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Steven Alter
University of San Francisco, alter@usfca.edu

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HOW FACETS OF WORK ILLUMINATE SOCIOTECHNICAL CHALLENGES OF INDUSTRY 5.0

Research paper

Alter, Steven, University of San Francisco, San Francisco, USA, alter@usfca.edu

Abstract

This conceptual contribution explains how the idea of "facets of work" can refocus traditional sociotechnical concerns to increase their relevance in increasingly automated and digitalized workplaces far removed from situations studied by early sociotechnical researchers. A background section summarizes how the sociotechnical approach seems pervasive but possibly outdated in some ways. It explains how the idea of "facets of work" emerged from attempting to bring richer, more evocative ideas to systems analysis and design. Focusing on facets of work during initial discussions of requirements could provide guidance without jumping prematurely to precision and notation needed for producing technical artifacts. Tables with one row for each of 18 facets or one row for the first 9 (reflecting length restrictions) illustrates that the 18 facets 1) point to areas where the coexistence of people and robots in workplaces poses challenging sociotechnical issues, 2) apply to both sociotechnical and totally automated systems, 3) are associated with specific sets of concepts, 4) bring evaluation criteria and design trade-offs, 5) have useful sub-facets, and 6) imply open-ended questions for starting discussions. The conclusion summarizes this paper's contribution to understanding challenges of Industry 5.0 and discusses next steps in developing and applying its ideas.

Keywords: Facets of work, Industry 5.0, Work system theory

1 Work Is Work even if Done with or by Robots

The advent of industry 4.0 seems like yesterday, but now the CFP of the Sociotechnical Perspectives Track of ECIS 2020 contemplates the next stage: "The advent of Industry 5.0, the human-robot interaction frontier, and the immersive technology era call for a deep rethinking and a new gaze on the unexpected and sustainable ways to shape our lives, environments and society." The CFP asks "what artificial intelligence and extreme automation would bring in human existence, workplaces, and professions? What are the models, languages, interfaces and organizational settings of human-robot interactions and collaboration? What are the infrastructural, configurational and organizational challenges, roles and knowledge at play?"

An obvious answer to those difficult questions is implied directly by almost any attempt to describe how well either experts or non-experts anticipated positive and negative consequences of sociotechnical developments in the last 20 years, such as social media, cloud computing, machine learning, facial recognition, and surveillance capitalism (Zuboff, 2015). The obvious answer is that the many future interactions between social, technical, regulatory, and application unknowns imply that no one has a reliable approach for answering those questions. Experts and non-experts in industry, government, or academia can extrapolate from the last 20 years, can speculate about important quandaries, can do Delphi studies, or can use other approaches. They might identify interesting issues and further questions, but it is quite unlikely that they will be able to predict the future reliably.

A more modest approach. Instead of proposing a direct answer to some of the CFP's questions, this paper contributes to the discussion of a sociotechnical perspective in an era of Industry 5.0 by describing a way to look more deeply at the nature of work, regardless of how "labor" is divided between people and robots in specific situations and regardless of whether the work situation occurs today or 10 or 20 years in the future. Extending a previous definition in Alter (2013b, p. 82) it treats work as the application of human, technical, informational, and/or other resources to produce results that are meant to be useful within an enterprise, to the customers of an enterprise, to parts of related business ecosystems, and/or to society as a whole.

This paper proposes the idea of "facets of work" as an organized approach for understanding more about what a sociotechnical perspective on Industry 5.0 might entail. That idea grew out of a combination of concerns from otherwise unrelated research projects, one about types of subsystems of work systems, one about techniques that reflect different purposes of enterprise modelling, and several concerning capabilities. As explained in Alter (2019a), the resulting idea of facets of work is best illustrated through a series of tables that summarize important topics related to specific facets of work. Those facets are directly relevant to Industry 5.0 because initiatives under that umbrella will address some of the facets and probably will ignore others that should be considered from a sociotechnical perspective. Many Industry 5.0 initiatives could encounter difficulties or even failure if they ignore or underplay a variety of sociotechnical realities related to specific facets of work.

Applying facets of work to Industry 5.0 situations is straightforward. Look at any situation involving work performed by any combination of people and robots. Describe the various facets of work that are relevant to that situation, such as making decisions, communicating, processing information, coordinating, etc. Look at the positive and negative aspects of each facet of work, possibly while considering some of the knowledge built into tables such as those in this paper, and think about how to improve the situation. Seeing those issues from a sociotechnical viewpoint would call for much more than a purely mechanistic approach of assuming that people are like robots, only with different capabilities and different forms of agency – including noncompliance. A sociotechnical perspective could make the suggestions more interesting, valuable, and humane because it would call for honouring the humanity and personal values of the people involved in the situation.

Goal and organization. This paper is a conceptual contribution that pursues the following goal:

> Show how the idea of facets of work is potentially useful for analyzing, designing, or improving work systems in which consequential actions, responsibilities and agency are shared between human participants and computational and/or physical robots.

