Industry 4.0– Where Does This Leave the Human Factor?

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Abstract

Industry 4.0 is the new buzzword in the manufacturing industry. It comprises the entire value chain process in manufacturing goods and providing services. The designers of the concept appear to have a good grip on the technology (hardware and software) of the system, however, the human factor seems not to be considered adequately. Humans are involved everywhere: as a team of system designers, a groups of workers and our society as the clients of the manufactured goods. The requirements and needs of each individual involved in the process should be included in the system by means of a modified mediation process. A mediator acts as a facilitator to assist communicating needs and requirements amongst everyone involved. By creating the ownership in the system acceptance is achieved. This process allows society to actively influence and control the design and the use of the Industry 4.0 concept.

Keywords: *Industry 4.0, Human-Machine Interface, Human Factor, Mediation, Needs, Cyber Physical Systems*

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Introduction

Industry 4.0 or 4th Industrial Revolution is a new buzzword in many parts of industries manufacturing goods and distributing services. The idea behind the concept is to connect not only all elements of the value chain process itself into one single system but to include many parts of our day-to-day life as consumers. All elements are connected through "smart" information technology systems. The so called "Internet of Things" is part of that system. In the future, our fridge already orders foodstuff before we have even thought about what to add to our shopping list.

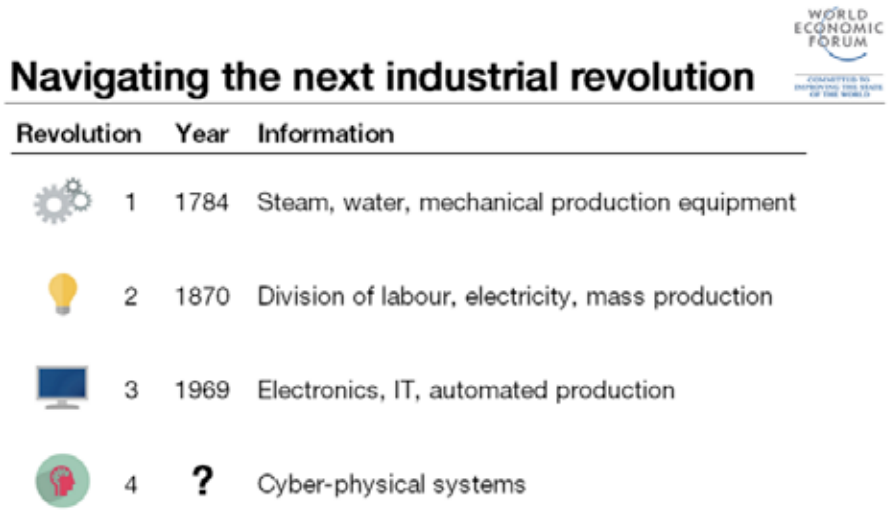

Figure 1. Industrial Revolutions (Schwab, 2016).

We have seen a number of industrial revolutions in the past, starting from the time when steam power was introduced in the second half of the 19th century. The invention of electricity established other new technologies in the late 19th century. The early 20th century saw the launch of the assembly line into the manufacturing process and later, in the second half of the 20th century, the computer controlled manufacturing process changed the industrial world again (see Figure 1).

All these revolutions have changed our societies and the way we live. Workers had to adapt to the new systems and acquired new skills. Globalization is a part of that last big change. Due to the availability of worldwide instant communication and a global logistics infrastructure parts of manufacturing lines could be outsourced to factories on the other side of the world.

According to industry experts we are now experiencing the next industrial revolution, the 4th one (Schwab, 2016). The term *Industry* 4.0 was first used by a group of expert at the Hannover Fair in April 2011 (Kagermann, Lukas & Wahlster, 2011). According to some experts (Happacher, 2013), the idea is based upon the concept of the computer integrated manufacturing (CIM), developed in the 1970ties. So called Cyber-Physical Systems (CPS) are operating in a self-organized and decentralized manner but are interlinked with other members of the chain by means of

information technology (IT). Some other key words that are often cited in connection with the 4th Industrial Revolution are:

- Big Data
- Cyber-Physical Systems (CPS) and Cyber-Physical Society (CPSoc)
- Internet of Things (IoT)
- Smart Manufacturing Environment, Smart Factory
- Hyper-Connected Society and Economy
- Ubiquitous Computing
- Urban Computing and Urban Visualization

For those of us not directly involved in these technologies these keywords may cause a certain degree of anxiety. Often the meaning of these expressions and abbreviations are a bit fuzzy and their exact meaning might not be known even to the people using them.

