15th Triennial World Congress, Barcelona, Spain

# REVISITING THE SOCIAL IMPACT OF AUTOMATION

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Abstract. Discussions on Social Impact of Automation are active in IFAC for more than three decades. The paper presents the main issues from past research and development in the area, indicates most likely trends and puts forward some basic premises for further development. The authors argue that it is necessary now to revisit the social impact of automation, in order to become ready for new challenges. They propose essentially two things: first, to look at the social impact of automation from a wider perspective, and second, to increase the intensity of working on these issues in the future. 

Keywords: Social impact of automation, Human factors, Socio-technical systems

## 1. INTRODUCTION

The relations between automation and society are in IFAC mostly (but not exclusively) considered within the Technical Committee (TC) "Social Impact of Automation". Under this title, the TC deals with following issues defined in its scope (IFAC TC GES, 1999):

- social effects of automation,
- socially desirable requirements for the development of automated systems,
- socially acceptable alternatives for design of automated systems,
- environmental, health and safety implications of automation,
- engineering ethics, professional responsibility and public policy.

Initially, the fore-runner of the current IFAC TC "Social Impact of Automation" was established in 1971 under the name "Social Effects of Automation". Then, the aim of this committee was to concentrate on the "interaction between automation techniques and conditions in industry" (Withers and Rijnsdorp, 1978). During its existence, this TC has undergone different organizational forms, used different ways of working and included quite a number of professionals of various profiles.

The past professional orientation of the IFAC TC "Social Impact of Automation" can best be seen from two plenary presentations at the IFAC World Congresses (later published in journal Automatica), namely those in Kyoto (Sheridan et al., 1983) and in Tallinn (Martin et al., 1991), as well as from a couple of papers written by leading or otherwise very active members of this TC, e.g. Withers and Rijnsdorp (1978), Margulies and Zemanek (1983), Martin (1983), Martin et al. (1987), Butera (1987), Rodd (1987 and 1994), Rosenbrock (1989), Martensson (1993 and 1999), Brandt and Černetič (1998). Their work and also the work of many other authors represented a successful response to the challenges of those times in terms of making automation more socially appropriate. However, time goes on quickly, bringing along changes with associated new problems and new challenges: technological, social, environmental.

In order to make a step to issues satisfying these needs, the aim of this paper is the following:

a) to present the main issues from the past research and development in the area "Social Impact of Automation",
b) to indicate most likely trends and promising aspects in this area, and based on this,
c) to put forward some basic premises and assumptions for further development.

The structure of the paper is as follows. The second chapter gives a short summary from the extensive survey of literature, partly in quantitative and partly in qualitative terms. The main findings from the literature survey are given in chapter three, with a view to the past. A view to the future is given in chapter four, by indicating three desirable directions for further development.

## 2. ANALYTICAL OVERVIEW OF LITERATURE

The aim of this chapter is twofold: first, to give a quantitative indication of "publication density" during the past three decades, and second, to make a relatively short overview of significant literature, structured according to the current Scope of the IFAC TC "Social Impact of Automation".

### *2.1. Short quantitative analysis of publications*

As an introduction to surveying the literature, a short quantitative analysis of publications was made, in order to: a) get an insight into the intensity profile of relevant publications over the three decades and b) find the most important highlights in the last 10 years. Detailed description of methods used and results achieved is given in a separate report (Strmčnik and Černetič, 2001). Here only a short summary of findings is given.

For this analysis, the following three databases of scientific publications at the Institute for Science Information (ISI) from Philadelphia, USA were searched: Science Citation Index Expanded, Social Science Citation Index and Art & Humanities Citation Index. These databases cover over 8.000 journals with over 26 millions of various documents.

*Estimation of publication frequency*

To get this estimate, the investigated time period was divided into six time segments, each covering five years, with the first time segment beginning in 1971. Then the publication databases were searched for the number of publications within a selected time segment that are associated with the issues of "Social Impact of Automation". The combination of keywords for search was constructed from two parts. The group of keywords covering the notion "Social Impact" was defined in more detail through 28 additional keywords. The keyword "Automation" was initially expanded to "control systems", "computer-based systems", etc., but it appeared after some search trials that the original keyword "Automation" gives similar distribution patterns. The titles of publications found through each search went through a visual inspection, in order to discard those publications, which had contents different from expectation. The results of the first part of analysis are given in Table 1.

