publish-Ing.

Journal of Production Systems and Logistics
Volume 2 | Article 4
Published: February 2022

Development Of A Software-based Tool For Factory Communication Structure Evaluation In The Context Of Industry 4.0

Yeong-Bae Park[1], Lena Papke[2], Peter Nyhuis[1]

[1]*Institute of Production Systems and Logistics/ Leibniz University Hannover, Hannover, Germany*
[2] *Phoenix Contact GmbH & Co. KG*

Abstract

The environment of manufacturing companies is constantly changing. Industry 4.0 as an overarching contemporary trend constantly places new demands on production technology. But Industry 4.0 does not only have new requirements to the production technology, but also to the communication in factories. The capacity for innovation and thus the success of companies is significantly influenced by the effective communication between the employees. Therefore, it is necessary that companies systematically adapt their communication structures according to these communication requirements. This paper addresses this aspect, by developing a method and a software-based tool which should allow the mentioned adjustment. The aim is to enable companies in the manufacturing sector to capture and evaluate their communication structures at low cost. Furthermore, they should be able to derive effective measures efficiently through the developed method and to use them for their individual needs.

Keywords

Factory planning; Factory evaluation; Communication concept; Communication evaluation

1. Introduction

The complexity in the factory environment has increased in recent years due to increasing customer individualization and shorter development and product life cycles. Low prices and adequate quality must still be met. Accordingly, the accompanying dynamics in the factory environment require competitive players to be more adaptable. [1–3] Additionally, a high level of innovation is required to maintain competitiveness [2]. These innovations mostly result from employee communication, thus assigning indispensable importance to communication in factories. Knowledge is generated and applied in communication processes, which is why these should be designed appropriately and effectively. [4] Here, major influence on the design is exerted by upheavals in the factory environment and the accompanying changes in external structures. These cause changes in communication structures, which in turn are reflected in new challenges for communication. [5]

In particular, Industry 4.0 as a contemporary trend provides for changes in the factory environment with alignments to the production area and accordingly influences the communication structures [6]. Pure face-to-face communication has already been largely replaced as a communication type by media-based communication, although it is still important. Even though simple notes can also be meant by communication media, it is clear that in the course of Industry 4.0, electronic media in particular, and thus communication

This Paper has been reviewed by the Certified Reviewer Community of publish-Ing. – 1 review – single blind

DOI: https://doi.org/10.15488/11715
ISSN: 2702-2587

via these, are at the heart of the consideration. In order to maintain competitiveness in the factory environment influenced by Industry 4.0, the requirements of the new communication structures must be met efficiently and communication must be designed. For the design, it is decisive to implement this efficiently and in a resource-saving manner for the factory [7]. In this context, extensive research work has already been carried out at the Institute of Production Systems and Logistics at Leibniz University Hannover and a new communication concept has been developed, which describes requirements for communication in the context of Industry 4.0 and enables these to be evaluated [6,8].

2. Model for describing, evaluating and designing communication structures in factories in the context of industry 4.0

PARK ET AL. (2020) describe a generic communication concept in the context of Industry 4.0. The concept consists of 14 requirements that have been modelled to evaluate communication structures in factories. This approach is adopted and further developed in PARK & NYHUIS (2021). Characteristic configurations are derived for the generic requirements of the developed communication concept and are provided with an evaluation logic (Figure 1).

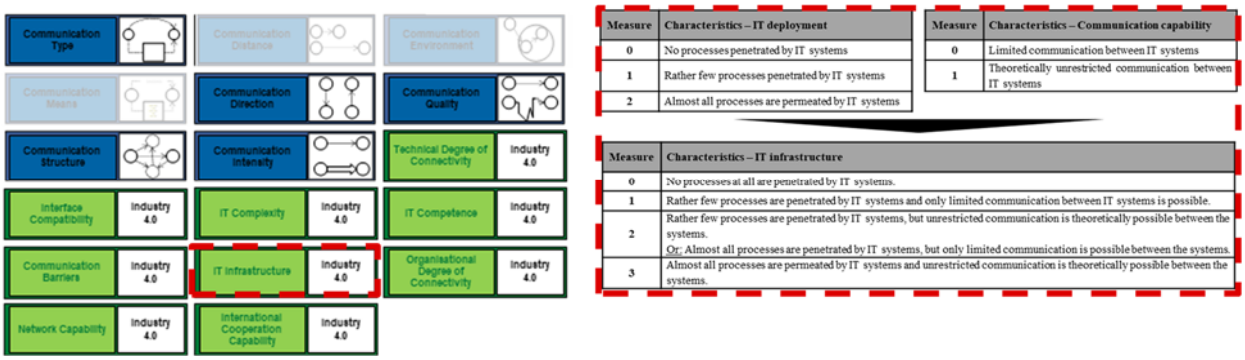

Figure 1: Forms of expression and evaluation logic of the communication concept in the context of Industry 4.0 using the example of the IT infrastructure requirement

The evaluation logic is chosen in such a way that the evaluation of the communication can be carried out through a maturity model and is as transparent as possible for the user. The resulting evaluation model thus offers an initial base concept for describing and evaluating communication structures in factories in the context of Industry 4.0. Depending on the results of the evaluation of the communication structures, the base concept also offers measures that help to improve the quality of communication when designing the communication structures. This model still is only a concept that is difficult to use in this form in an industrial environment. Although the focus on the description and evaluation of communication structures leads to a solid model, the design aspect must be considered more intensively. This includes, among other things, the implementation of the concept in an easy-to-use, software-based tool and the integration in a standardised process method. The process method must be holistic and include description, evaluation and design. Only such an implementation enables an efficient and effective use in the industrial environment.

