AN EVALUATION FRAMEWORK FOR WORKER-CENTRIC SOLUTIONS IN PRODUCTION ENVIRONMENTS

L. Hannola[1*], F. J. Lacuera-Pérez[2], M. Steinhueser[3], K. Kokkonen[1], V. Ojanen[1] and M. Schafler[4]

[1]*Lappeenranta University of Technology, Skinnarilankatu 34, 53851 Lappeenranta, Finland.*

[2]*ITAINNOVA Instituto Tecnológico de Aragón, María de Luna 7-8, 50018 Zaragoza, Spain.*

[3]*University of Zurich, Binzmühlestrasse 14, 8050 Zurich, Switzerland.*

[4]*Virtual Vehicle Research Center, Inffeldgasse 21a, 8010 Graz, Austria.*

Abstract

Evaluating how an Information Systems (IS) intervention in the workplace affects daily work and impacts on workers and organizations is a challenge that requires a very broad research approach. IS researchers have derived several models to explain and measure IS success, taking various perspectives and system types into account. This study presents an evaluation framework for measuring the impacts of an IS intervention especially at the shop floor in production environments. In this framework, we take a broad scope of examination and apply an integrated model that comprises elements from several methods for analyzing the acceptance and the impact of the new solutions. Thus, the aim is to further develop and enhance the existing methods and models for measuring the acceptance and the impacts of the sociotechnical interventions in production environments.

Keywords:

Evaluation, practice change, technology acceptance, information systems, production, individual and organizational impact, shop floor, smart factory.

1 INTRODUCTION

The potential of ubiquitous Information Systems (IS) for empowering workers at the shop floor have not yet been fully exploited in industrial production environments. The amount of data and required knowledge is increasing in factories, which demands more decision-making, social interaction and innovation skills among workers at the shop floor. In consequence, manufacturing enterprises should perform sociotechnical interventions adopting IS capabilities for supporting the changes in their work practices [1; 2]. This study is a part of the on-going FACTS4WORKERS (F4W) project, which develops and demonstrates worker-centered solutions that support the inclusion of increasing elements of knowledge work on the shop floor of smart factories. Originally, the SmartFactory^{KL} initiative came from industrial and academic partners for creating, demonstrating and researching a test environment for factory technologies of the future [3].

Whenever someone starts an IS project, concerns about its success start to appear. These concerns are even bigger in projects that are centered on users, where different targets can affect the project development because of communication issues [e.g. 4; 5]. F4W, as worker-centered IS project, shares these concerns and risks, and it aims to advance in their mitigation.

Evaluating how an intervention in the workplace affects the daily working practices as well as the workers and the organizations implies a very broad research scope. In this paper, we define a framework for evaluating worker-centered smart infrastructures within the production facilities of the industrial partners (IP) of the F4W project. In this framework, no specific model is used for examining a certain solution, but we take a broader scope and develop an integrated model with several methods for analyzing the acceptance and the impact of the new solutions at the shop floor. The aim is to further develop and enhance existing methods and models for measuring the acceptance and impacts of the sociotechnical interventions in the production environments.

As a basis for the framework construction, we have first investigated several theories and frameworks on job satisfaction, technology success and acceptance, system quality and industrial processes performance. Based on this review, central elements and categories have been selected.

The evaluation framework was created for demonstrating and evaluating the benefits introduced in factories when worker centered IS interventions are deployed. It has two main purposes: 1) to define metrics, key performance indicators (KPIs) and methods for measuring the impact of the smart factory on workers and organizations; 2) to plan and describe proper methodologies for an iterative evaluation of the aspects defined with end users and experts. For creating the framework, several design requirements were taken under consideration: it should be applicable at different stages of implementing a smart factory IS solution; it should consider software artefacts with different levels of maturity; it should support the perpetual beta conception of the F4W project; and the set of tools and methods to be proposed have to be suitable for each production process phase, as well as to be flexible enough for combining scientific research interest and practical needs.

Once the first release of the framework has been created, it has been tested (and evolved) on the developments of the specific use cases defined by the IPs. The application of the framework provides a set of short-term and longitudinal measurements which are used for analyzing the impact that IS interventions have on workers and also for validating the deployed IS artefacts by the workers. The purpose of the evaluation is to directly give feedback for the development with required improvements on deployed capabilities or indirectly by identifying new needs or scenarios.