The rationale behind the *Industry* 4.0 development undeniably does have its benefits. *Industry* 4.0 is not only designed to streamline the manufacturing process and make it more cost effective. The idea is also to save energy and other valuable resources such as raw materials and natural resources. In theory the entire process is designed to run more or less in a closed loop. Whatever materials can be regained will be recycled and fed back into the process. All processes are interconnected to each other by exchanging data back and forth. The so called "Internet of Things" is part of the idea. It allows our clothing to have little devices incorporated that measure the amount of wear and reports it back to the manufacturing plant for them to produce a replacement in time. Ideas such as Urban Computing, Urban Visualization and the use of Big Data (collecting and using a large amount of data from all areas of our lives) are used to steer and engineer an entire society or parts of it. System designers claim that this is for the benefit of us all. Is it? For some this sounds scary.

The Neglected Human Factor

When I started to talk to *Industry* 4.0 experts on congresses and conferences I first observed a high degree of enthusiasm. I got the feeling that the new system had been invented by people deeply in love with systems, processes, with analysis and computing algorithms, with software and hardware. Sometimes technology for technology's sake seems to be their prime motivator. Then I asked those experts at which point of their concept they had included the human factor and the answer these experts gave was not really satisfying. Often it seemed that the consideration of humans or the human factor was nowhere to be found on their list of functional specification requirements.

A quick analysis of the scientific literature using the Scopus database (www.scopus.com) reveals that the human factor obviously only plays a marginal role amongst *Industry* 4.0 experts (as of August 9, 2016):

- Keyword "Industry 4.0": 630 occurrences
- Keywords "Industry 4.0" AND "Human Factor": 33 occurrences (5%).

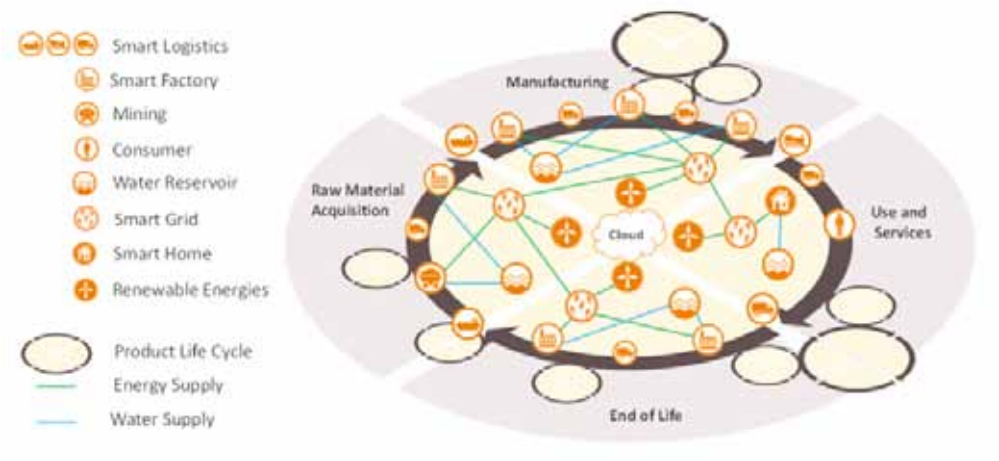

Figure 2. Macro perspective of Industry 4.0 (Stock und Seliger 2016).

Figure 2 depicts one example of the concepts of the *Industry 4.0* design. In this system, humans only play a role as the "Consumer". Everything else appears to work entirely without any human intervention.

Studies dealing with automation and mechanization in other areas also mention a lack of considering the human factor in the design-phase of the systems. During my research on automation and system design in the offshore oil and gas industry I came across a Norwegian study named "A study of a technological development process: Human factors – the forgotten factors?" (Saetren, Hogenboom & Laumann, 2016). One of the central messages of the study is about omitting the human factor:

> "The complexity of the project may have contributed to the failure to conduct human factors analyses."