This paper pursues that goal by explaining the idea of facets of work, identifying 18 facets that are often important to consider, and showing that facets of work is a potentially valuable approach for analysis related to some of the challenges of Industry 5.0. The next section summarizes the background in four areas, 1) Industry 5.0, 2) the sociotechnical perspective, 3) the work system perspective, 4) the sources of the idea of facets of work. The subsequent section uses tables to identify 18 facets of work and to show some of the ways in which consideration of various facets could help in understanding almost any situation involving division of labor between people and robots. A conclusions section notes that situations with human and robotic workers call for extending the sociotechnical perspective in the direction of the work system perspective and facets of work.

2 Background

This section provides background in the following areas: Industry 5.0, sociotechnical perspective, work system perspective (WSP), and sources of the idea of facets of work.

2.1 Industry 5.0

A fundamental issue regarding Industry 5.0 is the difficulty of separating research, punditry, consulting hype, and science fiction. Industry 5.0 generally refers to work being done cooperatively by people and physical or computational robots, with various twists related to specific personal or commercial interests. A white paper from the consulting firm Accenture (Adoob and Quilligan, 2017) uses the term Industry X.0, perhaps to avoid seeming outdated when Industry 6.0 comes along. That white paper says, "Industry X.0 is the digital reinvention of industry. Industry X.0 businesses embrace constant technological change—and profit from it. They move beyond experimenting with IT bundles or SMAC (social, mobile, analytics, cloud) stacks, combining digital technologies to drive both top-line and bottom-line growth. Industry X.0 businesses incorporate Industry 4.0's core operational efficiencies, but also leverage combinations of advanced digital technologies to continuously create new, hyper-personalized experiences in both a business-to-consumer and business-to-business context." A quite different approach to key aspects of Industry 5.0 was expressed by the title and content of a 2-day IFIP 8.2 workshop, "Living with Monsters? Social Implications of Algorithmic Phenomena, Hybrid Agency, and the Performativity of Technology." (Schulze et al., 2018).

The difference between the Accenture description of Industry X.0 and the IFIP workshop title exemplifies the tendency for descriptions of Industry X.0 (for almost any X) to emphasize management concerns such as efficiency, effectiveness, and competitive advantage, but make little use of sociotechnical thinking, ignore substantial risks related to the interplay of people and robots, and say little about how the work will change. What are dimensions of changes in the division of labor? Will changes in some areas reinforce or degrade changes in other areas? And what are those areas anyway?

2.2 Sociotechnical Perspective

The sociotechnical perspective often seems to be taken for granted as little more than considering both people and technology when thinking about organizations, system, and work. Related viewpoints and interpretations show that the reality is more complicated. Sarker et al. (2019) review papers in *MISQ* and *ISR* between 2000-2016 and argue that IS research has lost sight of the discipline's sociotechnical character. Beyond editorial choices by two journals, some of the underlying issues probably stem from the way the STS perspective has evolved over seven decades. Eason (2014, p. 234) describes a possible dilution to "a banner under which many different concepts and design principles can flourish that have little relation to one another." Aspects of those issues are related to the evolution of significantly different North American, Australian, Scandinavian, and Dutch variants on sociotechnical theory and practice (van Eijnatten, et al., 2008), plus distinctions between sociotechnical theory (STS-D), design (STS-D), and change (STS-C). (Austrom and Ordowich, 2016).

Mumford (2006, p. 317) sees STS design as "more a philosophy than a methodology," … Its two most important values are "the need to humanize work through the redesign of jobs and democracy at work" (p. 321). "Although technology and organizational structures may change, the rights and needs of the employee must be given as high a priority as those of the non-human parts of the system" (p. 338). While emphasizing values, Mumford (2006, p. 321) spells out a complex method for STS design involving 'the joint optimization of the social and technical systems." That idea is problematic because the social system and technical system overlap greatly (e.g., processes are social and technical, information is social and technical, and even technology seems social in today's world of social media and BYOD - bring your own device). Difficulty defining or separating social and technical systems undermines the notion of joint optimization. The idea of optimization does not fit because a plethora of factors makes it unlikely that anyone would try to find a genuinely optimal solution. Fit, alignment, satisficing, or negotiated truce could be more appropriate images. The traditional sociotechnical concern for human welfare is more ambitious than that.

Perhaps more important, the assumption about the separate existence of a social system and technical system simply does not ring true in today's business world regardless of the interests and preferences of the sociotechnical community. In today's world, increasing digitalization and automation allow forms of computation, control, surveillance, remote work, and outsourcing that are very far removed from the sociotechnical examples of decades ago and might have seemed like science fiction only 20 years ago. Going forward, the sociotechnical perspective may need to be reframed to maintain focus on the values mentioned in Mumford (2006) while addressing many evolving issues related to work.