The final goal of the evaluation framework is to be able to demonstrate the achievement of the three project objectives: 1) the increase of worker satisfaction, 2) the improvement of innovation and problem-solving skills, and 3) the increase of workers' productivity. The construction of F4W evaluation framework is presented in this paper. More detailed definition of the framework is presented in the F4W project deliverable [6].

2 RATIONALE FOR FRAMEWORK DEVELOPMENT

The F4W project's primary goal is to develop, pilot and evaluate a worker-centered solution which is designed for industrial shop floor environments by using new models for work optimisation and utilisation of production systems. In terms of measurable indicators, the objectives of the project derive from this main goal. The focus lies on increasing problem-solving and innovation skills as well as job satisfaction (JS) of workers who are intended to evaluate the pilots. The aim to increase the average worker productivity and the deployment of the smart factory infrastructure at technology readiness level (TRL) 5-7 are additional objectives of the project. It should be emphasized that JS may be an important indicator for the successful design and introduction of socio-technical workplace interventions [6]. Reduced JS caused by insufficient software solutions (which do not consider requirements of the workers appropriately) may reduce interventions' long-term acceptance. This also may lead to increased absenteeism and higher worker turnovers [7]. In contrast, an increase in JS might improve relevant activities such as group decision making, participative management, job enlargement etc. [8].

Therefore, this section introduces the rationale which focuses on the measurement of JS and the impact of an IS intervention on blue-collar workers in a factory. F4W has identified four industrial challenges which deal with the facets of knowledge management in smart factories. These facets include knowledge transfer, acquisition, discovery and sharing [9]. On the basis of these challenges and the problem scenarios defined by the project´s industry partners, the development tasks for the software solution derive from refined mock-ups. These mock-ups were built up on the basis of gathered requirements. The general approach in the development of the software prototypes for different smart factory environments (because of different stages of its standards at the industry partners) is a challenging task. For this reason, the IS solution arranges reusable software building blocks whereas the development team follows the principles of an agile software development approach. The traditional development circle consists of first requirements allocation, second technology development (set of several software building blocks) and third technology deployment [10]. It is aimed to deploy a first set of building blocks and components in order to evaluate the implementation and after that to refine the solutions during the following development circles. The perpetual beta principle of the software prototypes allows for making continuous improvements on the building blocks based on the recommendations and feedback of the users [10]. In order to push technology acceptance, it is important to give constant feedback to the workers (or end user) and demonstrate further stages of the prototype development after the first testing phase [10].

The evaluation will be executed on a technical level and together with the workers that are split in two groups whereas one acts as a control group. In the first run of the intervention the expectations of workers and organizational preconditions cannot be fulfilled entirely. The measurements will be executed by surveys, interviews and observation techniques during the different phases of the evaluation. Especially the initial software prototype evaluation is confronted with some issues concerning measuring worker satisfaction. For example, in designing questionnaires and interviews, several issues have to be considered. Complicated, difficult, and confusing questions can make the evaluation unpleasant for users. It is also not a good user's internal state indicator as determining emotions and moods are difficult.

3 THEORETICAL BACKGROUND

The evaluation framework (section 4) has the goal to demonstrate and evaluate the impacts of performed interventions. The framework is made of a set of tools and methods, taking existing ones from literature as a base, tailoring them and defining new approaches when considered for measuring these changes and for trying to demonstrate that these changes result from the IS interventions. Based on the nature of the measurements (qualitative/quantitative), their goals (understand behaviors/corroborate changes), source of information (human driven/data driven) or the different academic research backgrounds we have classified the approaches in two big categories: Classical Approaches (CA) and Technological Approaches (TA), which are introduced in the next paragraphs.

3.1 Review of Classical Approaches

CA comprise a set of tools and methods for evaluating impacts of IS interventions for determining the change on worker satisfaction, innovation and problem solving skills, and productivity. The research in this field has traditionally used what we call 'social sciences evaluation tools'. These are composed basically of qualitative and quantitative data collection, analysis and field research design (i.e. observation, focus groups, expert evaluations, interviews, surveys etc.). Next, we briefly introduce the set of tools we considered for measuring the change in JS and innovation skills due to the success and acceptance of the introduced IS solutions as result of the quality of the solutions and the involvement of the workers in their development.

