic and methodological developments in sociology, and in large parts undertaken by sociologists, these workplace studies have emerged in the light of debates within disciplines such as Human Computer Interaction (HCI) and Artificial Intelligence (AI) rather than sociology *per se*” (Heath et al. 2000, p. 300). But many concepts issued from the work organization analysis, are connected with other concepts such as motivation, alienation, satisfaction, productivity, innovation, flexibility and business processes, learning organizations, networks and virtual enterprises.

2.2 A Number of Lacks and Some Research Activities

As Ennals and Gustavsen acknowledge, “at one level of analysis, hindrances can be identified as a lack of ability to incorporate the development of new forms or work organization into the agenda of the main social partners; a lack of willingness at the enterprise level to learn from each other and take ‘good examples’ to heart; a lack of supportive public policies, and the like. As the list grows longer, it grows, at the same time, more complex” (Ennals, Gustavsen 1999, pp. 3-4). Nevertheless, some research activities have taken place on these topics. For example, since the 5th EU Framework Programme, that is to say only from 1999 onwards, new projects have been supported to develop some specific concepts and ideas, like “participatory technology assessment”, “work process knowledge”, learning organizations, collaborative knowledge modelling, or “virtual organisations”, among others.

For instance, another term like “distributed cognition” is increasingly used to demarcate a concern with (socially) shared representations and the co-ordination of action by individuals in organizational environments (Heath et al. 2000, p. 306). At the European Commission level, “Collaboration@Work” is the name given by the New Working Environments Unit to the next generation collaborative working environments, comprising innovative technical solutions as well as socioeconomic and policy-related aspects. It aims at improving human

abilities to work collaboratively, thereby increasing creativity that, in turn, will boost innovation and productivity as well as support new value creation forms.

In fact, within the framework of research activities at the European level on the concept of new working environments, considerable attention is being given to the challenges of the increased competencies of people working together. This attention does not come only after 2000 with the so-called “Lisbon Strategy” but from decades earlier, for example, with the activities at the FAST unit of DG Research. This unit on ‘forecasting and assessment on science and technology’ assumed as research field the “anthropocentric production systems”, and paved the ground for new networks and research projects. In particular, that happened within some of the first ESPRIT projects (specially the ESPRIT 1217/1199 project on “Human-centred CIM Systems” that was pioneering the organised research at the EC level on these issues).²

This new enterprise approach implied the involvement of people at both the engineering level (technicians, product developers, designers) and the operational level (working groups, operators, shop floor stewards, quality controllers). It implied also a new research endeavour at the levels of multi-disciplinary research teams (as sociologists, psychologists, ergonomists, computer scientists, information systems developers, mechanical engineers and others).

In fact, the interest on this issue has become increasingly political. In April 1997 the European Commission published its Green Paper on “Partnership for a New Organisation of Work” (European Commission 1997). As Brödner and Latniak mention, “it did not really produce a signal for departures to new frontiers; it was rather turned down instead during public debates that followed. In the time after, a Communication Paper entitled ‘Modernising the Organisation of Work – a Positive Approach to Change’ (European Commission 1998) was issued in November 1998, and in March 1999 the European Work Organisation Network (EWON) has been established. These initiatives signalled the weight the Commission assigned to the theme. Yet, their impact on the further development of new forms of work organization has been rather low so far, although the Network appears to be necessary and helpful for improv-

ing the knowledge base across the member states, for exchanging experiences, and for raising public awareness for work organisation issues” (Brödner, Latniak 2002, p. 7).

2.3 Working in Common Projects: No Reflected Understanding

One can agree with some authors that these substantive developments, both technical and social, are also serving to render more traditional technocratic models of human-computer interaction problematic, and are directing attention towards the social, interactional, and contingent aspects (Heath et al. 2000, p. 303). Many such theories are grounded in practice within organisational psychology, industrial sociology and human resource management, though they continue to evolve, as we understand better the various mechanisms that make up the knowledge process and the construction of competences (either social, or occupational). What is less well studied, and perhaps surprisingly so, is what exactly individuals do when they come together to work on common projects. These projects can be understood as from the highly-qualified projects (engineering, scientific, artistic, technical) to the most common working tasks in the same organisation (in the same working groups, or in different tasks).