3. Development of a method for the evaluation of communication structures in factories

3.1 Base concept for captureing the status quo of the existing communication structures

The development of the concept is based on a maturity model. Maturity models are particularly suitable for the analysis and evaluation of the development status and for the identification of improvement potentials of an object to be evaluated, which can exhibit both qualitative and quantitative characteristics. [9,10] For this reason, it is obvious to capture the status quo of the existing communication structures on the basis of

questionnaires which are an essential element of maturity models [9]. The questionnaires are designed in such a way that employees of production companies can independently capture the status quo of the communication structures. The focus of these questionnaires lies on communicative aspects only in the main business processes of product development, order acquisition and order fulfilment with their respective core processes [6]. The target group for answering the questionnaires are the individual area/department managers who are responsible for the corresponding core processes. The operationalized communication requirements in PARK ET AL (2020) and PARK & NYHUIS (2021), which are to be used to evaluate the communication structures of a factory, form the basis for the creation of the questionnaires.

Each communication requirement forms a block of questions with corresponding questions that make it possible to evaluate the respective communication requirement through operationalised characteristics. The questions are based on the characteristics of the respective communication requirement. For example, the *technical degree of connectivity* consists of the two characteristics which are "use of IT systems" and "contribution of information to the value creation process" [8]. Accordingly, two questions must be formulated, with one question relating to the use of IT and the other question addressing the contribution to the value creation process (Figure 2).

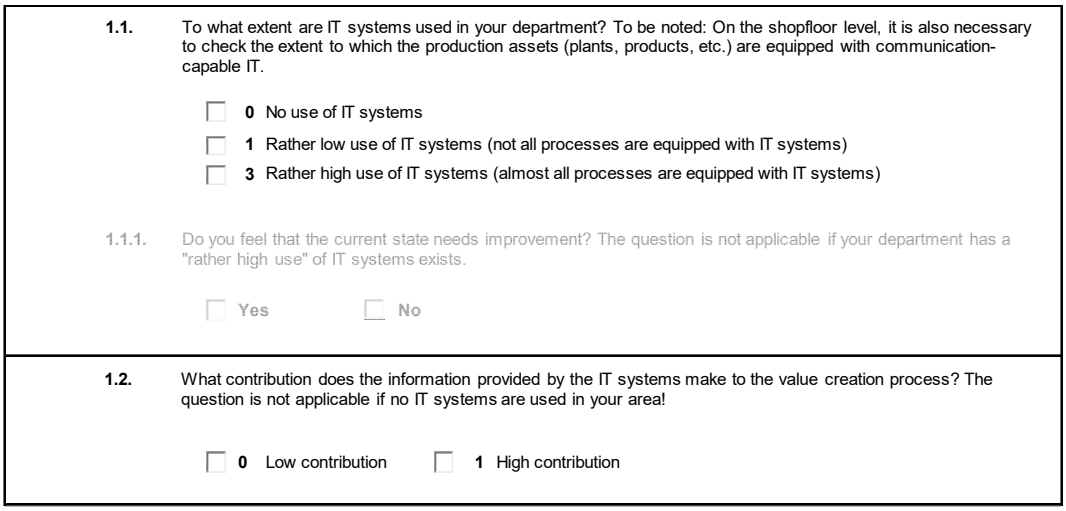

Figure 2: Questionnaire for assessing the current communication concept - Questions on the technical degree of connectivity

Some communication requirements are not department-specific but must be viewed across departments. For example, it is not sufficient to evaluate the communication requirement *communication barriers* exclusively within an individual department without reference to the other departments, as this requirement is particularly relevant in the context of interdisciplinary collaboration. This makes it necessary for each department to evaluate the *communication barriers* with reference to the other departments. Same applies to the communication requirements *interface compatibility, organizational degree of connectivity, communication type* as well as *communication intensity*. Due to the cross-departmental evaluation of these communication requirements, it is necessary to create a questionnaire for each department. Although their questions do not differ from each other in terms of content, the answer options to the questions of the mentioned requirement vary depending on the surveyed department. The difference consists in the fact that in each questionnaire always that department is omitted within the answer possibilities, for which the respective questionnaire is intended. In this way, the evaluation of one's own department is avoided in the corresponding questions. For example the work preparation cannot evaluate itself with the evaluation of the *communication barriers*. In total, this results in 12 questionnaires with 14 question blocks each. For better understanding and easier handling, each block of questions is briefly explained at the beginning and illustrated with an example.

3.2 Evaluation of the status quo communication concept

The evaluation of the communication requirements presented in PARK ET AL (2020) and PARK & NYHUIS (2021) is based on the characteristic of the respective requirement. In order to enable a standardised evaluation the value of the corresponding characteristic is assigned to each answer option within the questionnaires. Figure 3 shows an example of this for the *technical degree of connectivity* by means of the red markings. The exact system behind the red marked scoring can be taken from PARK & NYHUIS (2021).