Table 1. Distribution of »Social Impact of Automation« publications from 1971 to 2000.

| Time period searched | No. of doc's in the database | No. of doc's from entire query | No. of doc's from only "Automation" | % of "Soc. Impact" doc's |
|---|---|---|---|---|
| 1971 - 1975 | 2345312 | 25 | 602 | 4,2% |
| 1976 - 1980 | 3422975 | 24 | 710 | 3,4% |
| 1981 - 1985 | 4233099 | 60 | 1226 | 4,9% |
| 1986 - 1990 | 4453014 | 38 | 1092 | 3,5% |
| 1991 - 1995 | 5776620 | 29 | 861 | 3,4% |
| 1996 - 2000 | 5776620 | 25 | 907 | 2,8% |
| Total (average) | 26007640 | 201 | 5398 | (3,7%) |

In Table 1, the meaning of data in individual columns are the following:

- column one - the investigated time period,
- column two - number of documents in the database for that time period,
- column three – number of documents found using the complete keyword "Social Impact of Automation", after discarding the non appropriate ones,
- column four - number of documents found using only the keyword "Automation" and
- column five – proportion (%) of documents relating to the keyword "Social Impact", found within the document groups gathered by the keyword "Automation".

The distribution of the number of "Social Impact of Automation" publications is graphically presented in Fig. 1.

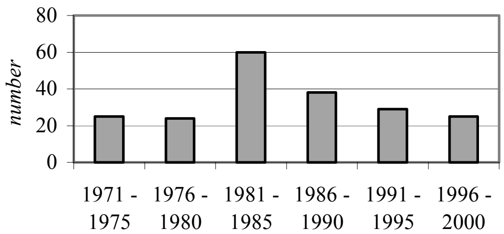


Fig. 1. Distribution of the number of "Social Impact of Automation" publications

It can be seen from Fig. 1 that the maximum number of publications has appeared somewhere during the eighties. After that time period, the number of these publications is gradually falling towards the level of the seventies. The same pattern of publication distribution was obtained when the same analysis was performed on the INSPEC database of scientific publications. (Note that the latter database contains also publications from conferences, appearing in proceedings.)

Most probably, the mentioned decline in the number of "Social Impact of Automation" publications during the past decade cannot be attributed to less research activities. The trend can be explained firstly by a greater number of corresponding applications which are usually less described in scientific publications, secondly the decline results from the fact that the word "Automation" is less used in later publications concerning research on Human-Machine Interface (HMI), Human-Computers Interaction (HCI), Human-Machine Systems (HMS), etc. Thirdly, many of the researchers dealing with "Social impact of automation" topics have been integrated into the design of different complex automation systems worldwide. Thus certain research areas have not needed further research activities under the heading of "Social Impact of Automation" because they have been followed up by other engineering and work psychology activities.

*Estimation of highlights*

In searching for the main highlights discussed in the past publications the analysis was limited to the time period from 1991 to 2000. In this analysis the keyword "Social Impact of Automation" was also divided into two parts. The "Automation" part was extended with eight additional keywords whereas the "Social Impact" part was extended with 16 groups of keywords. The latter keywords consisted from one or more sub-keywords. These 16 groups of keywords have included the main keywords taken from the Scope of the TC "Social Impact of Automation" and also some other keywords taken from the most significant papers. The results of this part of publication search were then grouped under nine "final" keywords. The findings are presented in Table 2 and Fig.2.

Table 2. Distribution of highlights from publication during 1991-2000 according to grouped keywords.

| Keywords | No. of hits | Proportion |
|---|---|---|
| social effects | 23 | 7% |
| culture | 47 | 14% |
| job, organizat. | 34 | 10% |
| human factors | 99 | 28% |
| participation | 33 | 9% |
| operator | 23 | 7% |
| employment | 26 | 7% |
| skill | 26 | 7% |
| methodologies | 37 | 11% |
| All | 348 | 100% |

The results indicate that the topics concerning human factors (HF) were the far most interesting area of consideration. The highest rating of HF is probably also a consequence of the fact that under this keyword often other topics from the list were hidden. Nevertheless, the issues related to human and culture are obviously emphasized.

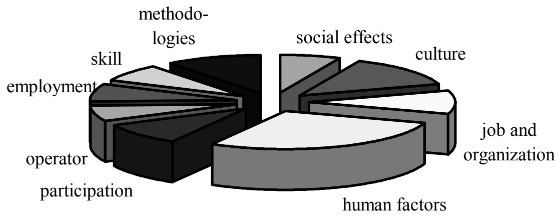


Fig.2. Distribution of highlights during 1991-2000.