2.3 Work System Perspective

This paper describes the idea of *facets of work* in relation to the work system perspective (WSP), i.e., thinking of systems as though they are work systems. The WSP includes work system theory (WST) and the work system method (WSM), which have been described in detail many times (Alter, 2006, 2008, 2013b, 2015), plus various extensions related to workarounds, services, design principles, system interactions, and other topics beyond the current scope. Sociotechnical researchers have used the idea of work system for decades (e.g., Trist, 1981; Sinha and Van de Ven, 2005; Mumford, 2006), and it appeared prominently in the first edition of *MIS Quarterly* (Bostrom and Heinen, 1977).

WST defines work and work system carefully in order to support the goal of helping business and IT professionals visualize systems and collaborate around analyzing, designing, and improving IT-reliant systems in organizations. Work was defined in the introduction. A work system is system in which human participants *and/or* machines perform work (processes and activities) using information, technology, and other resources to produce products/services for internal and/or external customers. Work systems (WSs) operate within an external environment that matters, rely on shared human, technical, and informational infrastructures, and may or may not be guided by explicit strategies. An organization can be described as a set of WSs whose operation and interactions maintain the organization and produce its product/services. The concept of WS is a general case whose many special cases including ISs, service systems, supply chains, projects, and totally automated WSs. For example, an IS is a WS most of whose activities are devoted to capturing, storing, retrieving, transmitting, manipulating, and/or displaying information. Inclusion of both sociotechnical and totally automated ISs and service systems requires the inclusion of the first *and/or* in the definition of WS. That inclusion is necessary for complete and flexible analysis of Industry 5.0 systems even though the situations that inspired early sociotechnical insights many decades ago could be described and analysed without it.

Said in a different way, the definitions of work and work system lead to two assumptions that could help in adapting traditional sociotechnical ideas to an era of Industry 5.0. First, a work system can be sociotechnical (with human participants) or totally automated. (Note that analysts, designers, and other who specify or create work systems often are not participants in those work systems. Rather, they are participants in separate work systems that create work systems.) Second, regardless of whether joint optimization remains as a slogan that is taken for granted by experienced consultants, the frequently repeated notion of joint optimization of social and technical systems within a work system cannot be taken literally due to issues mentioned above concerning Mumford's (2006) analysis of the state of the sociotechnical perspective in 2006. Those two assumptions are stepping-stones toward analyzing Industry 5.0 situations as an integrated work system involving people and robots or other machines.

2.4 Sources of the Idea of Facets of Work

The idea of facets of work grew out of research attempting to bring richer and more evocative concepts to systems analysis and design (SA&D) in order to expand its scope and facilitate analyst/stakeholder interactions. A key goal was to provide useful guidance to process- and system-related discussions without requiring attention to burdensome details, precision, and notation that are useful after initial understandings are attained. Ideas explained in this paper grew out of conceptual leaps spanning partial overlaps between separate research efforts rather than through a structured literature review, research gap analysis, or other more typical research approach. Those conceptual leaps might represent the type of intellectual freedom that Grover and Lyytinen (2015, p. 286) described in *MISQ*.

The first leap involved the realization that the idea of "an overarching modelling metaphor" (Ferstl and Sinz 2013) that guided modelling research reported in Alter and Bork (2019) might be linked to previous research in Alter (2013a) that tried to develop an approach for applying metaphors in the broader IS discipline. The second leap was based on familiarity with the idea of capability-driven development (CDD), which led to realizing that *system capabilities* fit as the second item in a sequence of increasingly focused models of an operational system. The third leap came from thinking about different degrees of specificity in producing models embodying any specific type of modelling focus, which led to the idea of *facets of capabilities* (Alter, 2019b). The fourth leap came from recognizing that limitations of facets of capabilities implied that *facets of work* would be a more useful central metaphor for achieving the purposes of the current research.

That progression can be summarized as follows: Previous research on system-related metaphors (e.g., Morgan (1986), Oates and Fitzgerald (2007), Winter and Szczepanek (2009), Kendall and Kendall (1993)) inspired the identification of 8 types of generic subsystems of work systems described in Alter (2013a). The generic subsystems approach was not developed further, largely due to the common expectation that subsystems should be contiguous and non-overlapping. The current research builds on the earlier ideas by re-imagining and expanding the generic subsystem types into 18 facets of work.

The idea of *facets of work* expands on the earlier idea of *facets of capabilities*, which itself emerged partly from an attempt to address problems with formal modelling methods noted by Sandkuhl et al. (2018), van der Aalst (2012), Karagiannis (2015) and many others, as discussed in Alter and Bork (2019). Subsequent discussions related to the idea of capabilities led to concluding that it is a valuable idea for many purposes, but that its connotation of not involving process details is too limiting for the purposes of the current research. That led to moving from *facets of capabilities* to *facets of work*.

Meanwhile, the idea of facet had been used in many different ways in disciplines including computer science, information science, and psychology. Those uses are not directly related to this paper's notion of facet, which is based on an analogy to how a cut diamond has multiple facets. Google Scholar searches on "facets of work" demonstrate how that idea is almost totally absent from the literature. A Feb. 6, 2020 search on "facets of work" returned only 3480 hits, almost all of which were about other topics such as facets of work value, facets of work-life balance, facets of work autonomy, facets of work support, and facets of work method ambiguity. Note also that the term *aspect* might have been used instead of *facet*, but the term *aspect* also is applied in many ways in many different fields, e.g., aspect-oriented programming in computer science.