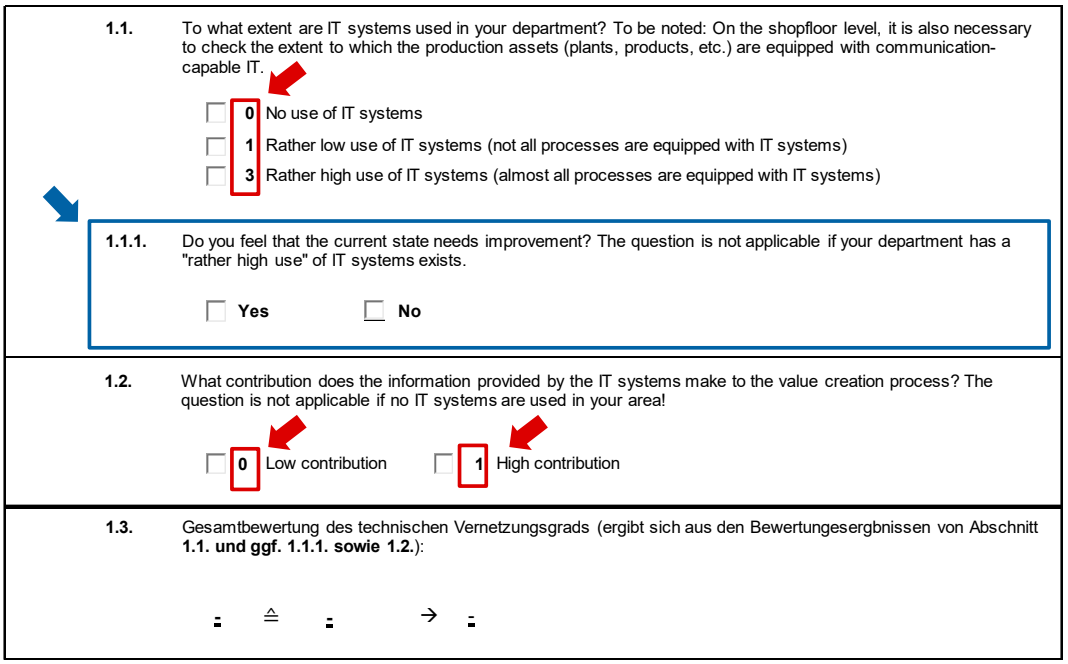

Figure 3: Questionnaire for assessing the current communication concept - Questions on the technical degree of connectivity

The target value to be aimed for with regard to each question is determined by the answer option with the highest value. However, a department may not be placed in a worse position if it cannot fulfil this theoretical target value, because there is simply no need for achieving this value through improvement measures. In such a case the optimal condition for the respective communication requirements is present within this department. In order to consider this case in the evaluation, it must be examined for each answer whether it corresponds to a condition worthy of improvement (see blue marking in Figure 3). If this check is negative, the target value is assigned to the respective answer. Exemplarily, if there is a rather low level of IT use within a department, but this state is not worthy of improvement for the respective department, the answer is given a score of 3 instead of 1. This scheme can be applied to almost all questions relating to the new communication requirements operationalized in PARK & NYHUIS (2021) that result from Industry 4.0. Exceptions to this are the questions on the requirements communication barriers and international cooperation capability as well as the sub-question regarding the contribution of information to the value creation process. For these questions, the aim is to achieve as high value, since a low contribution to the value creation process and high communication problems in the context of interdisciplinary or international collaboration always appear to be in need of improvement. Furthermore, this scheme does not apply to the questions regarding the general communication requirements from PARK & NYHUIS (2021). With the help of experts with industry and scientific experience, it was possible to determine clear target values for these requirements that each department should strive to achieve. Accordingly, any deviation from the target value must be classified as a need of improvement.

The final comparison of the target state and status quo is performed for each communication requirement of the communication concept. In general, the actual assessment is compared with the target value for each

requirement by setting them in relation to each other. This procedure is easily possible for the communication requirements *IT complexity, IT competence, international cooperation capability and communication direction*, since the assessment is only department-specific and based on one characteristic. The requirements *interface compatibility, communication barriers* and *communication intensity* are also evaluated on the basis of a characteristic, but it should be noted that the evaluation of these communication requirements is carried out across departments. Therefore, the comparison of the target state and status quo is carried out per department. In this way, those departments can be identified that have distinct deficits. The requirement *communication type* is also evaluated on the basis of a characteristic. However, the evaluation is carried out against the background of different scenarios, which result in a different value of the individual characteristic values. On the one hand, the *communication type* is considered across departments as part of day-to-day business, and on the other hand it is considered department-specifically for each project phase. Here, too, the comparison of the target state and status quo is carried out for each department or project phase. The same applies to the requirements for *communication quality* and *communication structure*.

However, if a requirement is assessed on the basis of two characteristics, as in the case with the *technical degree of connectivity, IT infrastructure* and *network capability*, the sum of the individual assessments for each characteristic must first be formed for the comparison of the target state and status quo. The same applies to the target value. The two totals can then be compared with each other. In the case of the organizational degree of connectivity, this procedure is again carried out for each department, as this requirement is to be assessed on the basis of two characteristics as well as across departments.

Finally, the overall result per communication requirement is determined in order to be able to compare the departments more easily with regard to the individual requirement. In order to be able to determine the overall result for the requirements that are evaluated across departments or per scenario, the sum of all actual evaluations per department or scenario must first be calculated. This sum is then set in relation to the sum of all target values per department or scenario. The ratio generated in this way finally forms the overall result of the respective requirement. For communication requirements that are not evaluated across departments or per scenario, it is not necessary to determine the overall result, since the overall result corresponds to the evaluation result. Overall, the comparison of the target state and status quo shows how well or poorly the respective communication requirement is fulfilled overall or per department or scenario.

In order to ensure a clear interpretation of the evaluation results, five interval levels were defined, which assign a clear value to each result (Table 1). The intervals were selected in such a way that the various evaluation results of the communication requirements can be meaningfully classified. The "x" in Table 1 represents the respective evaluation result.