There are few, if any, robust conceptual models of “collective intelligence”. There is also little documented evidence of observation or cases of working practices in the organisational environments in which people work together. A better understanding of the ways individual and collective capabilities are combined to deliver “capacity to act” is central to the challenge of delivering higher productivity and better, more effective and widespread value creation in the working environment.

This issue can come to be more difficult to be analysed when this capacity to act is also determined or strongly influenced by the ICT. The concept of human-computer interaction deals also with this dimension. Studies of the use of computers are largely experimental and driven by a concern with developing cognitive models of the users’ activities. “Underlying the analysis is the idea that human action is governed by rules, scripts and plans, and that through manipulation of symbols and the de-

velopment of representations, individuals are able to execute intelligent action and interaction” (Heath et al. 2000, p. 302).

2.4 Ambiguity and Not Linearity of Procedures

At the level of relations among organizations, the information systems analysis in networks of manufacturing companies can be understood as socio-technological networks. These networks reflect more complexity characterised by ambiguity and not linearity of procedures that supports the capacity to act or decide in such organisations. This non-linear type of procedures is strictly necessary in heterogeneous engineering processes (quality control, production management). And it embraces factors so different as the technological, social, economical, and the political ones. The main aim of such decision processes is to find solutions to problems. In manufacturing such problems rise from the networking relations of organisations (supply organisations, clients, sub-contractors, outsourced units, equipment providers, market experts, technology support centres).

At the same time, it’s been suggested that the decomposition of vertically integrated firms is leading to ‘hybrid organizational forms’. Such forms imply an increasing necessity for organizations to become more flexible and responsive to a constantly shifting and unpredictable market. That is why many studies are suggesting a convergence between technological innovation and organizational change, underlying the fact that complex systems and technological infrastructures will emerge to interweave telecommunications and computing to support and enhance new forms of co-operation, collaboration and work organisation.

On the European level, the interest in such issues is also increasing. In 2004, the Collaboration@Work Expert group (CWEG) meeting was held which drew up the “Next Generation Collaborative Working Environments” report. The latter includes a list of nine main issues that will have to be tackled in order to realize the vision of “Next Generation Collaborative Working Environments” (NGCWE) delivering quality of experience to co-workers, based on flexible services components and customized to different communities”.³ These nine issues,

as well as the related research and development challenges, are the following:

1. Reference architecture for collaboration at work.
2. Ontologies for collaboration at work.
3. Plug&Play interoperable service oriented architecture for collaboration at work.
4. Smooth “upper layer” middleware interaction with the underlying layers.
5. Interaction among peers (workers, systems, robots).
6. Utility-like computing capacity and connectivity.
7. Contextualization and content.
8. Group-level security, privacy and trust.
9. Mobility at work.

Regarding the reference architecture for collaboration at work, one can point out the reference architectures defined by consensus creation. The most important challenge is to agree on common reference architecture that enables the development of re-usable and interoperable service and application components for collaboration at work. Thus, the distributed collaborative working environments need a semantic description of the preferences of the users, the relevant computing components and the collaboration acts and processes. It will allow the matching amongst the required capabilities for a specific task and the available services. It will also identify the most adequate interaction given an actual context. It should improve modelling languages and models to consider the complexity of distributed groups of workers. In this sense, the development of ontologies for semantic compatibility or for specific domains, must yet to be developed.

The web services and ontologies can enable interoperability among services that should allow automatic composition of services to adapt to dynamically changing environments. The current infrastructure for more ubiquitous, secure and reliable software based collaboration at work services is yet to be improved. New mechanisms and methods for collaboration at work service composition should also be created.

In this process, one can investigate the usage of new collaboration at work services using communication systems. This can also improve the way to get network information related to quality of service, security, multicast, and loca-

tion for groups of workers. In other words, this should incorporate mediation algorithms to manage complexity and interworking with sensor or mobile networks of workers. This would be interesting especially in the above-mentioned network of organisations in the manufacturing industry. The proposition would be to create overlay networks which integrate network services with content services in order to adapt the collaboration services to the available network capabilities and the context of the co-worker.