Likewise the German economist Klaus Schwab recognizes that the human factor should be part of the equation. In his article (Schwab, 2016) he sends a clear message:

> "In the end, it all comes down to people and values. We need to shape a future that works for all of us by putting people first and empowering them. In its most pessimistic, dehumanized form, the fourth industrial revolution may indeed have the potential to "robotize" humanity and thus to deprive us of our heart and soul."

However, he and many of his colleagues do not provide answers to the questions: how can people be part of the system? How can the human factor be included in the design and how can people gain ownership in the concept? How can society gain control in order to shape the new system so that we all benefit from it?

Industry 4.0 and Humans: Where are the Interfaces?

Each technical or industrial system has humans involved at some point. Often, however, the interfaces are not clearly defined. Everybody recognizes immediately

that there are people in front of the computer screens or workers operating the manufacturing machines. Also, the customers of the manufactured product are part of a manufacturing process, often just know as "the client". In the case of a complex system such as the *Industry 4.0* concept, the entire society is at the "output" end of the automated manufacturing process.

Systems do not (yet?) create themselves. There are teams of experts behind every new idea and very specialized engineers and software designers are required to convert the ideas into a working software. What do we know about these teams, what about these people who create something that will massively influence our daily lives? How do they know what we need?

Complex Systems Communicating with Humans

Modern workplaces in a technical environment usually contain an interface between humans and a machine. Following a definition by Kramer and Zimolong a machine is a device made by a number of technical components (Kramer & Zimolong, 2005). Within a machine, there are a number of interfaces designed to provide the communication of the control signals between all components, such as control lines, sensor signals or the commands of a computer based control system. A more complex machine or the combination of machines can be called a system.

This system communicates with the human being(s) by means of a user interface. This may consist of gauges and control lights or, more likely today, of a computer screen. In return, the human controlling such a system enters commands by pressing buttons or using keyboards and control sticks. Timpe and Kolrep include the component "human" into a technical system and call this component "socio-technical component" (Timpe & Kolrep, 2002).

The System User(s)

A conventional human-machine interface as described in Helander can be seen in Figure 3. (Helander, 2006). In view of today's complexity of control systems it seems to be somewhat oversimplified.

First of all often there is not only just a single person communicating with the system. Typically a group of people is involved (see Figure 4). This group of individual humans follows sociological group dynamics. Each individual member of the group interacts with the group as well as with the machine. Each individual member of the group has a unique personality, has different moods that may change throughout the day and brings a distinctive set of capabilities to the table.
It is a challenge for any system designer to predict exactly how the group will react, in case anything unusual is happening, due to the way the group communicates and interacts.

The System Designer(s)

This brings us to the system designer. The system is not just "God given" instead it is usually a result of a very complex engineering design. In complex systems, such as the ones that will be used in the *Industry 4.0* concept, the system is designed

by a team of engineers and software designers. Same as the group in front of the computer system (the "users"), the team is made up of individuals. Every member of the team comes with their particular expertise and their unique set of competencies and abilities to communicate. This process in itself is already a challenge. Not only the hard- and software has to properly interact with each other. The information technology engineers responsible to keep the hardware running need to understand the requirements of the software designers and vice versa.

Now we are adding another layer to the complexity of the system. How does the team designing the entire system make sure that they are doing the right thing? How do they make sure that the system they are setting into operation is matching the requirements of the group of users? How do the designers make sure that they include unusual reactions from one of the user group members in their design so that the system works flawlessly?

We have all heard of system failures and accidents in which an accident evaluation team stated "human errors" as the root cause for the disaster. Is this really a root cause or possibly a design flaw? Was the system really ready to include the human factor in a way that the human error was accounted for?

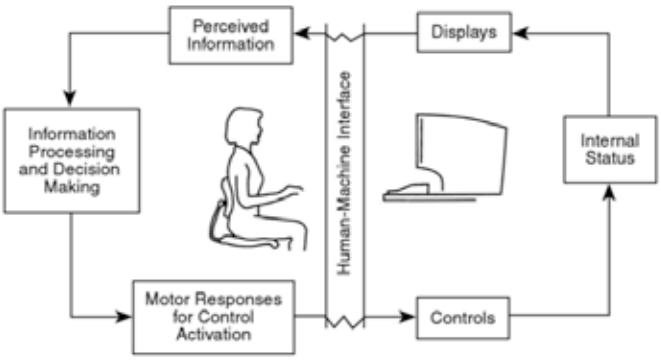

Figure 3. The human-machine interface described by Helander (Helander, 2006).