Table 1: Intervals of the evaluation results

Interval	Evaluation
$0 \leq x \leq 0{,}2$	Very poor result with regard to the respective communication requirement
$0{,}2 < x \leq 0{,}4$	Poor result with regard to the respective communication requirement
$0{,}4 < x \leq 0{,}6$	Medium result with regard to the respective communication requirement
$0{,}6 < x \leq 0{,}8$	Good result with regard to the respective communication requirement
$0{,}8 < x \leq 1$	Very good result with regard to the respective communication requirement

How the presented evaluation model is ultimately to be applied and how it can be used to determine action measures for the respective communication requirement will be explained within the framework of the following procedure model.

4. Development of a software-based tool for communication structure evaluation

4.1 Integration of the evaluation method into a logical method of procedure for the design of communication structures

The process model builds on the previously developed models, combines them with each other and thus makes them methodically usable. The methodological procedure consists of a total of three steps (Figure 4).

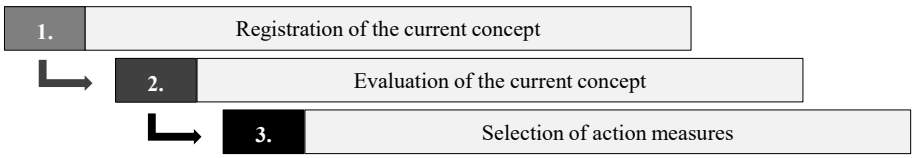

Figure 4: Systematic approach to capturing, evaluating and designing communication structures in factories

In the first step, the status quo communication concept is captured with the help of the evaluation model explained in the previous section (Section 3.1). For this purpose, each department that can be assigned to one of the three main business processes product development, order acquisition or order fulfilment receives a questionnaire. This questionnaire enables the capturing of the current actual state for each communication requirement of the communication concept in the respective department.

The evaluation of the captured status quo communication concept takes place in the second step. Within the framework of a comparison of the target state and status quo, key figures are determined for each communication requirement, which provide information about their degree of fulfilment (Section 3.2). This step is also carried out for each department.

Finally, the third step is the selection of suitable action measures [8]. These measures should serve to fulfil the respective communication requirement under consideration. For this purpose, the overall results of all departments are compared with each other for each requirement in order to be able to identify those departments that have similar deficits with regard to a communication requirement. Therefore, the overall results of the communication requirement are divided into classes. If there is only one department within a class, department-specific action measures are suggested for this class. For classes containing more than two departments, interdepartmental actions are recommended, which are to be carried out in a uniform manner for all departments of the affected class.

When determining the class step size, care should be taken to ensure that it is not too large but also not too small. A too large step size would possibly prevent the case that to some classes only one department can be assigned. A step size which is too small would make the assignment of several departments to a class more difficult on the other hand. In both cases a meaningful application of department-specific as well as department-spreading measures would be hardly possible. To prevent this, a step size of 15 percent points was selected. It should be noted that the method only provides a choice of several action measures. Which measure ultimately appears to make sense and should be implemented depends on the specific application. Thus, the actual selection of a suitable action measure is at the discretion of the user.

In order to make the application of the procedure model as simple as possible, it was converted into an Excel-based application tool.

4.2 Demonstration of the Excel tool through exemplary application

The Excel tool is used for the systematic and efficient capturing, evaluation and design of communication structures in factories by quickly evaluating the captured data so that a corresponding statement about the communication concept can be made in a short time. Overall, the tool consists of an input module, a processing module and an output module (Figure 5).

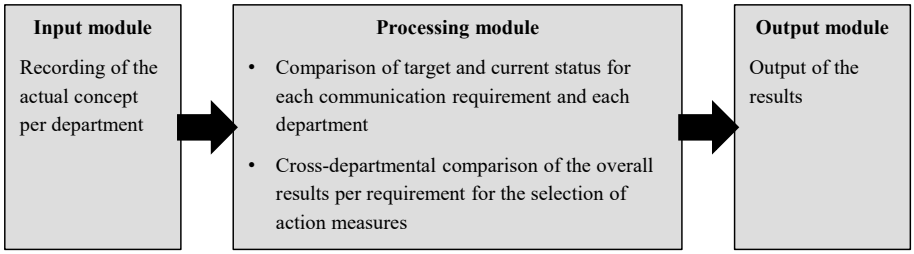

Figure 5: Schematic structure of the Excel tool for evaluating communication structures

The input module represents the interface between a user and the tool. It serves the structured capturing of the actual concept per department with the help of the developed questionnaires. Thereby, each questionnaire for the respective department is located in a separate Excel file. In turn, each file contains a separate spreadsheet for each communication requirement that includes the corresponding questions. The evaluation of the captured data takes place in the processing module. There, the captured data of each department is subjected to a comparison of the target state and status quo and then used to determine department-specific as well as cross-departmental measures. Finally, the output module clearly presents the evaluation results for each department in the corresponding file and illustrates them graphically. In addition, it visualizes the overall results as well as the determined actions per department and communication requirement in a separate file. This file also contains a spreadsheet for each communication requirement, which summarizes the overall result for each department as well as suitable action measures. In the following, the developed Excel tool will be explained using an application example.

In the context of the application example, a fictitious company with four departments is to be considered. The departments are work preparation, production, logistics and sales. Since the Excel tool is used in the same way for each department, it is sufficient to describe the procedure for using the tool from the perspective of work preparation. For this purpose, the three steps of the procedure model are run through. For reasons of the clarity, it is renounced however to regard each individual partial step of the evaluation. Only the special features of individual sub steps will be discussed.