Worker Satisfaction and Innovation Skills

Van Saane [11] provides a survey of existing frameworks for measuring and analyzing JS without considering external factors. The paper identifies 11 factors (dimensions) which are measured: autonomy; work content; communication; financial rewards; growth/development; promotion; co-workers; meaningfulness; supervision, feedback, recognition; workload; work demands. Finally, the paper compared studied methods based on the assessed factors.

Because of its possible generalization and the covered dimensions, *the Job Satisfaction Survey (JSS)* [12] seems to be the more appropriate to be considered for the framework under definition. However, JSS does not cover the autonomy, growth and development factors. Moreover, JSS only partially covers the workload factor [11]. We consider the *Job Descriptive Index (JDI)* [13] and *Job Diagnostic Survey (JDS)* [14] suitable for assessing job satisfaction of those factors which are not well covered by JSS.

Technology success and acceptance

Because F4W aims to improve worker satisfaction and increase innovation and problem solving skills of workers by introducing IS solutions, it is important to determine how systems are accepted and what the determinant success factors are. Davis [15] introduced the *Technology Acceptance Model (TAM)*. This model proposes the factor perceived usefulness, which means the degree to which a person believes that using a particular technology will enhance the job performance. Another factor of TAM, perceived ease of use, means the degree of effort the utilization of a particular technology requires. These are the fundamental determinants of technology adoption, and examines their mediating role between systems characteristics and the probability of system use [15]. TAM is confessed as one of the main adoption theories in the field of IS [16; 17].

The *Unified Theory of Acceptance and Use of Technology (UTAUT)* [18] integrates the theory and research on individual acceptance of IS into a unified theoretical model that captures the essential elements of previously established theories and models like TAM. The model introduces four determinants of user acceptance and usage behaviour: performance expectancy, effort expectancy, social influence, and facilitating conditions.

DeLone and McLean [19] updated the *Information Systems (IS) Success Model*. It considers that an IS artifacts' quality is composed of three dimensions: information quality, systems quality and service quality. They have to be measured separately as determinants of the artifact use and user satisfaction [19]. For example, information quality can be assessed based on how effectively it's presented, how useful is it etc. System quality refers e.g. to the system's easiness to use, user friendliness, stability, security etc. High quality service should be prompt, responsive, fair, knowledgeable and available [20]. Based on these theories, we propose indicators and some related elements for the assessment technology success and acceptance as a part of the evaluation framework.

Human machine interface assessment

Human Machine Interface (HMI) evaluation can be used for assessing three main issues of an IS artifact: physical interaction (restrictions to be considered) and user feelings about it; shown content (usefulness, consistency, etc. of information); and user attitude and understanding [21]. In consequence, HMI assessment has to be considered when determining the quality of a system and it is going to determine its success, its acceptance and the satisfaction of users.

In user-centered design, the evaluation process evolves together with the product development. It should be started as soon as any artefact, such as a mock-up of HMI prototype, would be available. Because they have a reduced cost, easy and cheap (re-)implementation and they enable stakeholders' communication, they contribute to improve users' involvement and motivation with the project development. The results of the evaluations can be used for different purposes: gathering requirements, refining design, assessment of worker acceptance etc.

Several frameworks have been developed for the purposes of evaluate the HMI interfaces. They can be classified in two kinds*: Usability frameworks* and *user experience frameworks.* Usability frameworks deal with the user's evaluation of the interfaces considering its efficiency, satisfaction, learnability, memorability and errors. Examples of these methods are; expert evaluation approaches [22], benchmarking with similar applications; or questionnaires like SUS [23] or UMUX [24]. User experience frameworks deal with the sensory and emotional state of a user. They are implemented in questionnaires like HED/UT [25].

All these CA methods are based on external measurements, which are obtained on regular shots and which are subjective, i.e. they are taken on an evaluation event not while performing daily tasks. Logging information while using applications could provide more objective measurements [26]. These real-time measurements could include analysis on how an interface is being used and on readings from sensors. While these measurements can be used, i.e. to determine the stress level of the cognitive load of a user [27], before considering their use it must be taken into account that the process is time consuming (affecting system performance) and there are legal issues to be considered.

3.2 Review of Technological Approaches

Classical approaches are well tested methods for measuring JS, technology acceptance, IS quality, usability and user experience with a solid background. They are the only ones that can be used during the initial stages of the development of an IS project [28]. However, their application in practice is not easy. For example, they require the direct interaction with the worker for determining the quality of the information of the system while technological approaches can be assessed from application and log data [30]. Furthermore, CAs can hardly be used for measuring productivity (efficiency and quality) which can be measured from timestamped application and log data.