*2.2. Overview of significant literature*

The time period of literature surveyed begins from early works published in 1974, but emphasis is given on publications from the last decade. The main sources of information are the works presented in IFAC publications: preprints, proceedings and journals. The second important sources of information are the relatively recent journal papers obtained through various electronic literature search services like Scirus and Science Direct by using appropriate search keywords. In addition to these main sources, various other books, journal papers, proceedings and also documents available through the Internet were used.

*Social effects of automation*

Under this heading, the overview concentrates mainly on the effects of automation on some key social categories or attributes, like employment, work, work organization and culture.

Employment. The impact on employment was one of the first concerns of professionals dealing with consequences of automation. Two different aspects of human work are affected. On the one hand, physical work of humans or animals is replaced by mechanization. On the other hand, sensory and intellectual capabilities (or work tasks) are replaced by automated devices and/or computers (Williams, 1999). In this context, fear of loosing jobs by massive introduction of Automation and Control Technology as well as Information and Communication Technology (ACT/ICT) seems to be (and mostly is) logical (Rodd, 1987). In particular, this holds for segments of human employment where the jobs are very simple and repetitive (e.g. Bjorn - Andersen and Jappe, 1978). In such cases, automation is perceived as "job killer" technology. Beyond it, however, automation can be "job creating technology" (Margulies and Zemanek, 1983). In this sense, a certain re-distribution of workplaces takes place (Sheridan et al., 1983). Surely this can hurt many workers, primarily those with lower work qualifications.

Interestingly in this context, it is reported that there are no facts available on the macro-economic level in supporting the thesis that higher level of automation should diminish the number of workplaces (Rijnsdorp, 1981). Similarly, the predictions made around the eighties have shown that automation alone changes mainly the structure but not so much the number of workplaces (Farber, 1986). Different observations/assumptions about the same issue are given by Broedner and Martin (1981). They argue that the loss of 1.7 million workplaces in Germany can be attributed mainly to the introduction of computer-aided automation.

For the other part of the world, Gong (1999) states recently that many workplaces have been lost in China, but mainly due to economic reforms. Nevertheless, it can be understood in this case that these reforms are deeply rooted in general change of work technology.

In any case, it can be seen that the general trend of replacing more human work in industry, agriculture and also in services will continue (Fleck, 1987). As a partial consequence of this trend, human work migrates into services. This is in line with predictions that, at the end of the 21st century, only 20 % of people will work, producing enough goods for the other part of population.

*Work and work organization.* The basic idea of automation was to relieve the human of heavy, repetitive and dangerous work. But it is no doubt that this same technology has brought about the greatest changes and problems into the area of work and work organization. A great part of reasons for these problems can be found in conflicting goals of automation (Docherty, 1978). Namely on one side, management aims to achieve better exploitation of resources, whereas the workers want easier jobs and satisfaction of their personal and social needs (Bullinger and Korndoerfer, 1987; Martensson, 1999).

Inconsiderate introduction of automation that ignored the needs and capabilities of people had many unwanted effects on the contents of work. But, as expressed by Margulies and Zemanek (1983): "*The troubles of our world are not caused by technology but by the way technology is being applied and used*". The changes in the contents and way of working brought about by automation appear in different forms, causing alienation of workers from their work (Sheridan et al., 1983). One of typical consequences of automation is the change of work pace and rhythm. E.g. the operators of some automated processes or devices (chemical industry, long-distance flight) experience long periods of boredom followed by a sudden occurrence of multiple concurrent alarms that cause an enormous stress and erratic mental workload on the operator.
This situation has been called by Lisanne Bainbridge (1983) as one of the "**ironies of automation**": "*the more advanced a control system is, so the more crucial may be the contribution of the human operator*". Namely, the automated system takes over from the human operator mostly the simpler work tasks, while the more complicated and unpredictable ones remain the responsibility of the human. The consequences of this are manifold. First, absence of regular work activity causes the operator to forget his/her essential work skills. Second, the stress and high mental workload in situations when the automated system needs to be put back to order by the human, often require actions and handling speed that exceed real capabilities of the person at certain moments, leading to frustration and bad feeling of being out of control (Margulies and Zemanek, 1983; Martin, 1983; Martensson, 1990). All this causes loss of motivation for work and, in more severe cases, loss of self-respect in the worker.

Another problem in a similar context is also caused by centralised control in automation systems. This often causes in the human a fear of being supervised and, again, bad feeling due to having less possibilities for own (local) decision-making. These issues are reported by a number of authors, often supported by empirical investigations (e.g. Broedner and Martin, 1981; Margulies and Zemanek, 1983).

