Centres of Control for Industry, Business and Government

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***Abstract*- In recent years the concept of 'control rooms' has changed tremendously. As their roles and functions have expanded, it is often more appropriate to talk about control centres. A modern approach for considering work in control centres uses recent concepts of creativity and learning/developing environments. Today, process control encompasses a new generation of computer systems which have enormous capabilities but which tend only to be actively used for a small proportion of their operating time. This surplus capacity can be used for simulations to support decision-making and operational learning, and also for development of processes and technology. In other words advanced IT have today a potential of being, to a very large extent, integrated and interrelated with human factors, organizational and technological development. Primarily, the main function of a control centres is to fulfil its main objectives and missions, e.g. in relation to safety and productivity. Obviously this will also be so in the future. Monitoring and supervising all relevant prime and secondary functions were in the past the total dominating part of the work in a control room. But to an increasing extent the control centre supports the development of the operators' skill and knowledge and also the development of the process as such and the people-technology organisation. The operators will in this way be better prepared for, and also more able to anticipate, early warnings of disturbances in the system. In other words the operators will not only react to incoming and displayed data, signals and alarms but they are also able to anticipate and predict critical situations. They will fulfil an important role in managing and reducing economic, human and environmental risks. Control centres will in the near future also incorporate more or less all parts of an organisation. Logistics, finance, trading and business, marketing, cash flow, long term development, customer-relations and services, HR, etc will all be interconnected into an integrated "data ware housing" system of an organization. The board room (of private and public organisation) will be like a control centre where the top executives will spend an increasing part of their time.**

***Keywords*- control rooms, control centres, data ware housing**

OVERVIEW

Sixty years ago control rooms did not exist. In manufacturing industries workers and supervisors together spent all their work time out on the shop floor. Forty years ago, in the 1960s, separate control rooms didn't really exist in the sense we understand this concept today. Instead, operators and maintenance workers in an industrial plant worked for short periods from a purpose-built cabin, one purpose of which was to protect them from noise and air pollutions. These objectives were very important, especially in the Scandinavian countries. In Scandinavia legislation existed to protect industrial workers, and long-standing traditions had built up trust and cooperation between workers and employers. In this environment acceptance of such legislation was assured as its intent was mutually understood. However, one disadvantage was that by working in the cabins, the workers/operators became distanced from the machineries and processes they were supposed to supervise. Contemporary research showed that there were differences in behaviour between old and young workers: older workers spent much more time out on the shop floor than their younger workmates (Singleton, 1967).

Twenty years later, in the 1980s, we began to see special control rooms where operators could supervise, and to some extent control, industrial processes (see Ivergard, 1989 and Ivergard & Hunt, 2008). Early examples were electrical power production and distribution. Inside the control room the process flows were represented in visual displays. It was frequently a combination of static information (e.g. drawings of process flows on walls and panels) and dynamic displays (instruments) presenting analogue or digital information. A few controls for adjustments and on/off switches were also available on wall or desk panels. When process flows reached a critical stage (for example when pressures became extreme or a risky situation was imminent), the control panel alerted the operator by emitting visual or auditory warnings such as flashing lights and/or sounds. At about this same time, control centres in the pulp and paper industries also came along on a large scale. In most, if not all of these uses, the main driving force was to improve process control and reliability and to avoid total breakdown of the process. In industry, restarts are time-consuming and very costly. In countries where electrical supply is inconsistent power outages are obviously extremely costly and disruptive.

A PARADIGM SHIFT FROM CONTROL ROOMS TO CONTROL CENTRES

In his classic book, *The Structure of Scientific Revolutions* published in 1970, Thomas Kuhn described the natural sciences from the perspective of models of thinking where one paradigm would be the universally accepted view. Paradigms encourage people to see things in a certain way, while overlooking alternatives (Clarke and Clegg, 1998). Writing in the early 1990s, Tapscott and Caston (1993) describe a paradigm shift in information technology and the resultant effects on organizations. Today we face a new paradigm shift. The control **room** concept seems to be on its way out. In new industries and professions where new technologies are used, control **centres** have become the norm. We will therefore talk about control **centres** as these incorporate a wider scope of supervision, control and development. In these contexts we will see greater complexity. For example, communicating and control systems will have complex hierarchical processes. Whether local, regional, national and global, the processes will enable communication to take place in real time between these different levels of the hierarchy. Operating between these hierarchies will be networks of sub-systems. A classic example is the reservations systems of airlines. These were among the first data and information systems to be globally networked allowing user access from anywhere within the network.