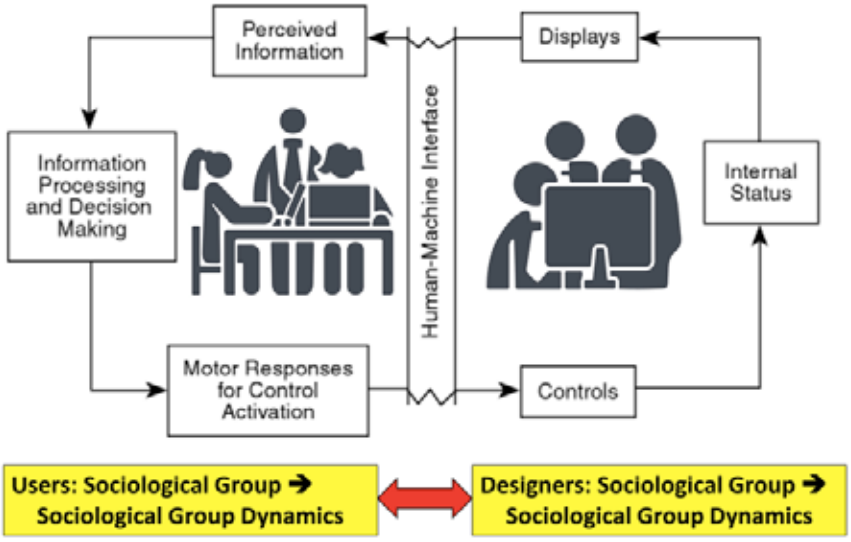

Figure 4. Human-Machine Interface with sociological groups involved on the user and the designer side, adapted from Helander (Helander, 2006).

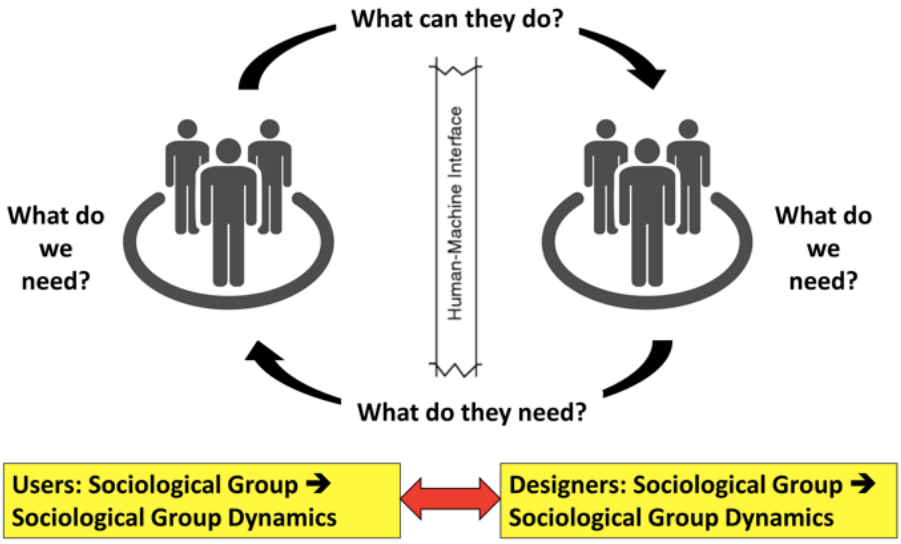

Figure 5. Communicating the factor "needs" within the teams and between them.

The Client(s) = Society

At the end of each manufacturing process there is a client or a group of clients. Marketing and business development specialists evaluate the expectations and requirements of the clients and report that back to the manufacturing place. In the case of the complex *Industry 4.0* concept this covers a large sector of our lives. Data collection is automatized and is done by computer algorithms which again were created by system designers and software engineers. We already face these systems in our everyday lives by so called "personalized" advertisements during the use of the Internet. Are these algorithms really able to reveal our needs? Is this the way that we want to be a part of the entire system? The client base here is not only single customers but it is our society.

