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Development of a Model for describing, evaluating and designing Communication Concepts in Factories in the Context of Industry 4.0

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Abstract

Far-reaching changes in the technical and organisational structure have influenced the communication between the elements of a factory. In particular, Industry 4.0 as a contemporary trend in production technology and many related areas of science places new requirements for communication. Thus, expectations comprise a wide variety of effects and potentials of Industry 4.0 on communication in factory systems. Exemplarily, efficiency and productivity increases are most frequently named as effects of industry 4.0. They seem advantageous by industrial enterprises, whereby the raising of these potentials is also a necessary competitive factor. However, such influences can trigger other effects with interdependent impacts on the components of factory systems. These effects can have both positive and negative impacts in factory systems. Still a comprehensive and generally valid description of these aspects is not yet available. Similarly, there is no understanding of the cause-effect relationships between the requirements for communication between the system components of a factory arising from Industry 4.0. The lack of specific understanding of Industry 4.0 caused effects and the cause-effect relationships between the requirements for communication between the factory system components lead to the inability to design effective communication concepts in factory systems. Therefore, existing communication systems remain exposed to undesired effects and leave desired effects underutilized. In order to close this research gap, a holistic model for the description, evaluation and the design of effective communication concepts in factories in the context of Industry 4.0 is in development within the frame of "Komm 4.0", a research project of the Institute for Production Systems and Logistics at Leibniz University Hannover and the WISSENSARCHITEKTUR Laboratory of Knowledge Architecture at TU Dresden. The pursuit of this research project is to describe and evaluate existing communication concepts, as well as design more effective concepts and to adapt previous recommendations in terms of communication concept design where necessary.

Keywords

Factory planning; Communication concepts; Industry 4.0; Description model; Effect model

1. Introduction

The factory as a socio-technical system and its various system components are linked by communication [1]. A factory defines a specific location where value is created by the manufacture of industrial goods through the utilization of division labour and production factors [2]. Profound developments in the field of technology and organisational structure influence the communicative and informational connections of the factory components (technology, organisation, employees, location and buildings) in particular [3] [4]. With the arrival of such developments such as industry 4.0, communication in factory systems has become more import to the operative tasks of the industry [5]. This contemporary trend particularly places new demands on communication in production technology and in related areas of science [6] [4] [7]. The establishment of these new demands depicts an influence of Industry 4.0 on the communication and therefore on the communication and information processes in production technology. Despite the importance of communication, it often receives insufficient attention [8]. These Industry 4.0 induced communication and information processes are here defined as "Communication 4.0" and are the result of the respective communication concept. These resulting processes aim to achieve individual corporate goals. Based on numerous definitions of the communication concept in general in the operational environment, it describes a process that transmits information from a sender to one or more receivers [9] [10]. In addition to this fundamental understanding of communication, further properties are of relevance [11] [12]. These properties include the communication type [13], communication means [14], communication structure [15], communication quality [16], communication environment [14], communication direction [17], communication intensity [14] and communication distance [14], which are brought together under the idea of the communication concept.