In summary, the past decade has seen a rapid growth in new areas (in addition to rational rooms/centres for control of industrial processes, eg power production and distribution, refineries and chemical, food, etc and also all the different areas of supervision and control of telecommunication networks) of application of control centres (presented here in order of scale of recent growth):

1. Security and Safety
2. Trading and Business (including ‘carbon’ and energy trading).
3. Central, Local and Regional Government sectors (next step of eGovernment)
4. International Organizations (including global environmental concerns)
5. Centralized Production Control in Manufacturing
6. Data Warehousing (for top executive direct control of a large number of amalgamated systems and databases)
7. The Service and Tourist sectors (merging of a number of e-systems)

The “control room concept” is spreading to many new areas, for example, the food processing and food technology industries nowadays include the traditional control room concept. One very fast growing application is in surveillance and security control centres. These incorporate much more than “policing” of urban, business, and residential districts. Yet another area is that of financial control and trading centres which began to emerge to some extent more than ten years ago. Today most large companies have control centres to improve the quality of financial planning, and to provide real-time data on market movements. Companies such as Reuters and Bloomberg have successfully exploited the need of the financial services industries for such data. One of the main objectives is to be able to make more rational and complex decisions.

The current global crisis in the finance sector is a good illustration of the need for a more skill full handling of facts vs opinions. Keywords are parallel information processing, artificial intelligence, data mining, etc. But this is not only tasks for senior experts, but even more the direct involvement of senior top executives. This in turn will demand an enormous high level of “**usability**” in the concepts and technology of information presentations, also in relation to an effective use the experiences and tacit knowledge of the top level executives. This will demand a change in the design and architecture of physical room or space of future control centers. It is not enough to have extremely high requirement on the ergonomics of the design. It also needs to fulfill the experiences of moving from a traditional boardroom in to an executives’ center of strategic decision makings.

In the public management sector, this past decade has seen the emergence of e-government systems. However, while development has been rapid, these systems have tended to be in isolation. Today more and more of the work of government departments are coordinated in e-government systems (Sandberg et al, 2004). In the near future one more-than-likely scenario is national systems inter-connecting all (or at least most) government services within a country. In this scenario there could be virtual connections between the member systems at different levels. And the different national systems could be inter-connected to create clusters of global systems. Existing systems of e-government and multinational systems such as the different agencies of the UN and the EU are likely to become embryonic control centres on a global scale. Good examples are new systems developed by the World Bank. A key issue for government and NGOs is the need for high quality information which is formally correct. In this, a critical issue in the future will be to decide how to handle the different legislations (e.g. regarding openness, public availability of government information and a clear and none dubious legal texts) that are involved when control systems have a global reach.

DEVELOPMENT OF ADVANCED COMPUTER SYSTEMS

Control centres using advanced computer systems based on advanced mathematical modelling have only just begun to be developed. Here, the key word is financial engineering as taught at schools of advanced engineering. This blending of analytical finance, stochastic mathematics, and mathematical modelling with process engineering is an excellent example of what we can expect of many types of control centres in the very near future. The energy sector is likely to create a visionary future. There is huge potential, opportunity, and ramifications in such diverse areas as energy conservation and environmental protection as well as in the optimization of business functions and processes. This new trend will give rise to increased concerns about corporate social responsibility (CSR). For any organization, the introduction of new technologies is a linchpin for both technological change and for organizational-wide process development and change (Hope and Hope, 1997). This is particularly so with the emergence of technologies that can aid and abet an organization’s activities in a phenomenon called “paradigm shift” (Tapscott and Caston, 1993).