Problems such as scalability, routing, replication, discovery of peers, resources and services, management of shared control and data among entities, must be resolved. The concepts of “virtual enterprise” or “simultaneous engineering” process, are dealing with such problems critically. Peer to peer systems (P2P systems) allow distributed resources to perform distributed collaborative work tasks based on dynamic discovery of peers and may use software agents or “overlay networks“, which seems to be the most adequate solution for distributed environments. The main difficulty is to implement P2P systems for collaboration at work with no central authority. Another difficulty comes with a new privacy and security paradigm within teams.⁴

2.5 Dynamic and Frequently Unpredicted Environments

Workers in manufacturing industry will also need computing resources, as well as connectivity to carry out their tasks. In recent years, some studies are being developed on algorithms for on-demand of resources for allocation to workers with requested quality and security. In some cases this means the integration of mobility and wireless sensor technologies with advanced network services, grid technologies and data centres to provide ‘always on‘ connection to co-workers. Such situation, although not so frequent, can occur in supply-provider relations or on cases where the space features can be important (different locations of working teams in the same organization, relation among different teams from different organisations, and so forth).

Workers in manufacturing industry are faced with dynamic and frequently unpredicted environments, and they will need systems to

complement human ability to act in a context of incomplete information derived from ongoing tasks, processes, communication, co-operation, etc. Specific algorithms (machine learning technologies) can infer meaning from unstructured content using statistical methods that derive patterns. Nevertheless, the convergence of work and private environments raise concerns on security and privacy issues. Enabling collaboration at work middleware will include means to secure business information while protecting private data and will support digital identity, peer authentication, integrity or even encryption. Some of the challenges for research and development are the inclusion of authorization infrastructures and new mechanisms for delegation within and among working teams.

The mobility management of workers (access devices, identity and location of people) is also a new research challenge. In addition, the concept of collaborative distributed environments (next generation of signalling protocols) has also emerged. Thus, one of the problems is the integration of signalling protocols and P2P as well as the generation of agent-based ontologies for collaborative mobile working environments. Such challenges are mostly related with the tele-work form of organising the tasks.

In this context, the sociological competencies (like group awareness, structures and data collection and analysis tools) are becoming a demanding challenge to engineering professionals, towards a better and faster integration in multidisciplinary teams. This integrated approach to system design will allow organisations to be structured in a “strategic intelligence” direction as well as a better understanding and development of concepts such as simultaneous engineering, converging engineering and flexible production (Moniz, 2002).

As Sampaio underlines, the “cooperative design” consists in the participation of future users of complex working systems during the whole design phase. One assumes that the operational people have normally a great difficulty in describing their own tasks, mainly when some kind of modeling needs to be established. In this perspective, the concept of cooperative design means that Human-Machine Interaction (or Human-Computer Interaction) can no longer be reduced to determinisms, as modern working contexts integrate a large number of human and

technological agents. Sampaio also suggests that this cooperation represents a decisive step to understand HCI from another perspective where human nature is considered as a constraint to systemic development and, on that perspective, solvable by technological means, like any other operational problem (Sampaio 2005).

3 Some R&D Projects

To face such issues and research topics, the EC Framework programmes tried to organise projects, networks and technology platforms with related working programs. A strategic objective of the 6th EU Framework Programme for Research and Technological Development (2002-2006) designed under the Information Society Technologies (IST) programme focused on three layered tasks following a systemic approach. The first task was centred on the design and development of innovative concepts, methods and core services for distributed collaboration at work. The second task supported the research on tools for collaborative work in rich virtualised environments. The upper focal point developed some innovative validating applications for collaborative work in content-rich, mobile and fixed collaborative environments. It was testing and integrating the core services and tools developed in the previous focal points.

Examples of responses to such challenges can be taken from those mentioned research projects. However, not so many projects were developed (or are being developed) in Europe about topics related to team working or collaborative work. Nevertheless, some efforts could be mentioned. Such is the programme on “Humanization of Work” in Germany (in the 1980s), and ANACT in France, as well as the position paper of the Commission on the “Partnership for a New Organization of Work”.⁵ In fact, several national programmes were organised to support these experiences. But it seems that was not sufficiently extensive, or with enough resources and compromise that could enlarge the frame of involvement.