3 Facets of Work

This paper's approach to *facets of work* is based on a series of assumptions and choices.

- Work has many facets. For example, work related to hiring new employees in a specific situation has facets related to making decisions, communicating, processing information, and so on.
- Initial analysis of a situation can explore questions about facets of work without documenting operational details, performance levels, or other information that deeper analysis would require.
- The concept of *facet of work* is generic. I.e., the same facets and related ideas can apply to many different situations. The 18 facets mentioned in tables in this paper apply to work in many situations even though a given facet may not apply significantly to work in some specific situations.
- The facets of work are all related to activities rather than to actors, information, environments, or other resources. Other researchers might prefer to define facets in a broader way, e.g., facets representing different types of actors, information, technologies, or other resources, but that would probably diffuse the coherence of the idea of facets of work.
- Any particular set of facets of work, including the 18 facets presented here, might be improved through exposure, discussion, and application. The 18 facets discussed here were selected in a highly informal manner starting with ideas related to the 8 subsystems in Alter (2013a) and then proceeding iteratively by looking at articles and case studies and thinking about whether possible facets of work were missing. Deriving a formally justified set of facets in the future might be worthwhile if the idea of facets of work proves useful in practice or in research.
- The various facets of work can be applied for thinking about real-world activities, capabilities, processes, operational systems, and ecosystems. They also can be applied to widely discussed phenomena such as digital transformation and service digitalization whose practical meaning assumes that work is performed. Thus, the same ideas can be applied to many situations.
- The 18 facets were chosen because they are easily understood, widely applicable, and associated with concepts and knowledge related to business situations.
- Despite requiring that each facet should bring associated concepts and knowledge, there is no need for the facets to be totally independent. Facets of work may overlap in practice, as when making decisions in a situation involves processing information and communicating.

4 Tables Related to the 18 Facets of Work

The following tables identify 18 facets of work and illustrate various aspects of their potential applicability to bringing available knowledge to the analysis and design of systems in organizations today and in an Industry 5.0 world with greatly enhanced interactions between people and machines.

4.1 Challenges for a Sociotechnical Perspective on Industry 5.0

Table 1 identifies the 18 facets of work and shows that each facet is directly associated with operational challenges related to Industry 5.0. It is possible to speculate about Industry 5.0 in general without mentioning any of those challenges. However, looking seriously at how Industry 5.0 applies to specific situations requires attention to at least some of the topics identified as facets of work. A sociotechnical perspective on Industry 5.0 should pursue facets of work in an organized way. Not doing so makes it more likely that important topics and issues will be ignored or downplayed.

Facet	Several Industry 5.0 issues related to each facet
Making decisions	Which decisions will be made by people or by robots? What should happen if a person disagrees with a specific type of decision that a robot makes? And vice versa? How to make it more likely that decisions will respect human dignity and democratic values?
Communicating	How will people communicate with robots, and vice versa? How will people know whether their communication was understood correctly by a robot, and vice versa? (e.g., numerous false alarms that waste the time of hospital medical staffs). What are socially acceptable ways for robots to control human co-workers?
Processing information	How should the processing of information be divided between people and robots in specific situations? Will there be backups when robots go down or when people cannot keep up with information processing tasks? How will errors be detected on either side?
Thinking	How will the division of labor between people and robots avoid interfering with thinking by people? In what sense will robots be able to think in specific situations? How to reconcile inconsistencies or direct conflicts in results of thinking by people and by robots?
Representing reality	Many information systems represent reality in ways that are misleading, for example by providing inadequate options for coding problems or incidents. Misrepresentation of reality has caused fatal accidents involving self-driving cars. What will assure the accuracy of representations of reality produced or used by robots?
Providing information	In many business situations people complain that they are not informed adequately about information or situations they should know about. What will assure that robots will tell their co-workers and other people what they need to know in specific situations? And how will human workers know what robots need to know when exceptions occur?
Applying knowledge	Significant business situations typically require the application of general and/or specialized knowledge which may be tacit or explicit and codified or uncodified. How will knowledge be shared between people and robots? How will people know whether robots have sufficient knowledge, and vice versa, especially when exceptions occur?
Planning	Inadequate planning is often viewed as a reason for disappointing results even though there are some situations where improvisation is more important than planning. How will planning guide the work of people and robotic co-workers?
Controlling execution	Options for controlling the execution of work attempt to find appropriate trade-offs between inadequate control to excessive surveillance. How will people control execution of tasks by robots? Will working with robots require excessive surveillance of people?
Improvising	Performing work in many settings involves improvisations and workarounds when exceptions and other conditions require deviation from established practices. How will improvisation operate when humans and robots are co-workers? What controls will assure that the results are both ethical and beneficial economically?
Coordinating	Efficient and effective operation of an organization calls for coordination between people performing related tasks and/or sharing resources. How will that coordination occur when robots perform some of the related tasks? In particular, what methods can be used to program or teach robots to coordinate effectively with people?
Performing physical work	The importance of creating, modifying, moving, or adjusting physical things will not disappear. What types of physical work will humans perform? What will happen to people whose jobs and careers are based on largely physical work? How will people and robots perform physical work together without endangering either the people or the robots?
Performing support work	Process documentation often does not include support work (also called articulation work) that relies on human flexibility to help in coordinating, obtaining needed resources, and overcoming unanticipated obstacles in a timely manner. How could robots perform such tasks without asking too many questions of human co-workers? How can human workers learn to support work performed by robots?
Interacting socially	Inadequate social interaction degrades performance by reducing cooperation; excessive social interaction generates inefficiencies such as absorbing too much time. How can interaction design overcome the "uncanny valley," where artificial attempts at social behavior by robots that lack human emotions seem unnatural and untrustworthy?