A key objective is to outline how design recommendations could be laid out in these future control rooms and future control systems. This objective is often the most difficult to achieve. The new control centres will have much ICT-based potential for more advanced work; for example, for the future development of design and innovation and optimisation of the systems for greater efficiency. There are also potential gains in communication efficiency (e.g. macro perspectives on safety and health, economics and finance, environmental protection and ecology, optimize use of natural resources, etc)

We strongly believe that the control centres of the future should be developed by the operators themselves with strong support from researchers and computer systems designers. We also believe that there needs to be a symbiosis between the learning and the design and the design and the learning. We propose that the design features of control centres should incorporate design for learning and that the control centre operators are key conduits of knowledge and expertise that should be incorporated into control centre design.

DESIGN FOR LEARNING AND LEARNING FOR DESIGN

Designing for learning in control centres is complex. For the subsequent learning to be effective, many aspects of the work need to be analyzed and many features of the user need to be taken into account. Aspects of the work and the features of the user both need to be incorporated into the design. Design for learning can ensure that the learning is optimized for the work situation, employee needs, and the organization. Important issues include: identification of learning needs, ensuring that these needs match organizational requirements, support and encouragement for the learning to take place, choice of technology to deliver the learning, feedback mechanisms on the effectiveness of the learning and reward systems for acknowledging and celebrating learning success.

Important factors in the environment are the learner’s awareness of the purpose for the learning and the utility of this learning to the organization through improved workplace practices. Issues which affect the learner include: prior learning experiences, expectations from the current learning, motivations (both personal and professional), preferred learning styles and time available to engage in the learning activity. Motivation (both extrinsic and intrinsic) plays an important role. Extrinsic motivation (such as encouragement for the learning through awards, bonuses and promotions) and intrinsic motivation (such as personal pride and an interest in self-development) can combine to produce a positive learning environment. The learning interface is where the learning content and methodology is delivered to the learner. This includes resources that facilitate the learning, learning content, the intended process through which the learner gains access to the learning content, processes to monitor learning progress, some means of assessment, feedback mechanisms, and expected learning outcomes.

Learning at work includes extra dimensions (Ellstrom, 2001; Paulsson et al, 2004). In addition to the learner and the learning process are the workplace environment and the organization at large. A key consideration needs to be the integration of learning with work tasks (Ellstrom, 2001). When the learning is expected to fit around work tasks, work-related stress may result from the pressures of engaging in learning and work activities (Paulsson et al, 2004). To take these additional dimensions into account requires the definitions and models of learning to be refined. Models that help explain learning in a workplace include Raelin (1997), Nonaka et al (1998), Takeuchi and Nonaka (2004).

New knowledge is created dynamically at the interface of tacit and explicit knowledge (Nonaka (1999). This is facilitated by the exchange of ideas between workplace colleagues so that tacit (personal) knowledge becomes at once more public and can be augmented and developed through the ideas of others. The SECI model (Nonaka et al, 2000) shows the development of knowledge from tacit-tacit (existential, face-to-face) through tacit-explicit (reflective, peer-to-peer) to explicit-explicit (systemic, collaborative). In this dynamic process, the individual brings new (tacit) knowledge and transforms this from knowledge held personally (‘indwelled’) to knowledge shared with others to become publicly accessible. This can be accomplished using our philosophy, which is based on an advanced action research model.

ACTION RESEARCH AND DESIGN

Action research is a qualitative approach to research investigations. Action research owes much to Kurt Lewin (1890-1947), “the founder of modern social psychology”. Lewin published his ideas on action research in the mid-late 1940s (Checkland and Holwell, 1998; Dickens and Watkins, 1999). Unfortunately, Lewin’s death meant that his conceptual theories were largely nascent and it was left to later scholars to develop the Lewin action research model (the so-called classical model of action research). The principles and practices of action research have thus been developed over time.