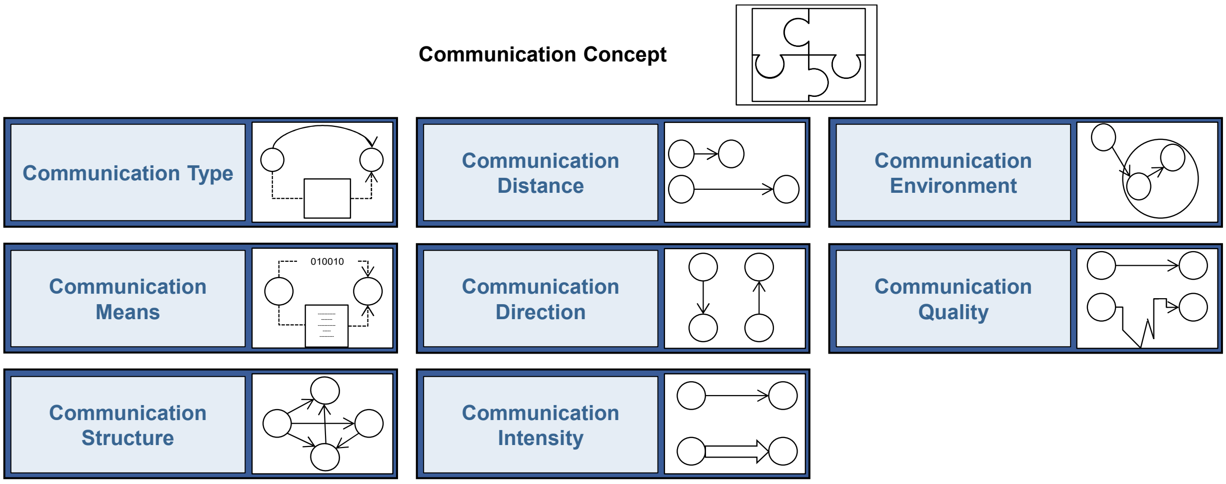

Figure 1: Current communication concept properties

As factory systems are evolving over time communication concepts that have grown organically and involuntarily in the rapid course of Industry 4.0 can lead to unwanted inefficiencies and loss of competitive advantages. In order to use the effect of communication concepts on the efficiency of an enterprise, more specifically on a factory, a comprehensive understanding of Industry 4.0 caused influencing factors on the configuration of the communication concept is necessary. Well-founded knowledge of the cause-and-effect relationships can enable a structured design of communication concepts. The application of this knowledge at an early stage can prevent potential loss of performance due to communication inefficiencies and support to realize performance potentials comprehensively.

2. Need for Research

The preliminary work on the topic of communication concept design in factories resulted in a uniform recommendation to increase the degree of organisational, procedural and spatial networking. The aim is to increase the frequency and quality of communication and consequently to increase the efficiency of the factory [18] [19]. Nevertheless, the increase in communication frequency and communication quality as the maxim of an increase in performance must be viewed in a more differentiated way. The application of findings of the attention economy to the context of communication concept design in factories, leads to deviating conclusions. The core idea of the attention economy understands human attention as the scarcest commodity [20] [21]. Consequently, this attention should only be used for those actions that represent maximum marginal utility [22] [23]. With reference to previous recommendations, the increase in the degree of networking does not show a constant marginal utility. If, for example, the communication time or the number of communication interfaces extent, this can lead to decreasing efficiency and effectiveness. Based on these findings, increasing the degree of networking in factories in the course of Industry 4.0 does not appear to be a direct maxim. Because of the contradictory findings from different scientific fields, this research project will, among other things, review and, if necessary, adapt the previous recommendations for increasing the degree of networking in the context of Industry 4.0.

Furthermore, previous research projects at the Institute for Factory Systems and Logistics have examined the importance of communication in factories and have highlighted it as an essential competitive factor [19] [24].These projects emphasize the targeted design of the communication concepts by factory planners and architects as an essential interdisciplinary component. Moreover, previously carried out work only forms descriptive models under constant conditions or evaluation models for the special situation of the change of the type of order processing. Furthermore, various studies predict versatile effects and potentials that emanate originate from Industry 4.0 on communication in the factory system [6]. These effects and potentials can drive changes. A comprehensive and generally valid description of these change drivers is not yet available. This also applies to a detailed understanding of the cause-effect relationships between the requirements for communication between the systems components of the factory arising from Industry 4.0. Therefore, no investigation of the possibilities of the targeted reinforcement of desired changes and the mitigation of negative effects of Industry 4.0 by generic measures is present.

Since neither a holistic model nor a method of procedure exists to describe, evaluate and design communication concepts in factories under the influence of Industry 4.0 as of now, the aim of this research project "Komm 4.0" is to close this research gap.

3. Approach to the Development of a Model and a Method for describing, evaluating and designing Communication Concepts in Factories in the Context of Industry 4.0

3.1 Approach

In order to close the research gap, this research project aims to develop a model and a method for describing, evaluating and designing communication concepts in factories in the context of Industry 4.0. The model should make it possible to design effective communication concepts and thus to support the maintenance and increase of the innovation ability in factories as a competitive advantage. The following approach aims to reach the formulated objectives within the frame of this research project.