Among the serious problems caused by changes in work organization through automation is also diffusion and neglect of responsibility for results of work. As often the lines of responsibility are blurred, some workers falsely put the guilt on the control system or computer (Sheridan, 1987). Related to this issue is also the distortion of trust (confidence) in technology. In fact, either the mystification of the "omnipotent" control system or a total mistrust is caused by the fact that the human operator does not understand the logic of "artificial intelligence" programmed into the technology.

The undesirable effects of automation enumerated above are often aggravated by a Tailoristic organization of work still present at many workplaces. This can lead to the feeling of workers that they are slaves of machines. If such a situation is further complicated by insensitive displacement of workers due to new organization of work, loss of social position related to work, and loss of primary working skills (e.g. Curran, 1981), then eventually the consequences of automation for workers can be disastrous.

*Culture.* Sometimes it appears that it is difficult to understand the connection between automation and culture, and why this issue is important. In the introduction to the 1st IFAC Workshop on Cultural Aspects of Automation, Jan Forslin (1991) has explained it: "*The social effects of a technical innovation can only be understood against the background of the specific cultural context ...*".

Under culture, it is usually understood "the collective attitude for the behavior of a larger group of people" (Bolk and Van Hanen, 1990). Forslin (1991) has used another definition: "... culture is the element by which wholeness is created in a society. Culture connects the technical, the social and the spiritual levels by creating a unique blend of values, mores, traditions, interpretations etc.".

As it is mentioned further below, cultural factors must be integrated into new technology that should be characterized as socially appropriate (Martin et al., 1990).

The authors state that the definition and requirements of “socially appropriate technology” critically depend on cultural peculiarities of the country where this technology will be deployed. It is not only the question important “which is cheaper: human or machine work?”, but there are more significant factors to be considered.

Cultural aspect of automation and other advanced technologies in different countries are dealt with in a number of papers given at the 1st IFAC Workshop on Cultural Aspects of Automation (Forslin and Kopacek, Eds., 1991). Examples are the papers presented by: Vavrin, Armendariz and Pacheco, Oliva-Lopez and Bojorquez, Imamichi, Weissbach, Javorcik and Lenart. Their ideas and views are best illustrated by the following quotation (Forslin, 1991):

> “*Today there is a heated debate on what are the future forms of work and how technology should be best utilized to meet both economic and social ends. In parallel, there is sharpened global competition in business, where technology in itself is less seen as the prime weapon. It is rather the way it is being utilized, which depends on human resources: skills, creativity, values, commitment etc. that gives the (competitive) edge. Such factors have a cultural background and we thus have to start to look at culture as a competitive advantage ... How to best make us of a culture’s strong side is now becoming a profound issue for research, where technical and social expertise have to meet*“ (Forslin, 1991).

*Socially desirable requirements and socially acceptable alternatives for design of automation.*

Under this heading, it is intended to discuss mostly guidelines, criteria, standards and other forms of recommendations for the development of socially desirable ACT/ICT as well as known paradigms, approaches, methodologies and good design practices leading to systems, which are socially acceptable.

To understand the efforts of researchers, it is necessary to be clear about what it means when a technology can be characterized as “socially desirable” or “socially appropriate”. Martin, Ulich and Warnecke (1987) give a thorough presentation of appropriate automation from the viewpoint of flexible manufacturing. They explain the principles and benefits of the so-called **socio-technical systems design** as the basis for the development of socially desirable systems. There are some very straightforward ideas behind these principles: the basic one is joint design (and optimization) of technology and organization. An excellent and systematic presentation of sociotechnical principles for system design, based on earlier formulations is also given by Clegg (2000).

In their paper Martin and his co-authors (1991) give a very systematic presentation of socially appropriate automation. Their message is very clear: to design such systems means “integrating technical, human, organizational, economic, and cultural factors”. Further, they give the basis of socially appropriate design (“People are in charge”) and three primary design goals: namely, technology should provide the means for

- helping humans overcome their limitations,
- helping humans enhance their abilities and
- fostering user acceptance.

When discussing about socially appropriate design criteria, the paper by Martensson (1999) must be also mentioned, that gives requirements and criteria for the design of work organization in a human-machine system. In close relation to that, the paper by Grote et al. (1995) describes a comprehensive set of criteria for complementary allocation of functions in automated work systems, to be used within a three-stage socio-technical approach called KOMPASS.

Probably the most outstanding paradigm that leads to the development of socially appropriate technology (including, in particular, ACT and ICT) is that of human-centered design. Indeed, the notion of “socially appropriate” automation somehow implies that such systems are **human-centered** and user-centered (it may be noted here that this implication in the opposite direction does not hold necessarily). The ideas of human-centered or anthropocentric (production) systems were very popular in Europe during the nineties, namely as a basis for “European competitiveness in the 21st century” (Cooley, 1990; Brandt, 1991; Wobbe, 1992).