Action research comprises three elements: research, action and participation (Greenwood and Levin, 1998: 6). The research component aims to bridge the gap between discovery and action through participation in both the discovery and the action. In this context, action means that the researchers will put the results of their investigations and reflections to use in their organizations. Participation means that the people whose work tasks and routines are the focus of the research can themselves contribute to the process of research as equal partners (Hartley and Benington, 2000). Participation by the action researchers themselves is a critical component. A fourth element is reflection. Reflection is an important element in learning and is as much a part of learning as experience (Raelin, 1997, 2001). The most relevant part of learning is “the reflexive and iterative nature of the learning process” (Udas, 1998: 602). We regard action learning as an opportunity to stimulate reflective learning from critical inquiry into the organization. These four components accord with standard models of learning (e.g. Schön, 1982; Kolb, 1984; Raelin, 1997). One such model is shown in Figure 1 (it is a development from Raelin, 1997).

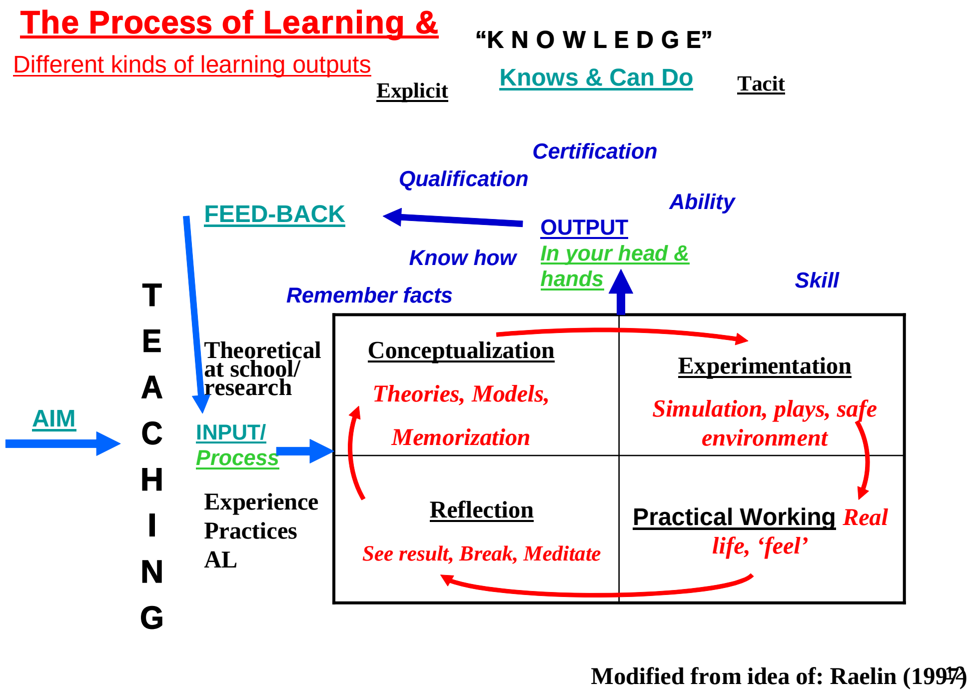

Figure 1: A Model of the Process Learning and its inputs and its different kinds of outputs.

The Raelin (1997) model shows two axes: Knowledge and Learning. Knowledge is explicit or tacit (pace Polanyi, 1966; Baumard, 1999). Tacit knowledge is the knowledge (know-how) possessed by an individual. Such knowledge is often difficult to explain or to codify (Polanyi, 1966). Explicit knowledge can be captured in databases, instruction manuals, and handbooks (Leonard-Barton, 1995). As such the knowledge is codified knowledge. The other dimension of this model is learning, which has theoretical and practical components. Learning needs to balance between theoretical knowledge (how processes are ideally executed) and practical knowledge (how processes are in fact executed by the people who carry them out as part of their job). The resulting 2x2 matrix has four cells. **Conceptualization** is explicit knowledge processed through theory. **Experimentation** is the application of theory into tacit knowledge. **Experience** is the practical application of tacit knowledge. **Reflection** is the practical application of explicit knowledge. Progressing through the four-stage learning process (as show by the arrows in figure 1) completes the learning cycle. Peer groups are important to action learning as they provide evaluation of others' performance and offer reciprocal advice, criticism and support (Revans, 1983). Peer groups facilitate "group discussion, trail and error, discovery, and learning from each other" (Zuber-Skerrit, 2002: 114-115). In the process of collaborative investigation of issues, co-researchers become co-subjects and the knowledge so generated becomes more practical (Reason, 1994). To make sense, the Raelin (1997) model must be viewed as a gross simplification. In real world of 'practice' and 'experience', 'tacit knowledge' overlaps with practical experience of 'explicit knowledge'. Practice learning of explicit knowledge is not only from processes of 'reflection'; in reality, reflection is a part of an iterative process with its focus on learning in the area explicit practice.