The first step is the development of a description model of communication in the context of Industry 4.0. This model should cover all relevant changes as well as the corresponding drivers that Industry 4.0 has on the communication and information processes between the systems components of a factory (technology, organization, employees, location and building). Based on the knowledge gained, the next step is the development of future requirements for communication in factories. Finally, the objective is to operationalize these requirements in order to integrate them into the existing communication concept as new components. Subsequently, the next step is to identify and describe communication barriers at the interfaces of the systems components. The phase ends with the definition of measures for the removal of communication barriers. The consolidation of the findings above will form a description model.

In a second phase of the approach, it is to verify and supplement the findings from the previous phase, which are consolidated within the description model. A further aspect of this phase is the identification of correlations between the components of the description model. A case study will verify the findings in a two-step approach. The first step comprises the comparison of the contents of the description model with information from industrial companies. The comparison includes the gathering of information on the elements of the description model from the respective companies. For example, Industry 4.0 technologies, which are already in use by enterprises both long-term and short-term, are examined regarding their impact as change drivers. Future requirements for the communication and information processes as well as existing communication barriers and the converted measures will be part of the documentation in the same way, as described for the verification of the elements of the description model. The comparison serves as a basis for formulating initial hypotheses on the relationships between the elements. In the second step of the case study, the formulated hypotheses will undergo a check with selected experts.

In the next phase after examining the formulated hypotheses, the development of a model for the evaluation and design of the communication concept of factories in the context of Industry 4.0 is done. This overall model is composed of the three components. An effect model, a process method based on it and an application tool. The effect model enables the visualisation of connections between change drivers, operationalized components of the communication concept and generic measures. The method describes the necessary steps for the evaluation and organization of the communication concept in detail. Based on this, the application tool enables a systematic evaluation of the existing communication concept as well as the selection of generic measures for the design of the communication concept.

The fourth phase comprises a final evaluation of the consolidated model for the evaluation and design of the communication concept. The practical tests in partner companies as well as adjustments based on these studies will be part of this final phase if necessary. The documentation and preparation during and after the processing of the preceding phases is an essential part of this project.

3.2 Current Findings

With regard to the first work package and thus the development of the description model, first results have already been achieved. Based on an extensive research of scientific literature as well as studies and surveys, relevant trends and technologies in the context of Industry 4.0 have been identified [25] [26] [27]. The positioning of the identified aspects in the factory system is based on the dimensions "hierarchy levels of a factory" and "main business processes of a factory" (Figure 2). Accordingly, it is analysed in which main business processes of a factory and at which hierarchy level the technologies are relevant.