Step 1: Capturing the status quo communication concept

In the first step, the questions are answered within the Excel tool by the department/area management of the respective department. Since the questions are closed questions where the answer options are predefined, this step does not require a detailed explanation. However, it should be noted that the "note" field may appear when answering the questions. This case only occurs if the respondent gives an answer that does not correspond to the target value, but does not consider it to be in need of improvement (Figure 6). Since in such a case the given answer is assigned the value of the best possible answer, it must be ensured that the respondent assesses the situation correctly. This is the only way to avoid a too good evaluation of the respective communication request. The respective note is intended to make the respondent proactively think, which may cause him or her to revise his or her answer regarding the worthiness of improvement.

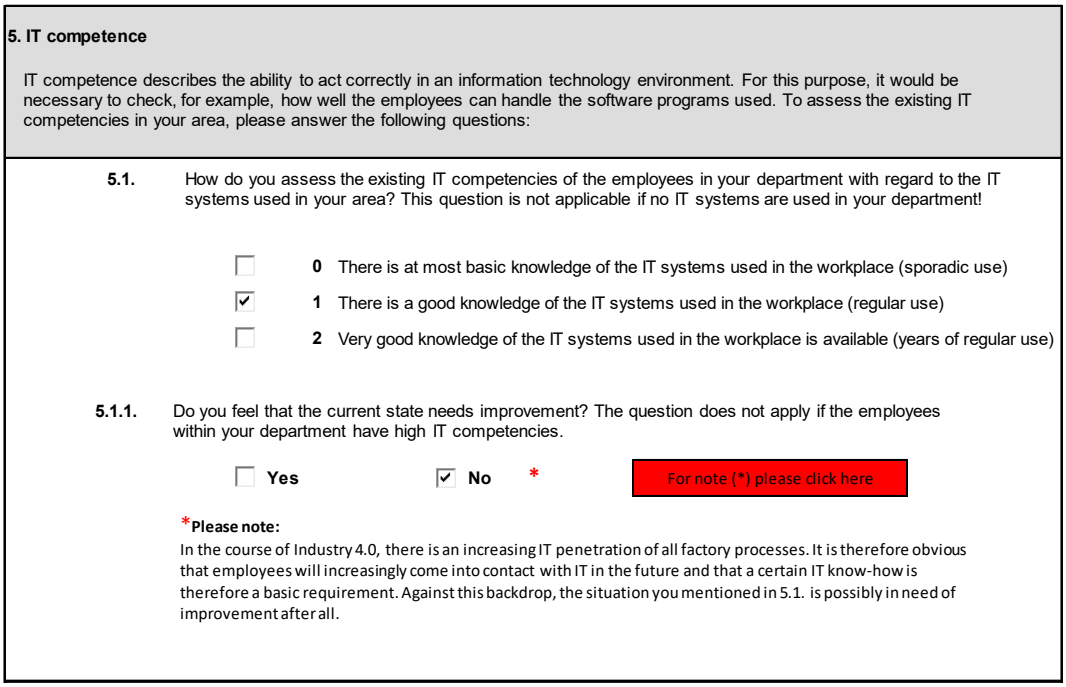

Figure 6: Application example - Capturing the current concept: IT competence

In addition, individual follow-up questions can be omitted in the course of answering the questions. For example, the question about the improvement worthiness is omitted as soon as the best possible answer has been selected for the previous question (see red marking in Figure 7). It can also happen that the answer given to a question makes it impossible to answer a subsequent question. For example, the question about the contribution of the information to the creation of the service, which was gained through communicative connectivity, cannot be answered if there is no communicative connectivity (see blue marking in Figure 7).

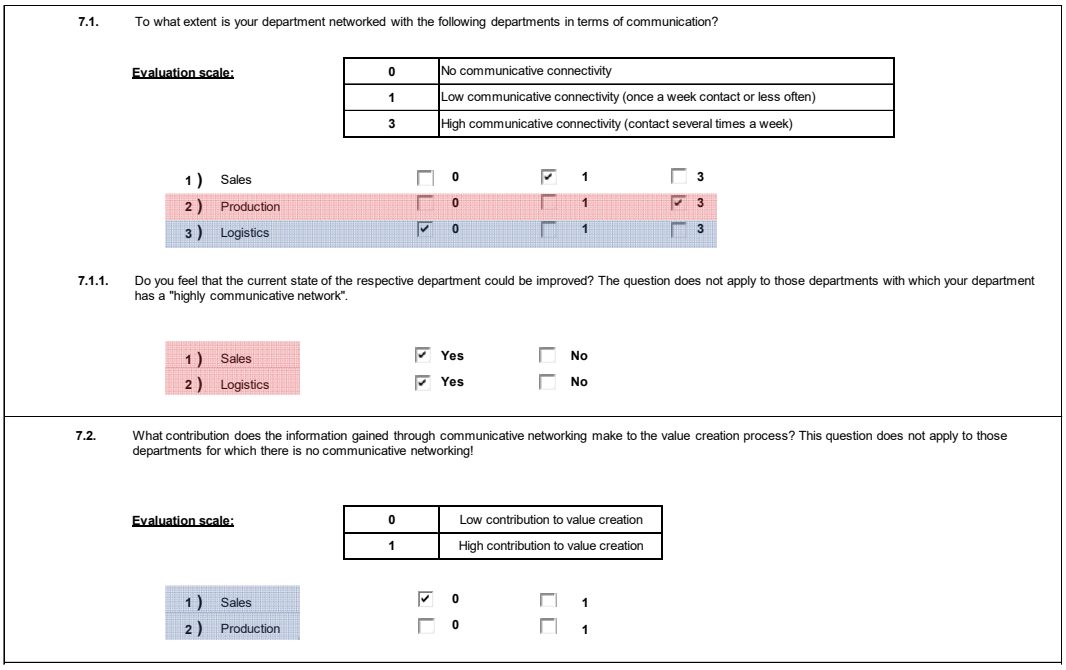

Figure 7: Application example - Capturing the current concept: Organizational degree of connectivity