Action research processes help organizations develop through learning about learning.

Traditionally, organizations that encourage and facilitate employees in action research have a means of generating new knowledge through the knowledge and skills of employees themselves. However, action research has also a great potential to facilitate creative and innovative work by the operators, who have valid insights into their workplace. If the organizational and workplace environment are supportive, an action research process could encourage creativity.

However, this potential is only effective if employees propose solutions to work-based problems. Through their everyday work roles and tasks employees have valid insights into their workplace. Action research encourages the development of these insights through, for example, collaborative inquiry with others. A key factor in this process is collaborative reflection so that shared learning and shared knowledge generates new knowledge. Collaboration and reflection can transform insights into strategies for action. Action learning has been defined as "learning from concrete experience and critical reflection on that experience" (Zuber-Skerrit, 2002: 114-115). Workplace teams are able to create knowledge for individual members, the team, and for other colleagues (Kasl et al, 1997). This in itself might also limit their ability for creative thinking (what is sometimes called "out-of-the-box thinking"). Traditional ways of thinking and paradigms will easily limit the scope of thinking. It is necessary to break this barrier. The process of action research must include an approach which allows ways of proposing new ideas and new thinking. The phrase "high ceilings" is used to describe environments which have a high tolerance for ideas and concepts which at first might look outlandish. This also requires mutual trust among co-workers. It also demands that leaders and managers to adopt a more consultative role. To be avoided is the "I know best" mentality as this precludes constructive dialogue.

The environment of modern control centres is well-suited for creativity and learning. For most of the time, the available computer power has an enormous surplus capacity available for other types of application. Computer capacity contains dimensions to cover peak loads, e.g. system breakdowns, major errors. This over-capacity can be used for simulations of different types of process applications or possible scenarios of breakdown and errors. These simulations could be used for operator training and also for updates of new equipment and systems, including computer systems for process control. However, the control centre operators should also be able to use the available computer capacity for development of the existing production system and also the computer control system, including the related peripherals. Management should emphasise creating a good and motivating "high ceiling" environment to facilitate high creativity in this type of development work.

ARTIFICIAL INTELLIGENCE (AI)

Control centres themselves will have built-in advanced artificial intelligence (AI) which will support this process. This will demand a completely new understanding of control room work and its need to be transformed from an environment for supervisory tasks to one where creativity and learning take place in an open environment. Our working definition of Artificial Intelligence (AI) is: the ability of machines and other devices to perform activities normally associated with humans, including the ability to modify behaviours on the basis of learning from errors and experience. In the long term AI could support the operators to build up a database and related systems for process optimization. It can also provide decision aids for error handling and even more important how the human operation can compensate imbalances in the technological system as discussed by Hollnagel, E., Woods, D. D. & Leveson, N. (Eds.) (2006). In this way opportunity will be available for the operator's own creativity and development work which might be outside the scope of AI. It is important to alert the operators to the risk of becoming too dependent on the AI system, because this system will always (or at least mainly) act within the current paradigm (i.e. thinking "within the box").

The big advantage of human operators is their potential to be proactive, creative and "out of the box" thinkers. However, a basic condition is that the organization and its top management and managers on all other levels are willing to accept the challenge of creative thinking. There is always a risk that creative thinking will be perceived as odd, unrealistic and perhaps (and in this context) dangerous. The use of simulations will be an obvious alternative to allow creative thinking and experimentation without intervening in the real system. In other words we are here focusing on the top right-hand box in figure 1. Simulation is a very good example of experimenting with new ideas and theories with the use of tacit knowledge (in this case a kind of feeling of new possibilities which from time to time come into the heads of creative experienced operators).