An overall view to human-centered manufacturing from a broader social an political perspective is given by Rodd (1994), while an overview of foundations of human-centered systems design is given by Gill (1996). This latter work includes a description of underlying ideas and concepts, the basis for a corresponding design methodology, the different European perspectives of the initiative called “Anthropocentric Production Systems” and a long list of references.

In a thematic issue of the journal “AI & Society” (Brandt and Černetič, 1998), several different approaches to design technology “around people” are described. Again, very recently, Brandt et al. (2001) give an overview of human-centered design of manufacturing systems, with the explanation of core concepts and with a number of practical examples. The contributions in this entire book chapter may be considered as the most significant results of the “Aachen group” that have been scattered in different, largely German publications.

Frequently the concepts of **user-centered design of systems** can be met, with contexts and ideas very close to those of human-centered and socially appropriate design mentioned here. For example, a relatively recent book by Noyes and Baber (1999) is a systematic introduction to user-centered design of systems, with understandable explanation of human and social issues during the three main life-cycle phases: system definition, system development and system deployment. Another useful reference, particularly for the area of automation is the paper by Kraiss (1998). In addition to giving an overview of generic systems functions with regard to possible automation, the paper presents possible structures and strategies for appropriate human-machine function allocation.

A different approach towards design and implementation of socially acceptable automation systems is using the concept of **"critical success factors"** (e.g. Tanaka, 1991; Černetič et al., 1996; Chung, 1996). In this context experiences of experts gathered in successful (and un-successful) application projects are synthesized into various recommendations.

*Environment, health and safety implications of automation*

The issues of environment, health and safety are included here because they are of great social and human concern in relation to both the actual and the possible impact of automation. In fact, as our extensive research of literature has shown, these issues are dealt with much more intensively elsewhere (i.e. outside of this TC, and even outside of IFAC), and they are approached from very different viewpoints. Nevertheless, some interesting papers can be mentioned for illustration.

For example, the paper by Marion Hersh (1995) discusses the role of information technology and networks in promoting sustainable development that harmonizes the conflicting demands for *environmental* protection and economic growth, particularly in the developing countries. Another paper by Rita van der Vorst (1997) reports on the new paradigm of "Clean Technology" in comparison with the older "Clean-up" and "Dilute & Disperse" paradigms, by illustrating the three options through corresponding case studies. Although not explicitly mentioned, the findings are relevant for designers of environmentally acceptable automation systems.

*Health* issues in the context of automation systems are addressed from two standpoints. Looking at the negative impact they are mainly discussed in papers considering operators and pilots and their stressful work as described at the beginning of the review. On the other hand, there are also many positive impacts related to implementation of control technology in biomedical and health care systems (see e.g. Stassen, 2001; Emspak and Trimborn, 1997).

The issues of *safety* are becoming more and more important and are extensively addressed by other TCs.

In the context of the TC Social Impact of automation, the approaches and solutions considering safety in relation with human and organizational factors are certainly not only interesting, but also very meaningful (e.g. Hancke, 1993; Mårtensson, 1999; Nishida, 2000).

*Ethics, responsibility and public policy*

Much of what has been said in introducing the previous heading is also valid for the issues of ethics, responsibility and public policy. *Ethics* and responsibility in the development of automation systems are dealt with e.g. by Schinzinger (1998); or by Cohen and Grace (1994).

The themes discussed by a number of surveyed papers, particularly those based on extensive national or international research, are either directly dealing with *policy issues* concerning novel technologies, or can be considered as valuable basis for design of such (governmental or enterprise) policies on national or regional levels. Into that group fall, for example, the papers by Park (2000), Beaumont and Schroder (1997), Doms et al. (1995). Almost all of these papers discuss issues relevant for higher levels of involved social entities, e.g. regions, nations or multinational firms.

## 3. MAIN FINDINGS - A SYNTHESIS

This chapter represents a synthesis of findings from the survey of literature summarized in the previous chapter. In essence, this synthesis consists of an indication of perceived **highlights** and **trends** from the past research in Social Impact of Automation.

The main highlights are given in Table 3, grouped for three surveyed decades: 1971-1980, 1981-1990 and 1991-2000. This table shows two main things: first the main issues or aspects (in the form of short keywords) that have been dealt with during the particular decade, and second, the way of dealing with these issues or aspects during that time period.