Step 2: Evaluation of the current concept

The Excel tool automatically evaluates the captured data from step 1 by concluding a comparison of the target state and the status quo. The evaluation results with regard to the respective communication

requirement are displayed directly in the corresponding spreadsheet. For example, the work preparation department has a medium *organizational degree of connectivity* (Figure 8). At this point, it is easy to see how this overall result is made up. First, the overall assessment for each department is determined on the basis of the individual assessment results in sections 7.1, 7.1.1 and 7.2 (Figure 7). For instance, the *organizational degree of connectivity* with regard to production is given a score of 4, since work preparation is highly connected with production in terms of communication. Furthermore, the information received from production also makes a major contribution to the value creation process. Since a maximum of 4 can be achieved for each department in terms of the *organizational degree of connectivity*, the target–status-quo comparison results in a ratio of one, which corresponds to a degree of fulfilment of 100.00 %. If this result is classified in Table 1 from Section 3.2, this corresponds to a very good degree of connectivity. Finally, the overall result for work preparation with regard to the organizational degree of connectivity is derived from the individual assessment results for each department. For this purpose, the measurement figures from Section 7.3 are added up and compared with the sum of the target values. The sum of the target values results from the individual target values per department and characteristic (see red marking in Figure 8).

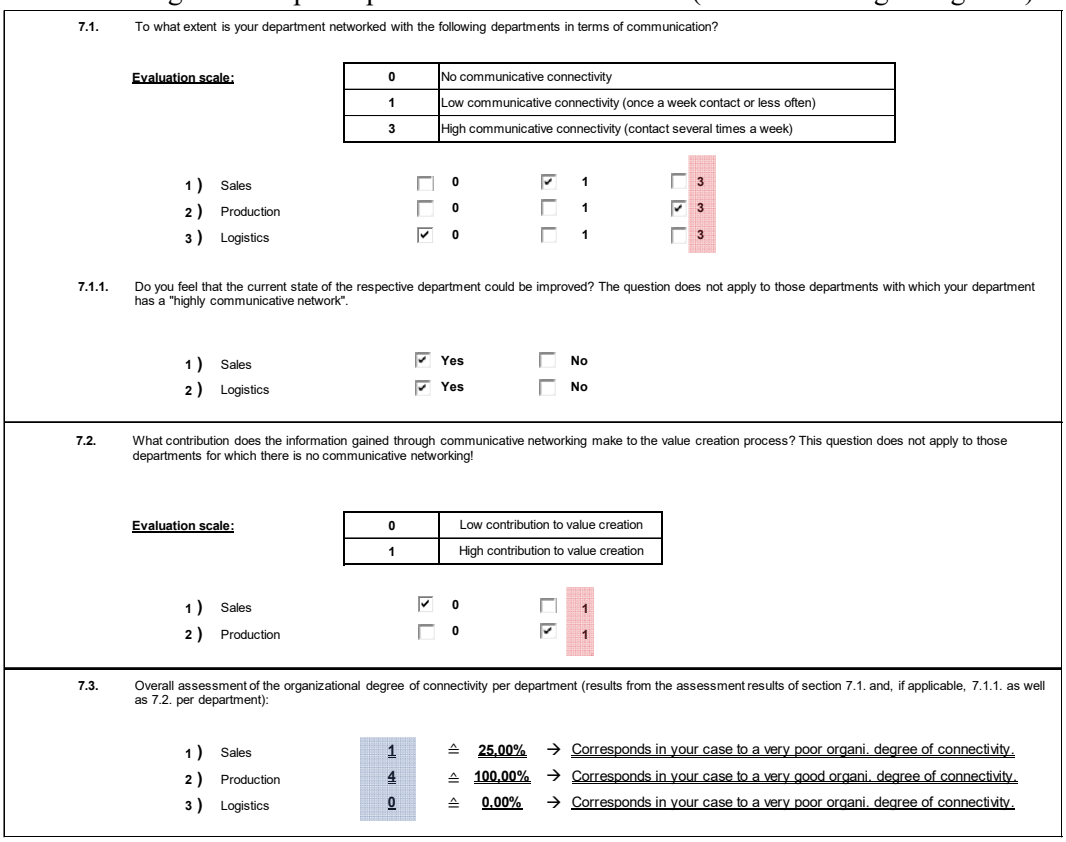

Figure 8: Application example - Evaluation of the current concept: Organizational degree of connectivity

At the end of the survey, all the overall results for each communication requirement are combined and displayed graphically in a two-dimensional bar chart (Figure 9). In this way, the weak points within a department are immediately recognizable. Exemplarily, Figure 9 shows that the work preparation department has clear deficits with regard to international cooperation capability, as this requirement is not even rudimentarily fulfilled with an overall result of 0.00%.