So why do we need to include the Human Factor?

As a consequence we need to make sure that the sociotechnical component *"group of humans in front of the control system"* (= on the left side of the human-machine interface) and the sociological *"group of humans that design the interior of the system"* (= the group responsible for the right side of the human-machine interface) need to be included in the system design (Kinzel, 2016). In an ideal world both groups, users and system-designers need to talk to each other. The system designers need to find out the user's requirements.

A third group of people to be taken into account is the client group. *Industry 4.0* turns a large part of our society into that group. This group also needs to be an active part of the system. So, what are the issues if the human factor is not taken into account? How will the system be affected? What are the hazards if the designers of the systems neglect the users and the way they act? The answer to this question lies in the psychology of human beings. It has to do with motivation, understanding, the feeling of being part of the group, of being included.

Needs and Motivation

In 1943, Abraham Maslow, a pioneer in motivation research, defined the basic needs that drive all human beings as follows in this article titled A Theory of Human Motivation (Maslow, 1943):

- Fundamental physiological needs (e.g. food, air, water, shelter from the elements, sexuality)
- Safety and security needs (stability, protection, order)
- Love and belongingness needs (love, belonging, affection)
- Esteem needs (self-respect, esteem of others, prestige)
- Self-actualization ("What a man can be, he must be" – Maslow)

Maslow puts these needs into a hierarchy in a way that he claims, that, once the needs of one level are fulfilled, the fulfillment of the next level is the next goal. Human beings, whose fundamental physiological needs are satisfied will seek to establish a safe and protected environment. Once this environment is assured, he or she will seek to satisfy the love needs.

In 1970, Maslow further detailed the hierarchy of needs by adding two additional classes of needs between the love needs and the esteem needs (Maslow, 1970):

- Cognitive needs (knowledge, meaning)
- Aesthetic needs (appreciation of beauty, balance)
- Additionally, on top of his hierarchy, Maslow added the transcendence needs, which is the desire to help others to achieve self-actualization.

Often, the Maslow hierarchy of needs is depicted as a pyramid as in Figure 6.

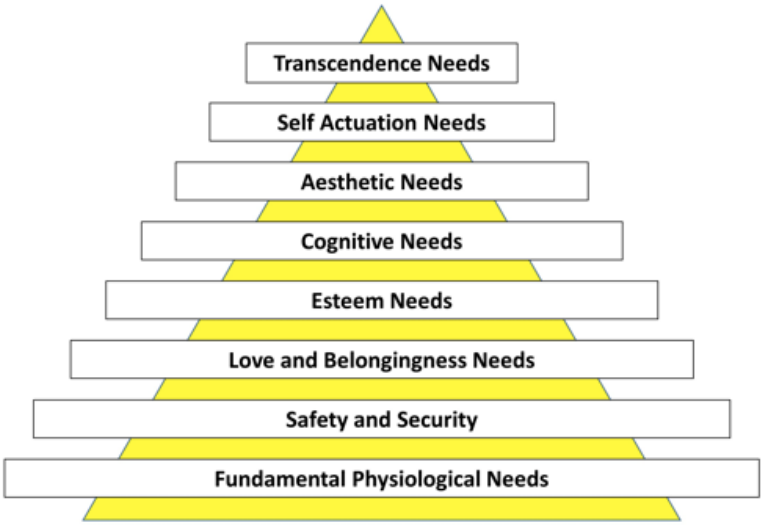

Figure 6. Maslow's Pyramid of Needs, adapted from Maslow (Maslow, Motivation and personality 1970).

Neglecting the Needs Results in Conflicts

According to the psychologists and their research, human needs are an important motivator. Not considering the humans in a technical system will have impacts on the system performance and the system's ability to function safely. Neglecting the human factor in a complex system such as the *Industry 4.0* might lead to a complete breakdown of the concept.

The Industry 4.0 concept, as it has been presented, will change the way we live and work. According to some designers of this concept the remaining workers who still operate the system need to acquire new competences. Others will probably no longer be needed because many of the roles that humans play in today's manufacturing plants will be replaced by computer systems. Most of the workers currently working in any of the fields touched by any of the components of the *Industry 4.0* concept will see changes in the way they work. In order to satisfy the needs of these people they need to understand the new requirements and need to recognize any benefits for them ("What is in it for me?"). The key is to engage those people (=the human factor) in the new processes as soon as possible (Edwards & Ramirez, 2016).