TAs take advantage of the fact that FW4 designs, develops and deploys IS tools and applications that will contribute to empower the workers on the shop floor. The use of these tools usually generates large amounts of data (logs and applications), which can be used to analyze how the worker is interacting with them and, thus, to be able to extract valuable conclusions about the impact of the IS artefacts. TAs require the existence of a working IS artefact. However, compared to CAs, they are less invasive for the workers and their measurements are more objective. CAs do not require the existence of a working IS artefact and they can provide more subjective insights.

We use the term TA for referring to all those methods and tools which use logged data and/or application data for measuring the impact of an intervention on workers and/or organizations. They can be used for measuring the productivity or determining the effects of new IS solution interventions (learning curve or repetition when used in parallel with existing practices).

The F4W solutions are defined in [31; 32], and they can be classified as:

1. Knowledge Management Systems (KMS), where knowledge can be either tacit (ERP, MES, etc.) or explicit (Web 2.0 Solutions) [33];
2. Team Supporting Tools (tools supporting relations between workers within a team but also other scopes);
3. Data Management (repositories, connectors, etc.);
4. Workflow Engines (as front end and orchestrator of services);
5. HMIs.

There exist several frameworks that can be used for measuring the quality of these kind of systems such as: KMS [33] for Knowledge Management Systems; [34] for Team Supporting Tools; [35; 36] for Data Management; [37] for Semantic Workflow Engine Metrics; or [38] for HMI measurements based on logged information [26]. There are quality system measurements and productivity measurements that are closely related, in particular, when considering systems supporting the sharing of knowledge between workers. Moreover, logged data can be used to quantify the overhead due learning to use the introduced artefact or to the need to perform some tasks twice because of the maturity of the artefact.

4 THE EVALUATION FRAMEWORK FOR WORKER-CENTRIC SOLUTIONS

The F4W evaluation framework divides evaluation in two different concepts, the impact analysis and the quality validation [6], following the concepts of Gable et al. [29]. The impact analysis is used for assessing the designed artefacts' impact on individual and organizational levels. According the project's main goal, the individual impact comprises indicators of job satisfaction, whereas the impact on an organizational level includes measures of efficiency and quality. For measuring the impact, following dimensions are used: 1) autonomy, 2) competence, 3) variety, 4) relatedness, 5) protection, 6) efficiency and 7) quality. The framework also relates impact dimensions with the measurement of the interventions on worker impact (dimensions 1-5) and organizational impact (6-7) and with project objectives. Finally, it anticipates the expected impact IS artefacts would have on the IPs context of use.

The quality validation refers to the process of determination if the evaluated artefact provides the (system, information and interaction) quality the user expects. The results of the quality validation strongly depend on the maturity of the artefacts. If we consider a mock-up/demonstrator, a functional prototype/pilot or a deployed solution, we can expect to probe the functional feasibility of an idea (proof of concept), the value provided by a solution (proof of value) or the capability of a solution for addressing complex issues of operational feasibility (proof of use) [39].

But, how can impact analysis and quality validation be combined for evaluating a worker-centered IS artefact in smart factories? Figure 1 shows it. It is a reformulation of the evaluation process introduced by Gable et al. [29]. When an artefact is introduced, the evaluation results are going to be influenced by the use and satisfaction that already existing artefacts have provided. In order to determine any impact of an intervention, the relevant indicators must, first of all, be assessed in advance. These measurements provide a baseline that can be used for analyzing changes that happen after the introduction of the new artefact. As a second step of the evaluation, the artefact itself has to be validated in order to determine the quality of the involved IS, their provided information and the technologies in use. The results of this validation would help to determine the future user satisfaction and use of the artefact.

Evaluations will be repeated through all the project life whenever a new artefact will be presented to the workers. The repetition of the evaluations helps to determine next steps in the project: stop the project because the impacts have achieved expectations, abandon the project because the expected impacts have not been achieved or the quality is not good enough, continue the project by implementing some new functionalities etc. In order to obtain the set of tools and methods which can be used for performing evaluations, a state-of-the-art research of available tools has been done (section 3) to perform validations and impact analysis. Figure 2 summarizes our findings. The framework proposes the use of CAs and TAs, for evaluating either the impact or for validating the artefacts itself. Figure 2 also shows time as an important determinant of the approach to be used and the focus of the evaluation. As time passes, the focus of the evaluation moves from the validation (of the design of the artefact) to the assessment of the impact. Moreover, as the artefact of the intervention matures, application and log data would become available and it will support less intrusive measurements methods. Finally, time and maturity will determine when the selected tool/method could be applied (ex-ante, on-going, ex-post) and the kind of data to be obtained (quantitative, qualitative).