Providing service	Most work activities contribute to outputs, actions, or conditions that facilitate benefits for others, implying that considering service aspects is often important. Other than maintaining robotic devices, how will people perceive and perform services directed at robots?
Creating value	Attention to value matters because outputs, actions, and/or conditions produced for others may not create value as intended. How will robots decide whether their actions produce intended value for intended beneficiaries? How will they adjust when failures occur?
Co-creating value	Increasing attention to value co-creation calls for observing the extent to which it really occurs and whether it might occur more efficiently or effectively. What is the meaning of co-creating value with robots if robots have no human-like emotions for assessing value?
Maintaining security	Many new threats have emerged due to the ease of accessing inadequately guarded digital assets. Privacy concerns and privacy regulations compound those issues. How will robots maintain their own security and the security of work systems and digital assets?

Table 1. A sociotechnical perspective on Industry 5.0 issues related to 18 facets of work

4.2 Applicability to Sociotechnical and Totally Automated System

Table 2 shows that each of 18 facets applies to both sociotechnical systems with human participants and totally automated systems in which all of the work is performed by machines or robots. The main exception is the facet *interacting socially*, and even that might appear in some form in networks and ecosystems consisting of automated entities that interact in a quasi-social manner. (Recall that people who create and maintain automated systems often perform that work in separate work systems that are devoted to creating and maintaining the automated systems.) Table 2 emphasizes the link to Industry 5.0 by using the word *robot* instead of words such as *computer, machine, or model* that appeared in a similar table in Alter (2019a).

Facet	Sociotechnical work performed by people	Automated work performed by machines controlled by software
Making decisions	People make decisions based on available information. Example: A marketing manager decides on the allocation of advertising budget.	A robot uses software algorithms to make decisions automatically. Example: A robot uses a marketing model to allocate an advertising budget.
Communicating	People communicate with other people as part of collaboration. Example: Sales managers meet to discuss issues, problems, and trade-offs.	Robots in various locations consolidate and transmit data collected using sensors. Example: A robotic inventory management system transmits inventory usage data.
Processing information	People capture, transmit, store, delete, retrieve, display, or manipulate data. Example: A researcher collects, filters and summarizes information.	A robot or other device performs information processing activities. Example: Robotic information processing via RFID system, MRI system, or digital camera
Thinking	People think about a situation, decide what is important, and make decisions. Example: A doctor considers medical evidence and decides what to prescribe.	A robot analyses the same situation and uses an algorithm to suggest an approach. Example: A robot uses an algorithm to make a recommendation from the same evidence.
Representing reality	People create, update, and use representations of reality. Example: Accountants perform financial analysis and create financial reports.	A robot uses software and data to create a representation of reality. Example: A facial recognition system identifies people in a location.
Providing information	People provide information upon request or on a periodic basis. Example: An employee submits a progress report before a weekly meeting.	A robot provides information, either by subscription or on demand. Example: A robotic news service provides a customized daily newspaper.