Empowerment and Ownership Creates Acceptance

As we all know from our own/personal experience, often when we try to forbid our children to do something without any explanation, there will immediately be an urge of the children to want to do the forbidden thing. This is a natural human reaction. It has been described by psychologists and is called psychological reactance (Miron & Brehm, 2006). If an individual feels that he or she is forced to deviate from their free will, there is a strong motivation not to follow these orders.

The key word here is the free will; the ability of an individual to follow his own will, which is a very strong motivator. Therefore, in order to make sure that people who in any way are connected to a new system such as *Industry 4.0* need to be able to be part of the system. They need to feel like they were a part of designing the system and that their needs were taken into consideration. It does not matter if this individual is a member of the design team, a member of the operating team or someone who is in any other way influenced by the system. Important is that the person feels some kind of ownership in the complex system and that he or she understands the design concept behind it.

The designers of any system such as the *Industry 4.0* concept need to consider this desire to be involved. Involvement creates ownership and acceptance. Without this acceptance the system will fail.

Human Factor Specialist: A Mediator?

How can the needs of everyone involved be considered? How can the human factors of all individuals be taken into account in the system design? How can conflicts amongst the team members, either of the design team or the team of users, be managed and mitigated?

Possibly there are multiple solutions. The call for assistance of a human factor specialist, as suggested by Saetren et al. (Saetren, Hogenboom & Laumann, 2016)

seems to be one of the more promising solutions. Additionally, the introduction of a process is helpful. The mediation process, traditionally designed to solve conflicts can be adapted and can be used in conflict prevention and also be used to assist to introduce the human factor into system design (Kinzel, 2016).

Mediation as a Process to Mediate Changes

Mediation is a well-established method to resolve conflicts. Mediation is a structured process in which an independent third party, the mediator, assists two or more conflict parties to identify the cause of their conflict and to develop and agree on a sustaining solution. The mediator will establish the communication between the conflict parties and guide them through a number of phases. Crucial for the process is that the conflict parties start an open and preferably creative conflict solution dialog. They need to be able to listen to the other sides and understand the requirements and needs of their opponent (Kessen & Troja, 2009). Often, the process of mediation follows a structure that can be divided into the following phases (Kracht, 2009):

- Preparation of the process
- Statements of positions, collection of subjects to be discussed
- Determining the underlying needs of all conflicting parties
- Creative development of several options to solve the conflict
- Joint assessment of these options
- Mutual agreement between the parties.

Figure 7 shows a simplified flow chart of this process. The important step is the transition between the positions of the conflicting parties to the needs. The theory states that if the underlying needs behind the positions of the conflict parties have been expressed and have been understood by the other party, this leads to the solution-finding phase.

Figure 7. Simplified flow-chart of the mediation process.

Mediators to Lead the Process

It depends on the style and personality of the mediator if, and how deep he is involved in the solution finding process. In an ideal world, the mediator is completely neutral and he or she is just conducting the communication process. In the real world, the mediator often helps to overcome obstacles in the solution finding process and even expresses his own opinion about a possible way to success, especially when asked by the conflicting parties. However, it is important that the mediating person stays neutral and impartial or, as it is also defined, he or she is an "all-party" mediator, meaning, that the mediator is valuing the interests of all parties as well as the mediation process. The mediator should never have the power to enforce any solution. The agreement on how to solve the conflict is the sole responsibility of the conflicting parties. The mediation methodology and the mediation process might not directly be applicable to world of complex processes such as the *Industry* 4.0 concept. However, ideas have been developed to adapt the mediation process in order to get people involved in processes so that they increase their ownership in the process design (Kinzel, 2016).

Figure 8. Communicating the needs amongst the groups involved in the Industry 4.0 concept.

Solution: Involve All Parties Concerned

Using the adapted mediation process we do have a tool available to communicate and consider the requirements and needs of all parties involved. The goal of this process is to develop a joint solution. Ideally the human factor specialist has a training and experience as a mediator.
In the case of *Industry* 4.0 this allows that all parties concerned are part of the mediation process:

- System designers and developers
- System users = Workers
- System clients = (parts of our) Society.