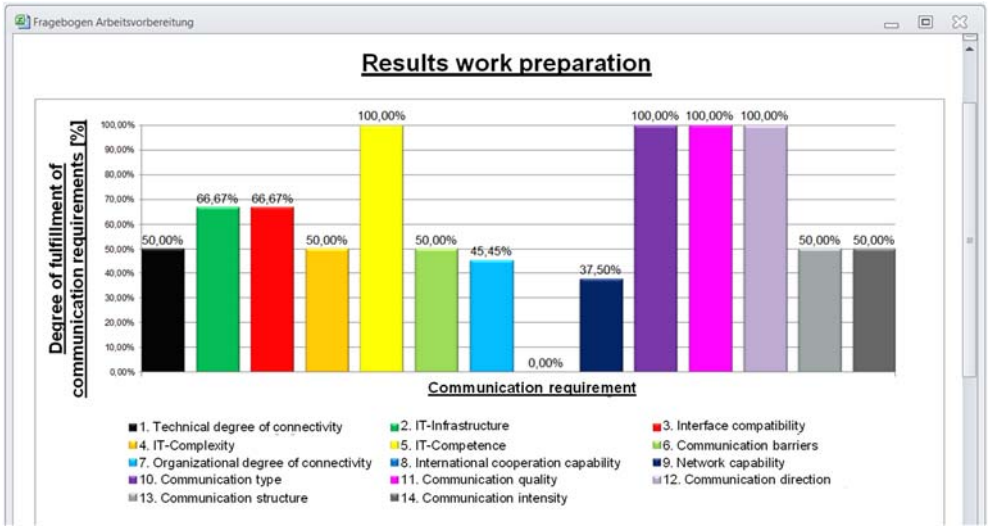

Figure 9: Application example - evaluation of the current concept: departmental result of work preparation

Step 3: Selection of action measures

After the capturing and evaluation of the status quo communication concept for each department has been completed, suitable action measures are selected with regard to the individual communication requirements. For this purpose, the overall results of the individual departments per requirement are compared in a two-dimensional bar chart. Figure 10 shows an example of this for the *organizational degree of connectivity*.

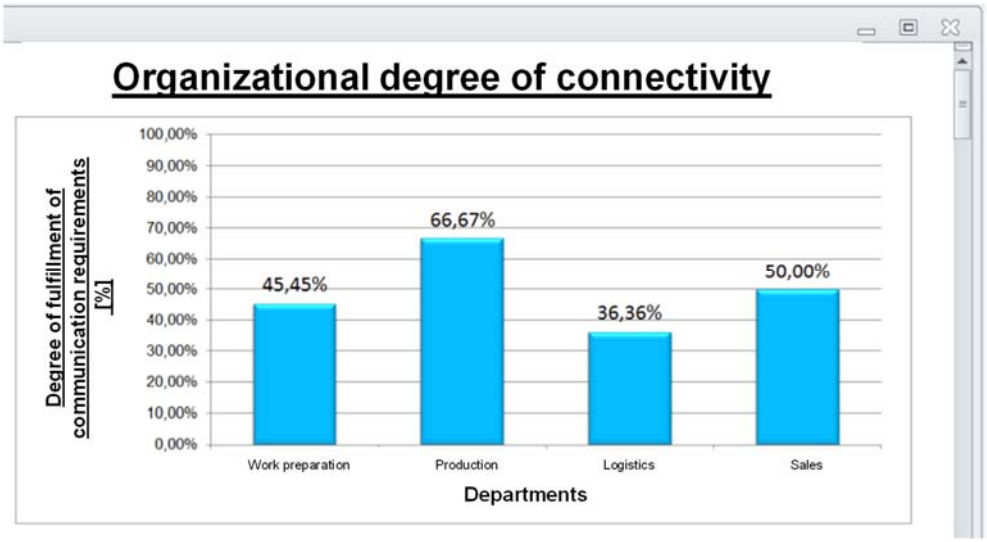

Figure 10: Application example - comparison of departmental results with regard to the organizational degree of connectivity

On the basis of this comparison, the individual departments are assigned to classes to determine which departments have similar deficits with regard to the respective requirement. According to this classification, department-specific and cross-departmental measures can then be made available for selection. In the present application example, work preparation and sales show a similar overall result with regard to the organizational degree of connectivity (Figure 11). This suggests that the two departments have similar deficits with regard to this communication requirement. In order to eliminate these deficits, the Excel tool provides a selection of different interdepartmental action measures from which the user can select the most suitable measures. However, it should be noted that priorities are automatically assigned with regard to the individual classes. The lower the class value and thus the degree of fulfilment of the respective communication requirement, the higher the priority of a class. The priority of the individual classes should

be taken into account when implementing the action measures. In the application example logistics fulfils the *organizational degree of connectivity* the least compared to the remaining departments. Accordingly, the class in which logistics is located has the highest priority. Therefore, this department should be given the greatest attention when implementing measures for action.

Action measures

The measures proposed in the following are intended to fulfill the respective communication requirement under consideration. With regard to the measures to be taken, a distinction is made between department-specific and cross-departmental measures. This distinction is made on the basis of a classification of the degree of fulfillment, whereby a step size of 15 percent was selected in each case. If there is only one department within a class, department-specific action measures are proposed for this class. For classes containing more than two departments, interdepartmental action measures are recommended, which are to be carried out in a uniform manner for all departments of the affected class.

Class	Frequency	Priority	Action measures per class	Action measure selection for class
Class 1 (0-15%)	**0**		-	
	0			
Class 2 (15-30%)	**0**		-	Select measure:
	0			
Class 3 (30-45%)	**1**	**1**	**department-specific**	Select measure:
Logistics	1			
Class 4 (45-60%)	**2**	**2**	**cross-departmental**	Select measure:
Work preparation	1			
Sales	1			
Class 5 (60-75%)	**1**	**1**	**department-specific**	Select measure:
Production	1			
Class 6 (75-90%)	**0**		-	Select measure:
	0			
Class 7 (>90%)	**0**		-	Select measure:
	0			

Figure 11: Application example - selection of action measures with regard to the organizational degree of connectivity