Taking these three decades as the time basis, the **trends**, i.e. the dynamics of changes between these time periods can be commented as follows. During the first decade after the establishment of the IFAC TC Social Effects of Automation (1971-1980), the basic issues of concern were discussed, a sense of awareness among control engineers and the need for interdisciplinary cooperation to solve relevant questions were primarily put forward.

During the second decade (1981-1990), the field has reached the maximum of scientific exploration: the importance of human and social issues gained on momentum on the international basis, the main problems became relatively well structured, the key concepts were defined and a number of meaningful solutions to main problems emerged.

Table 3. Identified main highlights in the field of Social Impact of Automation for the past three decades.

| Main issues (aspects) considered | How the issues were dealt with |
|---|---|
| **First decade: 1971-1980** | |
| ➢ impact of automation on employment<br>➢ work ergonomics<br>➢ human-computer interaction<br>➢ humanisation and dehumanisation of work<br>➢ human factors of work in design of systems<br>➢ improving cooperation between control engineers and social scientists<br>➢ optimisation of human-machine relationships<br>➢ need for broader education of control engineers | ➢ analysis of basic problems<br>➢ promotion of problem awareness<br>➢ analysis of impact of automation on work and people<br>➢ recommendations to control engineers |
| **Second decade: 1981-1990** | |
| ➢ "ironies of automation"<br>➢ skill based automation<br>➢ job and work design<br>➢ division of tasks between machine and people<br>➢ workers participation<br>➢ human-centred systems (Anthropocentric Systems)<br>➢ criteria for appropriate system design<br>➢ advanced manufacturing systems (AMS) | ➢ deeper analysis of problems<br>➢ structuring of problems<br>➢ quantitative analysis of problems<br>➢ basic problem-solving methodologies<br>➢ "philosophy" of automation<br>➢ recommendations to system design engineers and work psychologists |
| **Third decade: 1991-2000** | |
| ➢ automation and culture<br>➢ education for appropriate automation<br>➢ socially desirable automation<br>➢ ethics of automation<br>➢ gender issues in automation<br>➢ complex systems<br>➢ integration in manufacturing (IiM)<br>➢ links between ACT and ICT<br>➢ effects of globalisation<br>➢ networks of systems | ➢ application of concepts and methodologies<br>➢ inter- and trans-disciplinary research<br>➢ broader exchange of concepts and methodologies among other research areas<br>➢ identification of new problems in developing and implementing advanced technologies<br>➢ migration of problems from workplaces into everyday use of advanced technology |

This was the period when the principles of socio-technical system design were established as the methodological basis, and some other methodologies were formed, e.g. the notions of human-centered systems, socially appropriate automation etc.

During the last decade (1991-2000), the field Social Impact of Automation can be considered as relatively mature. The concept of human-centered systems was established internationally, although with a number of different connotations (Sheridan, 2000). The areas of discussion have broadened from the individual workplace and group work towards the levels of cooperating groups, networked enterprises and global cooperation.

The association of ACT with ICT became also more expressed than before and, consequently, the discussion of problems was made much more diversified.

## 4. SOME SUGGESTIONS FOR FURTHER RESEARCH AND DEVELOPMENT

### *4.1. Increase the intensity of working*

According to the findings presented in the previous two chapters of this paper, and especially due to the large diversification of problems, it can be first suggested that the intensity of working on various issues of "Social Impact of Automation" should be increased.

This suggestion is also based on some other facts that appear to be trivial unless they are related to the social responsibility of engineers on a wider scale of observation. For some of these facts, the reader may look into the texts of the Memoranda from the recent World Engineers' Convention (WEC, 2000).

### *4.2. Widen (extend) the areas of consideration*

The contemporary technologies are becoming more and more complex and less associated with a single field or discipline of research. The same holds for their social and other implications. To fully understand the underlying processes and be able to derive appropriate solutions, the areas of consideration within the field "Social Impact of Automation" should be further extended. This may be better explained by means of Fig. 3.

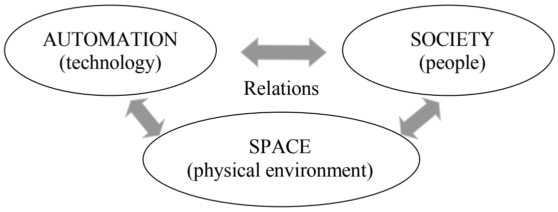


Fig. 3. The extended model of scope to be discussed within the area of "Social Impact of Automation".

In the following paragraphs, it will be briefly explained why and how the consideration within each of the three entities in Fig. 3 should be extended, in order to satisfy the needs of the future regarding the field "Social Impact of Automation".