All of them can express their needs, develop joint solutions and thus eventually have ownership in the new system(s):

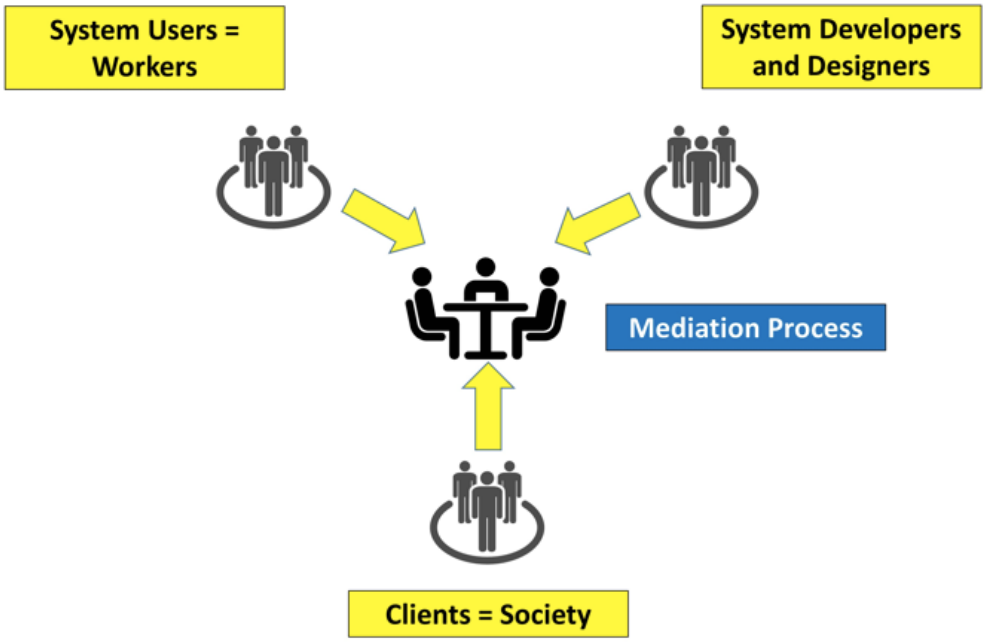

Figure 9. Communicating the needs and requirements amongst all involved, creating understanding, ownership and acceptance.

Conclusion

Industry 4.0 is the new buzzword in many parts of the producing industry. It involves the entire value chain process in manufacturing and producing goods and providing services. The idea behind this "4th industrial revolution" is to connect all elements of the value chain process into one single system. All components of the system are connected through "smart" information technology systems. The so called "Internet of Things" is part of the system, in which our fridge already orders foodstuff before we have even thought about what to add to our shopping list.
It seems as if the system designers commonly fail to include the human factor in the equation. They appear to be deeply in love with their systems, processes, with analysis and computing algorithms. Sometimes technology for technology's sake seems to be the prime motivator to work on these systems. Humans or the human factor do not make it to the list of system specifications.

Humans want to be involved, they want to understand what is going on and they want to be in charge of their lives. They need to see that they are able to communicate their own basic requirements and needs and that those are taken seriously. Currently the *Industry* 4.0 concept seems to be at a stage where a lot of people are skeptical about the new technologies, although some of the ideas and concepts behind the Big Data system are already in place, influencing our daily life. If the human factor is not included in the *Industry* 4.0 concept this 4th Industrial Revolution might end as other industrial revolutions have ended: people are being left entirely out of this process or at least they feel they are not really belonging to it. It might lead to frustration, the feeling of being excluded from society, which further leads to instabilities in our societies worldwide.

In a recent BBC documentation about Big Data and their influence on society, the Oxford Professor Luciano Floridi says (Frey, 2016):

> "We should be worried about what to do with these smart technologies, not about the smart technologies in themselves. They are in our hands to shape our future. They will not shape our future for us."

We need to take control of the systems before they can gain control over us. The proposed adapted mediation process allows everyone concerned to express their needs and requirements amongst everyone else involved. By creating the ownership in the system, acceptance is achieved. More importantly, this process allows society to influence and actively control the design and the use of the *Industry 4.0* concept.

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