In the 5th Framework Programme (1998-2001), some projects focused on the engineering domain combining the dynamical simulation tools, the formal documentation and informal rationale to closely integrate working, learning, collaboration and negotiation, within and be-

tween organisations.⁶ These projects involved the extension and integration of work on agents, on knowledge modelling, on document discourse tools, on simulation and on machine learning. But they were also to acknowledge the re-use within organisations in order to enhance productivity and support innovation. Other projects⁷ were supporting worldwide manufacturing networks and co-operation, especially between SMEs in rapidly changing working environments. The required high level of expert knowledge at the SMEs today hinders the application of industrial robots by SMEs. This knowledge has to be available either among engineering groups or among operators. As a result, robots are often not optimally applied and the SMEs do not benefit clearly from applying robots.

Other projects were undertaken in the Strategic Objective 'Applications and Services for the Mobile user and Worker' of the IST FP6 programme, supporting mobile workers who are part of networked organisations in their day-to-day work environments in distributed and location-sensitive settings (healthcare, manufacturing engineering, and rural and regional work environments)⁸. Others focus on virtual reality technology that has now being used in industrial applications.⁹ A third type envisage making a virtual work environment controllable by ordinary people and can have both global technological and societal impacts (self-awareness, support for automatic configuration arrangement of devices, services, and local connectivity in the user's local environment).¹⁰

In spite of these few European projects, other international research activities are also taking place on this issue: the IEEE Symposia on Human-Centric Computing Languages and Environments (HCC) since 2001¹¹, the yearly International Conference on Network-Based Information Systems (from 2004), the activities of the US Human Computer Interaction and Information Management Program¹² under the National Coordination Office for Networking and Information Technology Research and Development¹³, and the Japanese national programme on Improvement of Competitiveness and Problem Solving Skills of Industry & Government through IT (METI)¹⁴ or the Information Processing Society of Japan activities on Groupware¹⁵.

It is clear that several research activities are taking ground, either on conceptual level or experimental one. But recent approaches to shop floor control are mostly based on the idea of independent autonomous nodes (abstracting resources, tasks, humans, etc) that interact with each other regarding the achievement of local goals from which emerges the global expected behaviour. This "requires sophisticated software platforms and devices that are able to implement the advanced control concepts and metaphors of the new approaches. Amid the existing architectures multi-agent and service oriented are promising ones to support new control architectures" (Ribeiro, Barata 2006).

However, at this stage it is difficult to achieve once the typical industrial applications run on programmable logic controllers (PLCs) that do not support high level programming languages and concepts. Thus, new concepts of devices are emerging. Some focus only on the programmable automation controller (PAC)¹⁶ as a mix between a classical PLC and an industrial PC. Normally new approaches to control tend to abstract humans as agents. In practical terms this means that there will be agents acting on behalf of shop floor workers. Since agents are pieces of software, a properly designed agent can ease workers tasks. Routine complex tasks can therefore run almost automatically being performed by agents commanded by under-specialized workers.

During the 1970s and 1980s, the controversies were connected with the problems of work organisation and working conditions in order to improve the productivity level through the working live components. In other words, the competitiveness of firms could be achieved through the improvement of working conditions and better labour relations. Actually, the emphasis lays on the management and business processes and the technological platforms to support the competitive strategies. But the focus on the shop floor individuals and working team building is much less clear. In the 5th Framework Programme of the EU, some new concepts were developed such as "participatory technology assessment", "work process knowledge", learning organisations, collaborative knowledge modelling, and "virtual organisations", among others. In the 6th Framework Programme the mainstream concepts are the level of virtual

multimodal processes, simulation tools, collaborative work environments, or standard settings. Thus, when compared with the previous programmes in earlier decades, the concepts are clearly changing and moving towards new concepts.