Applying knowledge	People use expert knowledge to perform a complex diagnosis. Example: A physician determines that a patient has an unusual medical problem.	A robot uses a neural network to perform a complex diagnosis task. Example: The robot's neural network based on 50,000 cases diagnoses a medical problem
Planning	People use information and knowledge to create plans. Example: A manager plans factory production to satisfy existing orders.	A robot uses information and algorithms to create plans. Example: A robot uses an algorithm to plan factory production to satisfy existing orders.
Controlling execution	Managers use information and incentives to motivate employees. Example: Daily incentives push employees to meet daily goals.	A robot uses business rules to control execution of processes. Example: A robot uses BPM logic to enable the next step after a previous step completes.
Improvising	People decide how to proceed based on intuition and resources that are available in the situation facing them. Example: A police team responds to an unfolding public safety threat.	A robot decides how to proceed based on algorithms and resources that are available in a current situation. Example: A robotic autonomous vehicle identifies and avoids obstacles in the road.
Coordinating	People produce mutual benefit by coordinating activities and resource use. Example: Two teams coordinate work to share resources needed by both.	Robots use algorithms to coordinate activities and resource use. Example: Two autonomous robots take turns using a resource needed by both.
Performing physical work	People perform work requiring physical activity beyond processing information. Example: People move packages from one location to another.	Robots perform work requiring physical activity beyond processing information. Example: Robots move packages from one location to another.
Performing support work	People assure that others have resources they need to perform their work. Example: Support staff assures that computers are working properly.	Robotic linkages assure that people have resources they need to perform their work. Example: A robotic update services assures that users' software is up to date.
Interacting socially	People enact everyday social relations while participating in organizations. Example: People chat during work breaks or during meetings.	Interacting socially does not describe how current robots operate. At some point "social-like" interactions might help robots coordinate in enterprises or ecosystems.
Providing service	People perform activities for the benefit of others. Example: "Super-users" help others understand software features.	Robots perform activities for specific users, typically responding to requests. Example: A robot uses a search algorithm to compile search results.
Creating value	People produce product/services that matter to customers or users Example: An artist produces a painting that a buyer enjoys and values.	Robots produce product/services that matter to customers or users Example: A robotic alarm system produces a feeling of safety.
Co-creating value	People work together to produce outcomes that are mutually valuable. Example: A software firm produces customized software with the help of customers who ordered the software.	Robots serve as agents of people who want to co-create value. Example: Advertising robots assign ads to web pages based on cookie data, characteristics of ads, and advertisers' willingness to pay.
Maintaining security	Undisciplined computer usage generates opportunities for crime and sabotage. Example: Many large data thefts that are reported every year.	Computerized robots enforce data standards and access restrictions. Example: Digital rights management (DRM) robots restrict access using access rights.

Table 2. Relevance of facets of work to both sociotechnical systems and totally automated systems that might exist in an Industry 5.0 setting

4.3 Concepts and Knowledge Directly Associated with Specific Facets

All 18 facets of work bring concepts and other knowledge directly associated with that facet and not typically associated with other facets. Concepts for each facet are equally relevant regardless of whether robots are involved. The main implication in relation to a sociotechnical perspective on Industry 5.0 is that a great deal of knowledge is available that can be used to understand operational aspects of Industry 5.0 in depth. Note: Table 3 is truncated to 9 facets due to this paper's length limitations.

Facet	Related concepts
Making decisions	Decision, criteria, alternative, value, risk, payoff, utility, utility function, trade-off, projection, optimum, satisficing vs. optimizing, heuristic, probability, distribution of results, risk aversion
Communi-cating	Comprehension, one-way vs. two-way, messages, utterances, encoding, transmitting, decoding, interpreting, communication channel, media, media richness, wired, wireless, signal-to-noise ratio, attenuation
Processing information	[nouns] entity, relationship, data item, class, method, object, event, state, process, pre-condition, post-condition, business rules, [verbs] capture, transmit, store, delete, retrieve, manipulate, display, initialize, initiate, update, back-up, restore, roll back
Thinking	Thoughts, concepts, images, perceptions, memories, awareness, consciousness, reasoning, realizations, imagination
Representing reality	Entity, event, state, inclusion, exclusion, filtering, summarization, precision, bias, characteristic, measure of performance
Providing information	Inclusion, exclusion, accuracy, conciseness, focus, filtering, outlining, textual vs. graphical presentation, types of graphical displays, personal style related to information usage, information deficiency, information overload
Applying knowledge	Tacit vs. explicit knowledge, codified vs. noncodified knowledge, domain of knowledge, know-how, rules of thumb, knowledge base, neural network, expert system, cognitive computing, artificial intelligence
Planning	Plan, feasibility, needs, goals, forecasts, resources, dependencies, capacity, slack resources, planned resource utilization, strategic vs. tactical vs. operational planning, rational choice, planned capacity utilization, planned order fulfillment, planned versus actual results
Controlling execution	Goal, evaluation method, evaluation criteria, positive and negative feedback, standardization, rationale, business rules, chaotic behavior, informal vs. formal feedback

Table 3. Common concepts related to each facet of work

4.4 Success Criteria and Design Trade-offs for Each Facet of Work

All 18 facets bring common success criteria and design trade-offs that are equally relevant to work systems in Industry 5.0 and that might be considered in a sociotechnically informed analysis of a work system. Table 4 shows that success criteria and design trade-offs included for each facet are equally relevant regardless of whether robots are involved. Table 4 is truncated in the same way as Table 3.