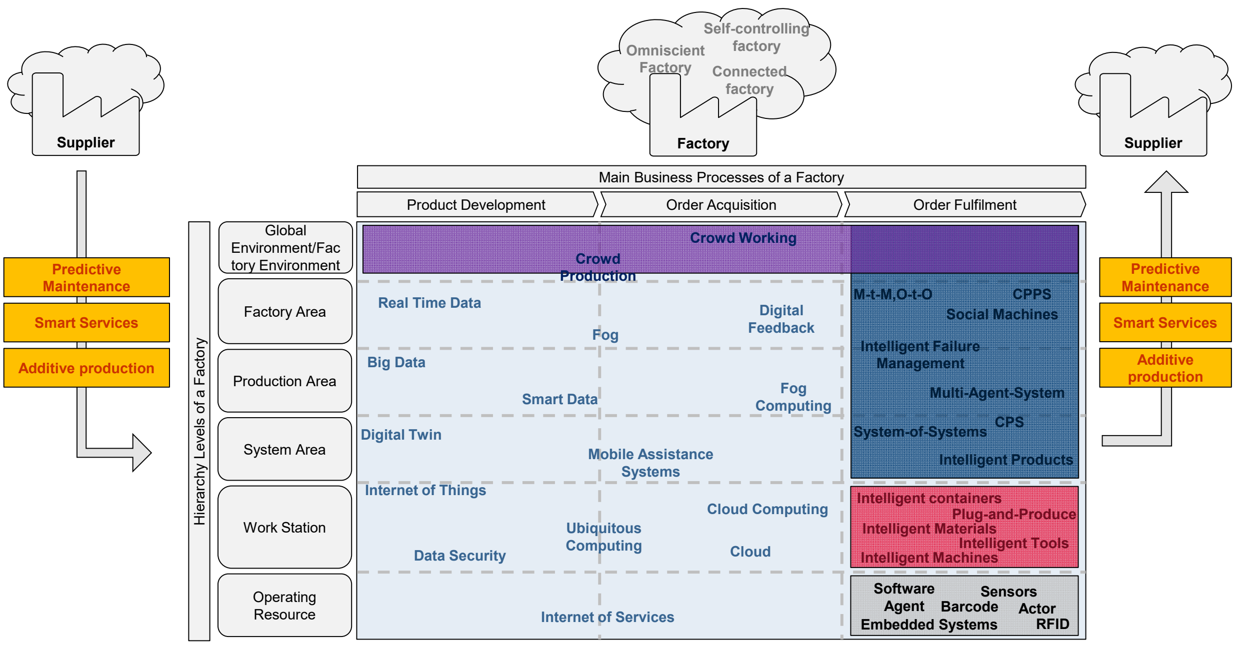

Figure 2: Positioning of the change drivers in the factory system

However, since the focus of the research project presented here is on communication in factories, the identified and located change drivers (Figure 2) are compared with the communication concept (Figure 1) described above. The influence of the change drivers of Industry 4.0 on the components of a communication concept have been analysed. The result of these analyses are hypotheses about the influence of the change drivers on the components of the communication concept. In the course of processing this step, it became clear that the components communication means, communication distance and communication environment are not to be taken into account for further action in the context of Industry 4.0. In the case of the communication distance and the communication environment, the reason for this is that Industry 4.0 has negligible or no influence. In the case of the means of communication, the influence is determined by the dependency on the component Communication Type. Further influences have not been identified.

At the same time, the formulated hypotheses represent the communication requirements resulting from the consideration of the already known communication concept within the framework of Industry 4.0. In a further step, the influences of Industry 4.0 have been further investigated by identifying new communication requirements associated with Industry 4.0. For this purpose, communication processes have been analysed and their future characterization under the influence of Industry 4.0 was examined. By considering the future communication processes between the system components of a factory, new communication requirements have been identified. In order to integrate these new aspects into the already known communication concept, an operationalization of the newly identified communication requirements has been carried out. The operationalization has been realized by the definition of different degrees of fulfilment of the new requirements. The integration of the new components into the existing communication concept leads to the communication concept in the context of Industry 4.0 (Figure 3).