4 Conclusions

The simpler working systems have specifications, production and integration phases that succeed in time and space on a chronological and foreseeable way. This is typical for the Tayloristic systems. The more complex ones are rather a recursive process. This means that a feedback is fundamental to meet the needs of the end-user in each of the design phases. In manufacturing, such processes are being developed as the client-supplier networks have evolved, as value chains become more complex, and the delivery times (or time-to-market) become more critical – not only for the managerial structures, but also at the operational levels.

As mentioned above, the existing complex relation between humans and the equipment emerges in the discussions on the role of workers in the decision process. The most important conclusions in such process deal with the fact that the Tayloristic division of labour cannot encompass the individuals' "capacity to act" in manufacturing environments. This can be more evident when such environments are using intensively ICT-information and communication technologies (in CNC machine tools, robotic cells, FMS). Or even in those environments with resilient situations (such as risky working conditions in construction, energy plants, or with large industrial equipments, or even in chemical industry plants or with aggressive environments).

Adding to this, the lowering labour costs are seen as management solutions in the same path of technological sophistication and quality increase. This is clearly a dangerous step towards competitiveness and modernisation. Other options and alternatives that aggregate the possibilities of quality of working life improvement with the emergence of virtual organisation concepts also exist. The latter also include technology, quality, and competition in parallel with qualification, productivity and stable work relations. In this sense, the infor-

mation systems design must always be integrated in a strategy of work organisation design and not the other way round.

Notes

- 1) With the support from CodeWork@VO project, financed by the Portuguese Ministry of Science and Technology (FCT-MCTES POCTI/GES/49202/02). The author wants to acknowledge and thank the important suggestions made by Bettina Krings and Peter Hocke. The responsibility for the final result lays only with the author.
- 2) Cf. Nichols and Jones, 1994; Laessoe, Rasmussen 1989; Bruns 2000.
- 3) Collaboration@Work Expert group. Report on Next Generation Collaborative Working Environments. June 2004. To be found on: <http://www.amiatwork.com/publications>
- 4) This is related to P2P connectivity and Internet Protocol Version 6 features that allow communication between all devices and machines used by the team members.
- 5) Developed by the European Commission DG-V.
- 6) For example, the CLOCKWORK project (Creating Learning Organisations with Contextualised Knowledge-Rich Work Artefacts) supported by the IST program. The objective was to support the knowledge sharing within distributed groups to promote reflection and improve work practices. Also, it can be mentioned the COCONET project that focuses on exploring a new type of collaboration environment that is person-centred through the use of context-awareness, knowledge support, and personalisation services.
- 7) The SCOOP project (IST 2520, from 2000) aimed to develop co-operation in dynamic SME networks based on planning and control collaboration systems.
- 8) The project MOSAIC is supporting efficient, intuitive, user-oriented and "human-centric" work environments where technology is aligned to organisations and human behaviour, enabling people to work together irrespective of constraints in location and time.
- 9) Like the INTUITION project (IST 50724) that tries to analyse the virtual environments in industrial processes and assess the impact of its penetration into the workplace and everyday life in terms of cost-effectiveness, health hazards and side effects on the users and its impact on the actual working environment, on an individual and at organisational level.
- 10) The project MobiLife (IST 511607, that started in 2004) which addresses problems related to different end-user devices, available networks, interaction modes, applications and services.

- 11) From 1984 until 2000 was called IEEE Symposium on Visual Languages (VL)
- 12) cf. <http://www.nitrd.gov/subcommittee/hciim.php>
- 13) In this national coordination several US Agencies, as the DARPA-Defense Advanced Research Projects Agency, the EPA- Environmental Protection Agency, the NASA-National Aeronautics and Space Administration, the NIST-National Institute of Standards and Technology, and the NSF-National Science Foundation, among others, collaborate (cf. <http://www.nitrd.gov/subcommittee/agency-web-sites.html>).
- 14) cf. <http://www.meti.go.jp/english/information/data/IT-policy/it-users.htm>
- 15) cf. <http://www.ipsj.or.jp/sig/gw/index-e.html>
- 16) This acronym is being used simultaneously by PLC vendors to designate their high-end systems and by PC control companies in an effort to sell intelligent devices in a language fit for industrialists.

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