Facet	Typical evaluation criteria	Typical design trade-offs
Making decisions	Decision outcomes, riskiness, level of participation, concurrence, ease of implementation	• Quick responsiveness vs. superficiality. • Complexity and precision of models vs. understandability • Brevity vs. omission of important details
Communi-cating	Clarity, understandability, conciseness, accuracy of the perception of a message, extent of empathy and warmth, signal to noise ratio	• Insufficient vs. excessive communication • Richness of multiple communication channels vs. confusion about which channels to use when. • Focusing on message production versus its impact
Processing information	Efficiency, cost, accuracy, precision, error rate, rework rate, downtime, vulnerability	• Cost and efficiency vs. completeness and detail. • Focusing on processing data vs. producing useful information that fits task or decision needs
Thinking	Clarity, precision, flexibility, insight, originality, focus	• Maintaining control versus freedom to think • Maintaining focus vs. out-of-the-box thinking

Representing reality	Completeness, accuracy, objectivity, clarity. bias, omissions, confounding effects, internal consistency	• Precision/ granularity vs. big picture issues and understandability. • Focusing on objective data collected automatically vs. reflecting reality more fully using subjective information.
Providing information	Information quality, completeness, usefulness, timeliness, accuracy, understandability, source, comparability, bias	• Informing vs. under-informing or over-informing. • Understandability vs. information overload • Predefined information vs. ad hoc specification • Focusing on informing and information transfer vs. human abilities to perceive and process information
Applying knowledge	Accuracy of knowledge, ability of discriminate between cases, appropriateness of application of knowledge	• Using too little knowledge vs. waiting until more knowledge can be obtained and filtered • Relying on human knowledge and intuition vs. relying on computerized techniques
Planning	Feasibility, goal achievement, capacity utilization	• Using capacity vs. allowing too little slack • Predictability of outcomes vs. risk of shortfalls
Controlling execution	Extent and duration of deviations from goals, delays, cost of monitoring, effectiveness of corrections, missing control targets	• Micromanagement vs. risks of non-compliance • Quick responsiveness vs. instability. • Focusing on control targets vs. minimizing negative impacts on participants or customers

Table 4. Typical evaluation criteria and design trade-offs related to each facet

4.5 Sub-Facets for Each Facet of Work

Most of the 18 facets have sub-facets that in some situations might provide guidance for looking at specific facets of work in greater depth. In many cases, that greater depth is necessary for describing or implementing Industry 5.0 capabilities. As with Tables 3 and 4, Table 5 is truncated to 9 facets.

Facet	Related sub-facets
Making decisions	Defining the problem; identifying criteria for making the decision; gathering relevant information; analyzing the information; defining alternatives; selecting among alternatives; explaining the decision to stakeholders.
Communicating	Formulating the message; conveying the message; receiving the message; verifying that the message was received and understood.
Processing information	Capturing information; transmitting information; storing information; deleting information; retrieving information; manipulating information; displaying information.
Thinking	Identifying the topic, visualizing the situation; identifying issues or concerns; considering knowledge or evidence; considering alternatives; iterating
Representing reality	Identifying key aspects of reality in the situation at hand; identifying ways to represent those aspects of reality; selecting representations in terms of usefulness versus cost; capturing and manipulating whatever information is needed to produce the desired representation of reality.
Providing information	Identifying alternative ways to provide information that might be needed; identifying the most appropriate way to provide required information; packaging information for conveyance to the user; transmitting and/or displaying the information.
Applying knowledge	Determining the domain; collecting a relevant dataset; using AI techniques to produce a neural network that represents the underlying knowledge; testing the neural network
Planning	Identifying scope and timeline; identifying objectives; identifying relevant resources; producing a plan; evaluating feasibility, likely goal attainment, risks; iterating
Controlling execution	Identifying control points and goals; collecting information related to the degree of goal achievement; using the information to stay on track

Table 5. Sub-facets related to each facet

4.6 Questions Related to Each Facet of Work

Table 6 shows that every facet implies open-ended questions that can start discussions. Those questions build in various ways on two simple questions that apply equally to most work systems regardless of whether Industry 5.0 is involved: 1) Where is this facet important for this real-world situation or research area? 2) What are important issues or opportunities related to this facet?

Table 6 can be seen as a starting point for analysis tools for exploring issues beyond the content of use cases, activity diagrams, and typical summaries of problems, processes, information, and constraints. The questions in Table 6 are straightforward and can be pursued without deep theoretical knowledge in each area. Some surely are pursued in some analysis efforts. Questions in Table 6 might minimize overlooking important issues. Templates related to concepts in each area might go further by including concepts, evaluation criteria, design choices, and sub-facets in Tables 3, 4, and 5.