5. Conclusion and outlook

Overall, the method developed provides a first good approach with which communication structures of factories can be described, evaluated and designed holistically and systematically in the context of Industry 4.0. The comprehensive description model, which includes new Industry 4.0 requirements [6,8] in addition to the already known communication requirements, ensures a holistic view and thus evaluation of the communication structures in factories. In addition, the Excel tool enables a systematic evaluation by guiding the user step-by-step through the method, making the procedure more transparent and comprehensible at the same time. In addition, a comprehensive visualization of the assessment results supports the transparency and traceability of the method. Above all, however, the method is characterized by a simple as well as relatively low-effort application, since it was designed in such a way that no special expertise is required for its implementation and it can therefore also be used by non-specialists. Only the reproducibility of the method cannot be fully guaranteed. Although the questions are answered largely on the basis of formulated forms of expression, certain sub-questions are more akin to a self-evaluation. In particular, the questions about the improvement-worthiness of the respective current state are meant at this point. Since these questions can only be answered with "yes" or "no," the respondent can only fall back on self-determined criteria in order to make a decision between the answer alternatives. Accordingly, it would appear to be expedient to convert these questions into questions which can be answered on the basis of clearly formulated forms of expression within the framework of further research activities.

Furthermore, from the authors' industrial experience, an extended use of this method seems obvious and interesting. The core of this method is the communication on machine as well as on human level between the different departments during factory operation. However, also during the planning of a factory the communication between the different departments as well as numerous specialized planners is of great importance. Even before the initiation of a planning project, it should be possible for a project-managing entity to evaluate which specialist planners communicate data, information and knowledge on different

planning tasks and how. Especially against the consideration of an increasing digitalization in the individual planning disciplines and numerous attempts to develop a digital link between them (e.g. the use of Building Information Modelling in factory planning), a communication-oriented consideration of the planning relationships seems to be of great interest. Currently, decentralized data silos and heterogeneous IT landscapes hinder the communicative exchange, so that inefficiencies continue to occur in factory planning projects due to missing interfaces or misinterpretation of data.

Acknowledgements

The Deutsche Forschungsgemeinschaft (DFG) - Project number 405932399 - supports the research project described above.

References

[1] Nyhuis, P., Heinen, T., Noennig, T., Schulze, J.R., 2010. Kommunikationsgestaltung in Fabriken: Methode zur Beherrschung schnittstellenübergreifender Kommunikationsbeziehungen in Fabriken. Werkstattstechnik online 100 (4), 254–258.

[2] Wiendahl, H.P., Nyhuis, P., Reichardt, J., 2014. Handbuch Fabrikplanung: Konzept, Gestaltung und Umsetzung wandlungsfähiger Produktionsstätten, 2., überarb. und erw. Aufl. ed. Hanser, München [u.a.], XXIII, 628 S.

[3] Wiendahl, H.-P., Wiendahl, H.-H., 2019. Betriebsorganisation für Ingenieure, vollständig überarbeitete Auflage 9. ed. Hanser, München.

[4] Nyhuis, P., 2010. Kommunikationsorientierte Fabrikplanungsprozesse: Gestaltung und Bewertung kommunikationsorientierter Fabrikprozesse an den Schnittstellen betrieblicher Arbeitsprozesse. Abschlussbericht zum DFG Forschungsvorhaben NY 4/22-1. Leibniz Universität, Hannover.

[5] Nyhuis, P., Noennig, J., 2016. Kommunikationsgestaltung in interorganisationalen Produktionsnetzwerken (InterKom), Hannover, 20 pp. Accessed 10 October 2019.

[6] Park, Y.-B., Hingst, L., Nyhuis, P., Kelber, M., Noennig, J.R., 2020. Development of a Model for describing, evaluating and designing Communication Concepts in Factories in the Context of Industry 4.0. Proceedings CPSL 2020, 418–425.

[7] Schenk, M., Wirth, S., Müller, E., 2014. Fabrikplanung und Fabrikbetrieb. Springer Berlin Heidelberg, Berlin, Heidelberg.

[8] Park, Y.-B., Nyhuis, P., 2021. Operationalisation Of Communication Structure Requirements In Factories In The Context Of Industry 4.0 // Evaluation Of Communication Structures In Factories In The Context Of Industry 4.0. Journal of Production Systems and Logistics 2021 (1).

[9] Allweyer, T., Knuppertz, T. EDEN - Reifegradmodell. Prozessorientierung in Unternehmen. 2009.

[10] Münzberg, B., Wochinger, T., 2010. Schlussbericht zum AiF-Vorhaben 14992 N. ProdLog-Design – Reifegradbasierte Entwicklungspfade zur leistungssteigernden Gestaltung der Produktionslogistik in kleinen und mittleren Unternehmen. https://www.bvl.de/files/441/481/522/578/2010_03_15_Schlussbericht_AiF_14992_N.pdf, zuletzt geprüft am 02.08.2016.

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 Hanover since 2019. He previously studied mechanical engineering at the TU Ilmenau (B.Sc.) and at the Karlsruhe Institute of Technology (M.Sc.).

Lena Papke, M.Sc. (*1993) has been a project manager in the Corporate Quality Unit at Phoenix Contact GmbH & Co. KG since 2017. She previously studied industrial engineering at the Leibniz University Hanover (B.Sc. / M.Sc.).

Prof. Dr.-Ing. habil. Peter Nyhuis (*1957) has been head of the Institute of Production Systems and Logistics (IFA) at Leibniz University Hanover since 2003. Prof. Dr.-Ing. habil. Peter Nyhuis was a member of the German Science Council (2014 – 2018) and has been Chairman of the Science Council of the AiF (GAG3) since 2015. He is also a member of the German Academy of Technical Sciences acatech and the Scientific Society for Production Technology (WGP).