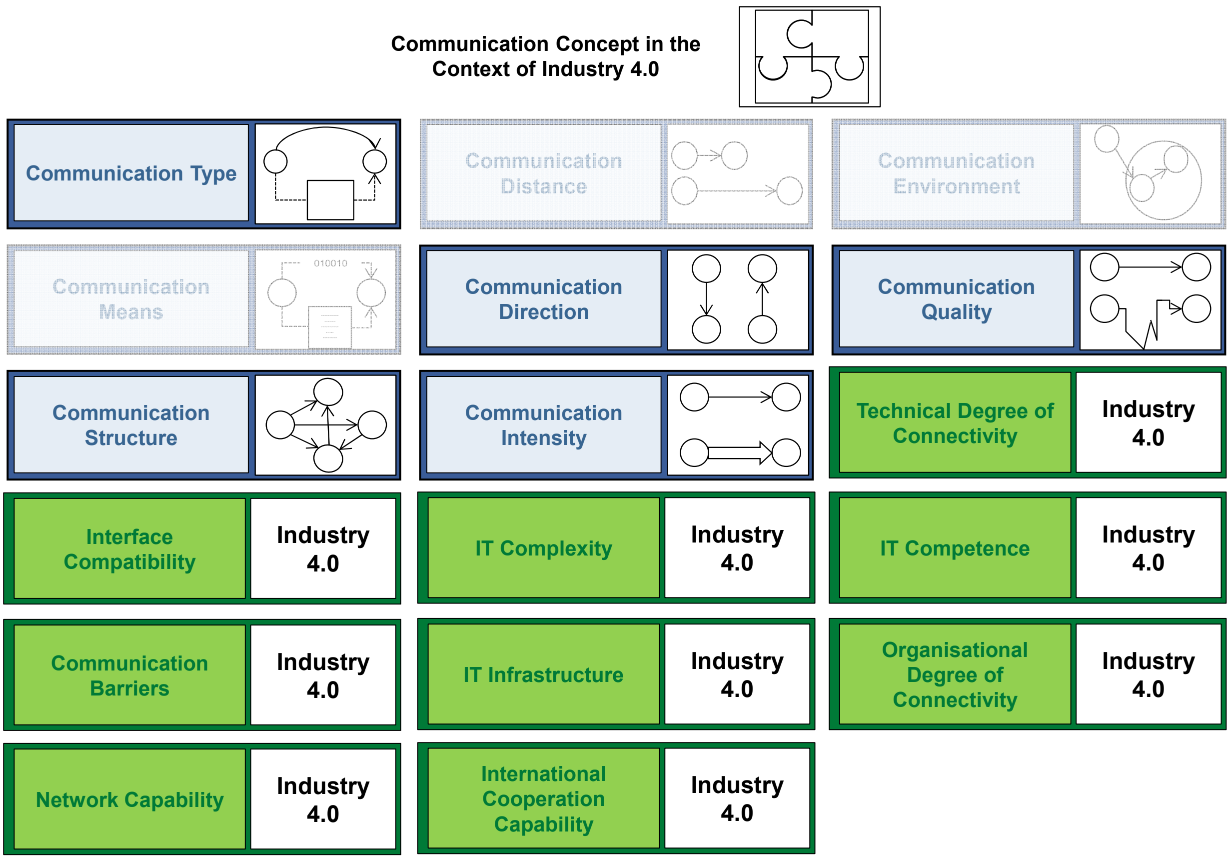

Figure 3: Components of the communication concept in the context of Industry 4.0

The communication processes between the system components of a factory have been again used to identify action measures to reduce or even remove communication barriers. Particular attention has been paid to the communication interfaces between the system components. In a first step, communication barriers have been worked out by means of a comprehensive research. Since each interface is related to a specific future communication requirement, the obstacles at an interface can provide information about which measures are necessary to be able to meet the respective communication requirement. The identification of the potential measures to remove the identified communication barriers at the respective interface has been carried out by means of a second literature search. All measures then have been assigned to the Industry 4.0-side communication requirements according to their interface and sorted according to their department-specific or interdepartmental character. The configuration thus put together describes the catalogue of measures. Described in the following for the example of the technical-technical interface. Previous research work has been able to identify the communication barrier "media breaks due to missing standard interfaces and heterogeneous IT landscapes" at this interface. [28] [29] [30] [31]. Within the framework of Industry 4.0, this obstacle stands in complete contrast to the required interface compatibility, which describes a continuous and media-break-free exchange of data and information between the IT systems used. In order to meet this future communication requirement, it is therefore necessary to eliminate the media breaks between the technical systems within a factory. A potential department-specific action at this point is the introduction of new, compatible software in the department concerned. If media breaks occur between several departments, the definition of standards with regard to uniform software must take place as a cross-departmental measure. Further measures can be taken, which can be found in the catalogue of measures.

4. Conclusion

Overall, the catalogue of measures developed forms the basis for the subsequent design of the communication concept within the framework of Industry 4.0. For the design of the communication concept in the context of Industry 4.0, however, it is necessary that the current findings are validated and adapted depending on the results of this validation. This step will be included in the next work package. To this end, case studies will be developed and discussed with industry partners to validate and supplement the description model and to identify correlations between the elements of the description model.

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Biography

Yeong-Bae Park, M.Sc. (*1994) has been a research associate in the specialist factory planning group at the Institute of Production Systems and Logistics (IFA) at the Leibniz University Hannover since 2019. He previously studied mechanical engineering at the TU Ilmenau (B.Sc.) and at the Karlsruhe Institute of Technology (M.Sc.).

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