*Expand the consideration from mere Automation towards Information and Communication Technologies (ICT)*

The relation between the Automation and Control Technology (ACT) on one side and the Information and Communication Technology (ICT) on the other side are often unclear. This topic is well worth to be opened here because an considerable amount of work has been done in exploring the social impact of ICT (e.g. Shackel, 2000). The results and implications of this work are highly related to the central topic of this paper.

The relation between ACT and ICT today can be approached, explained and argumented fully equivalently from two different viewpoints:

- the "outside-in" viewpoint of **automation technology**, resulting in the perspective of <u>machines</u> in the forefront, and
- the "inside-out" viewpoint" of **information technology**, resulting in the perspective of <u>computers</u> in the forefront.

It may be noted here that the former distinction criteria, delineating ACT from ICT based on whether or not a system or machine performs physical or intellectual work, and whether or not it contains any feedback control loops, are probably no more appropriate. Namely, modern ACT systems can perform highly complex "intellectual" control tasks (of course, thanks to their embedded computers). On the other side, successful operation of modern information systems (and even larger technological or social systems, such as an enterprise or corporation), is more and more dependent on complex control loops, many of them including "the human operator in the loop".

*Expand the consideration of SOCIETY*

The previously mentioned width of consideration in this paper refers not only to technology but also to **Involved Social Entities**. Under this keyword, any social entities are considered that have any important relation or involvement with ACT or ICT, respectively. In other words, these social entities could be also called "actors and victims" of that technology. Following the ideas of Martin and co-authors (1990) for the area of ACT, as well as those of Brandt and Henning (2001) for the area of ICT, there are not many (levels of) social entities in this globally Internet-connected world that can be left out of consideration today when speaking about the social impact of ACT and ICT. Therefore it is proposed here to look at larger systems of involved social entities that can be represented by four levels as given in Table 4.

<u>Table 4. Structure of hierarchical levels of social entities involved in or influenced by ACT/ICT systems (adapted from Martin, 1991 and Brandt, 1991).</u>

| level no. | social entities considered | typical ACT/ICT system |
|---|---|---|
| 4 | global an regional structures | networks, weapon systems, transport systems, e-commerce systems, power systems |
| 3 | organizations | networks within the organizations, customer-supplier systems, inter-organizational networks |
| 2 | groups | CIM systems, plant control systems, department LAN, workplace-or group-support system |
| 1 | individuals | single ACT-ICT system, personal computer, cellular phone |

*Expand consideration to SPACE*

It can be better understood from Fig. 3 that the current situation of automation technology needs not only to consider the relations between Automation (technology) and Society (people), but also must include Space as the third relevant entity that has relations not only to Society, but also to all advanced technologies, including automation and information technologies. . According to Manuel Castells (1996), technology is not being developed in a social vacuum, but in a space of continuous flow. In this context, the relations between the entities technology, society and space are defined as a very dynamic and interactive process.

There is also the question of how to integrate systematically into the consideration the (mutual) impacts of ACT/ICT on Nature in general, and on the human habitable environment in particular. Namely, the impacts of advanced technologies are exponentially growing, not only concerning the number of people (and the levels of social entities), but also concerning the physical space to be influenced. Think, for instance, how automation – in different physical forms of advanced technologies – has influenced many aspects of SPACE around people:

- the shape of many human workplaces,
- the arrangement, functioning and structures of human dwellings,
- the paths and structure of communication and movement channels of people,
- the physical, chemical, biochemical, electronic, and also psychological and social "noise" around people,
- the ways of material and human transportation,
- the appearance of industrial and inhabited regions,
- the stability of natural eco-systems,
- the appearance and behavior of parts of natural environment due to the exploitation of natural resources (water, energy, coal, minerals, ores, energy distribution, irrigation and transport infrastructure,
- the possibilities to "invade" and to "control" the immediate and distant vicinity of the planet Earth,
- and finally, the human conceptions and imaginations of people about the space in general.

All these mentioned influences are not directly aimed at any (living) social entities, but are nevertheless of great human and social concern, so that they could be integrated (more systematically than before) into the discussion area of "Social Impact of Automation", eventually under the simple heading SPACE.

*4.3. Take a look at the future trends*

The third suggestion for further work in "Social Impact of Automation" relates to the future trends of key entities to be considered, as they are presented in Fig. 3. In this way, the forecasts for the new millenium in the field "Social Impact of Automation" are supported by forecasts from both, the technological and from the non-technical perspective.