SUMMARY AND DISCUSSION

Why is it necessary to discuss the role of people in control rooms? For many of us it has been obvious for decades that we need to create a harmony between technology and the people involved in steering, controlling, and managing the technology. Countless accidents with very dramatic and severe consequences have been blamed on "the human factor". The human and environmental tragedies of Bophal, Brent Spar, Chernobyl, the Exxon Valdiz, Minamata, and Three Mile Island show what can go wrong when humans engage with machines. However, very early we learned and understood that the human operator was not to blame. The reasons for the catastrophes were defined as the lack of compatibility between people and technology. In essence, the interface between technology and people did not match. Today we talk about a lack of usability and ergonomic considerations. Earlier we used words like "human factors" and "human engineering". If some human agents need to be blamed it is the designer and the purchaser of the systems for overlooking the critical importance of technology-human factors. Most people in this audience are aware of these factors. But in Asia this remains a little understood area of knowledge. A 'nice-looking' control room is more prized as a place to show and impress visitors. A careful design of the inter-relationship between the operators and the control systems and its controlled processes is essential for a safe and optimal operation.

Every 15-20 years sees a paradigm shift in industrial and technological processes. The introduction of new technologies into organizational processes requires organizations (and their members) to "change paradigms" about how they work and behave (Clarke and Clegg, 1998). The inertia in this process of change is related to many factors, but probably the most important is the need for return on investment. Rapid developments in technology (including IT) create an urgent need for organizations to develop new skills, competencies and knowledge (Ivergard, 2000, Paulsson et al, 2004). The three elements of technology: as a driver of organizational transformation, as an enabler to deliver that transformation, and the needs of the organization for new skills and competencies. For many organizations, a critical issue is not in keeping up to date with the development of technology per se, but in developing competencies to enable the organization to gain full advantage of the technology.

The full potential of technology will only be realized if the organization succeeds in adopting new business processes and working routines into the organization as new ways of doing things (McKenney, 1995; Clarke and Clegg, 1998). Thus it becomes critical for organizations to develop new competencies in employees who use the new technology in their work. Introducing technologies into organizational processes requires organizations (and their members) to "change paradigms" about how they work and behave (Clarke and Clegg, 1998). This includes learning the skills needed to utilize new technologies in the workplace (Edmondson et al, 2003). Technology is thus a key driver for workplace learning as employees need to develop skills for managing and operating the newly adopted technology (Pisano, 1994). Learning the skills to perform using the new technology is critical if the technology is to be used from optimum benefit. As a complement, the new technology in itself has to be adapted to the existing competence and knowledge infrastructure of the organization (Paulsson et al, 2004). This is to avoid an overload on demand for learning (learning stress). The importance of this symbiotic relationship between technology and people in organizations is discussed by Ivergard, 2000. Technology is normally not an aim in itself but a means to achieve other aims, e.g. improve efficiency of learning or to reduce cost of leaning. Inherent in leaning at work are many possibilities of integrating learning technologies as a part of the control system of industrial and administrative processes. As such, technology has been a key driver for learning at work (Pisano, 1994; Edmonson et al, 2003). Good environment and tools for learning has also the potential to facilitate creativity and innovations. New ways of doing things are urgently needed to manage the severe problems confronting modern civilization. Artificial Intelligence (AI) has a new and potentially very fruitful area of application to support learning, the demand for learning and, in particular, to facilitate creativity. AI is restricted to existing knowledge and new combinations of existing knowledge. In this way AI as a part of advanced control system could reduce the load demanded for learning and also indicate potential areas for creativity and innovations. However, it is also obvious that eLearning and other forms of learning technologies can never – or at least very rarely – 'stand alone' for learning process. Rather, it has to be combined with other methods to create a holistic process of learning and creativity.

To build a good society we need to create harmony and balance between people and also between people and technology. To create a good production environment in balance with nature needs a good harmony and balance between people and technology and technology and nature. It is important for decision-makers to understand these points. It is necessary to define the problem, to recognize the benefits of worker participation in design, and to take appropriate action between to engage these two.

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