Facet	Open-ended questions for starting a discussion, plus follow-on questions
Making decisions	Open-ended question: How do the available methods and information help in making decisions? ... Follow-on questions: What decisions are made with incomplete, inaccurate, or outdated methods or information? How might better methods or information help in making decisions? Where would that information come from?
Communicating	Open-ended question: In what ways is communication effective or ineffective in this situation? ... Follow-on questions: Where and how does ineffective communication degrade performance or cause problems interpersonal issues? When is information garbled in communication? Are there areas where inadequate communication from one location to another causes problems?
Processing information	Open-ended question: Are there situations capturing, transmitting, storing, retrieving, displaying, or manipulating important information is ineffective, error-prone, or costly in time and effort? ... Follow-on questions: What information is captured or transmitted inaccurately? What information is difficult to store or retrieve? What information would be more useful if it could be refined further through calculations or visual display?
Thinking	Open-ended question: Are there situations where people seem not to have enough time or liberty to think carefully about what needs to be done? ... Follow-on questions: Does performance pressure or attention to minute details drive out the ability to think about important issues? Are people frustrated about how the work environment affects their ability to think creatively? Do people feel that they lack opportunities to think through problems with the help of their colleagues?
Representing reality	Open-ended question: What are examples of important information that does not exist in available information systems or is not represented well? ... Follow-on questions: Is information recorded or presented in a way that requires manual workarounds to figure out what is going on? Is the information from official or corporate information sources as accurate or timely as information from spreadsheets? What is the impact of shortcomings related to how available information represents reality?
Providing information	Open-ended question: How does the available information tell managers what is going on? ... Follow-on questions: When a manager wants to figure out what is going on, what information is mainly available through standard information systems? Through spreadsheets? Through face-to-face discussions? What important information is missing or difficult to obtain?
Applying knowledge	Open-ended question: How necessary is it to use explicit, codified, and computerized knowledge? ... Follow-on questions: In what ways is the knowledge and intuition of people in the setting inadequate for the purposes at hand? What datasets might be used to create a computerized approach to compiling and formalizing the knowledge? Why is it likely that those datasets do not have biases that would skew the results of decisions suggested by a computerized system? What are the limitations of whatever computerized system might be created?
Planning	Open-ended question: How effective are planning processes in this setting? ... Follow-on questions: Are plans taken seriously in this setting? What happens when it becomes apparent that current plans will not be achieved? How well do plans take into account risks and uncertainties about what needs to be accomplished?
Controlling execution	Open-ended question: How well do existing methods and information help the the organization meet its short-term and longer-term targets?

	... Follow-on questions: Is information related to controlling execution ever inaccurate or misleading enough that it causes management or execution errors? What changes in existing methods and information would help the organization control execution more effectively?

Table 6. Open-ended questions related to different facets of work

5 Conclusion

This paper is a conceptual contribution that proposes using a work system perspective and facets of work to extend the traditional sociotechnical perspective to make it more useful for analyzing, designing, or improving work systems in an imagined Industry 5.0 world. In that world, consequential actions, responsibilities and agency are shared between human participants and computational and/or physical robots. This paper argues that an integrated single-system approach to work systems that avoids defining separate social and technical system should be a more effective basis for analyzing situations where people and robots serve as co-workers.

The background section highlighted the tendency discussions of Industry 4.0 or 5.0 to focus on economic efficiencies and competitive advantage from new technologies rather than on sociotechnical concerns involving labor and humanistic values. The 18 facets provide an easy way to identify and discuss related issues. This is not about joint optimization of social and technical systems whose separation will be even more difficult to describe when people and robots serve as co-workers or even collaborators. Instead, it involves organizing and applying ideas that people encounter every day, such as making decisions, communicating, processing information, coordinating, and so on. Using facets of work to look at responsibilities of people and robots could reduce the likelihood of ignoring or downplaying many sociotechnical issues that are not dealt with adequately today. Furthermore, the ideas in the six tables support many possibilities for checklists, templates, and methods that can be used to assure that sociotechnical issues are treated seriously. Those tools and methods can be tailored for use by individuals or groups consisting of factory workers, consultants, designers, IT experts, and managers.

The idea of applying facets of work in Industry 4.0, 5.0, or X.0 situations suggests follow-on efforts:

Improve the list of facets of work. The 18 facets mentioned in this paper are the result of many iterations of a conceptual exploration. There is no reason to believe that 18 is the right number of facets for all situations or that the specific facets described here are the best possible set of concepts that can be described as facets of work. Improving this paper's list of facets of work requires trials in academic and real-world settings to assure their understandability, ease to use, and (sufficient) completeness.

Apply in practice and research. It is possible to test this paper's suggestion that useful checklists, templates, and methods can be developed based on the idea of facets of work. The testing should start with relatively informal inclusion of a checklist or template as an extension of existing approaches. A checklist could be used in a brief, lightweight exercise at the beginning of a typical agile development project to make it more likely that important sociotechnical issues are at least considered before the pressure to produce software takes over. A more elaborate and tightly managed approach would be appropriate before major investments in industrial robots. After all, why introduce robotic co-workers if the resulting work practices are likely to encounter problems that might be identified in advance? Similarly, the idea of facets of work could be applied in analyzing research case studies and in literature reviews by identifying whether and how multiple facets of work appear and are treated.

Make knowledge more accessible for practice and research. All of the 18 facets of work have been the focus of a substantial amount of valuable research. It might seem surprising that the results of so much research have not been used widely in creating and improving the sociotechnical systems through which enterprises operate. Making much greater use of established knowledge in systems analysis and design was a central motive of the research that eventually led to the idea of facets of work. A great deal of highly relevant knowledge simply isn't used in practice. The idea of facets of work might provide a variety of ways to make some of that knowledge more visible and more usable.

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