*Future trends in ACT/ICT*

The technological perspective of forecasts is covered by a selection from the possible **future directions of development in ACT** which cover also a part of **ICT** (Table 5). These were, in part, extracted from the conclusions of the recent IFAC Technical Board Working Meeting (IFAC TB WM, 2001), one of the Memoranda from the World Engineering Convention (WEC, 2000) as well as some other sources (e.g. Kelly, 1994).

Table 5. Possible future directions of development in ACT (and ICT)

**New theories**
- complex and large systems
- hybrid and discrete-event systems
- fault-tolerant systems
- intelligent control

**New technologies**
- computers, information technology (embedded, hidden, ubiquitous computing)
- communication technologies (real-time voice, data, video accessible, anytime anywhere)
- advanced mechatronics
- micro- and nano-technology (including micro-electro-mechanical systems - MEMS)
- biotronics, optotronics, neurotronics

**New applications**
- control of large distributed systems
- overall control of manufacturing
- control of service enterprises
- smart products (cars, appliances, entertainment, personal assistants, medical systems and devices, etc.)
- autonomous systems (underwater, land, air and space vehicles)

*Future trends in Society*

Similarly, the non-technical perspective is covered by a selection of recent findings about the **future of work, future of organizations and future of societies** (Tables 6a, 6b and 6c). These are taken from many different sources given in references, from which the papers by Bullinger (2000), Meyer-Krahmer et al. (1998) and Dassen-Housen (2001) may be specifically mentioned.

Table 6a. Future of work

**Future of work**
- new forms of workplaces, including tele-work
- new (more flexible) structures of working time
- group work supported by ICT and ACT
- greater empowerment of employees
- working in global and multi-cultural settings, teams and networks
- great work dynamics (with more stress)
- employees as micro-entrepreneurs
- increasing trends for both, professional and personal excellence and integrity
- high job mobility
- parallel jobs/tasks (multi-jobs)
- high integration (broader content) of tasks within particular jobs or workplaces
- frequent changes in job orientation, structure and contents
- integration of work, learning, teaching and living
- new forms of job training and qualification
- more free / leisure time
- higher quality of life

Table 6b. Future of organizations

| Future of organizations |
|---|
| ➢ developing regional structures and networking |
| ➢ globalization of business |
| ➢ high integration in production |
| ➢ complete service orientation |
| ➢ complex customer-supplier chains |
| ➢ product-line oriented manufacturing |
| ➢ minimization of material buffers between processing stages |
| ➢ just-in-time delivery of goods |
| ➢ virtual organizations/enterprises |
| ➢ "mega-corporations" |
| ➢ ICT supported business |
| ➢ knowledge as the main asset of organizations |
| ➢ high efficiency of production, farming, ... |
| ➢ (business) excellence, continuous improvement, quality circles |
| ➢ cutting-edge competitiveness |
| ➢ global (trans-national) strategic alliances |
| ➢ high control of industrial and communal "metabolism" |

Table 6c. Future of societies

| Future of societies |
|---|
| ➢ global impact (and possible interventions) of trans-national organizations and institutions |
| ➢ globalization of social structures |
| ➢ regionalisation and emphasis on greater subsidiarity |
| ➢ world-wide democratization |
| ➢ global openness of most societies |
| ➢ partial unification of social norms, culture |
| ➢ highly valued independence of various social entities, in spite of their greater interdependencies |
| ➢ greater control over individuals, families and organizations |
| ➢ partial transparency of governments and public services |
| ➢ greater differences between poor and wealthy |
| ➢ high respect for physical, economic, organizational, political and spiritual freedom (personal integrity) |
| ➢ high public concern for better natural environment |

*Future trends in Space*

In addition to citing Castells (1996), another part of these trends may be illustrated here by the positive vision of already mentioned sustainable development as it is expressed in words of the Bruntland Commision. According to this source, sustainable development means "... to meet the needs of the present without compromising the ability of future generations to meet their own needs." In this context, the dimension of SPACE (or physical environment) plays a critical role. Future developments in this area will therefore be strongly related to general acceptance of the sustainable development paradigm (FAW, 1998).

## 5. CONCLUSIONS

The presented survey of the past work confirms the fact that the area of "Social impact of automation" can be considered mature and has remarkably contributed to socially more acceptable automation and related systems. On the other hand, fast changes in the development of advanced technologies and their impact on society, as well as global changes within the societies themselves, require new actions. First, the work in the area should be intensified; second, there is a need to look at the social impact of automation from an even wider perspective than before; and third, the future development trends (as indicated by the recent IFAC TB Working Meeting and also Table 6) must be considered now, to hopefully prevent undesired consequences in the future.

**Acknowledgments**: This research has been funded by the Slovenian Ministry of Education, Science and Sport.

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