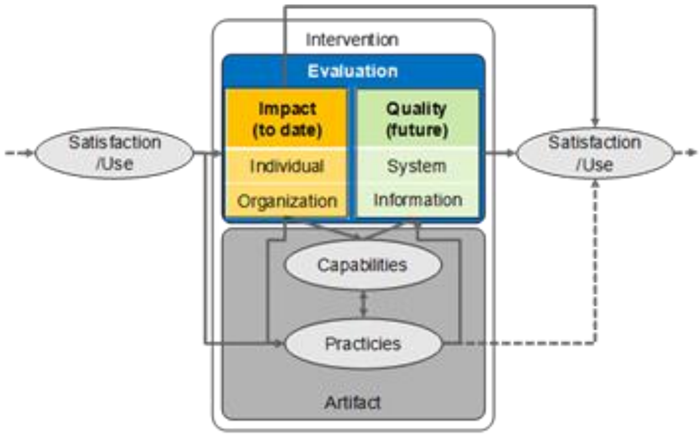

Figure 1: Conceptual formulation of the evaluation framework (reformulated from [29])

CAs for measuring the impact of interventions are based on the tools introduced in section 3 for assessing JS, the acceptance and success of systems and their perceived quality. These models provide validated measures that were transferred to questionnaires for assessing the project goals. The questionnaire provides a quantitative set of values as a result [6]. Questionnaires can be repeated through the time and fulfilled by many workers. Moreover, although they are performed in several languages, the data can be used for summarizing all results or for comparing the different IPs. However, as questionnaires restrict the focus of the attention of the respondent, they can hide some valuable insights about the reasons of the measurements either if they are due to the practices and/or the artefacts under evaluation. Moreover, the application of questionnaires could be hampered by legal issues in some scenarios.

The framework tries to solve these problems by considering some qualitative methods (semi-structured interviews, think aloud etc.) which include asking the questions defined in the questionnaires. While these qualitative methods would provide better insights on the workers' practices and needs, they can be difficult to be applied in some industrial shop floors, i.e. because of security reasons, and they require more resources from both the evaluated and the evaluator. In addition, the need of a control group of workers for trying to determine the effects that external factors have on JS and innovation and problem solving skills, would increase the difficulty of applying qualitative methods. In any case, the provision of both kinds of methods by the framework will help to adopt it to the requirements of each particular shop floor scenario.

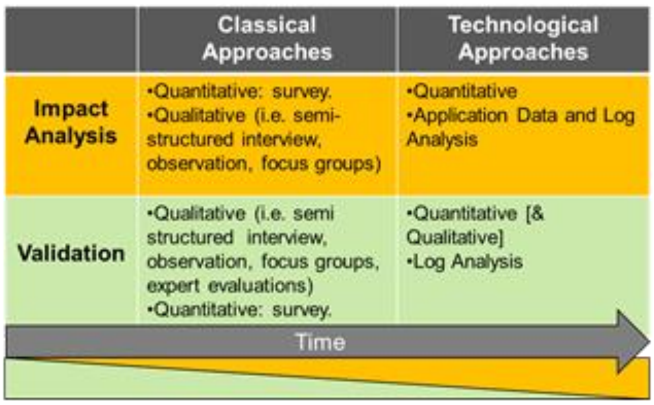

Figure 2: Tools and methods for the evaluation framework

Similar arguments can be provided for presenting the validation to be used for assessing the quality of an artefact. The framework proposes the use of a subset of the methods introduced previously (interviews, observation, questionnaires). Because the use of these tools aims to determine the quality of the artefacts, it's not required to consider a control group for comparison of the measurements. Moreover, while qualitative and quantitative methods are thought to be alternatives for the assessment of the impact, for validating an artefact's quality, they are considered in combination because they could provide more valuable insights. However, the maturity level of the artefact will determine the method to be used, the objective of the validation and its focus [40].

The maturity level of the artefacts will also determine the possibility of applying TAs or not, as the measurements would be dependent on the data gathered from application and/or logs. Data obtained from applications, either existing or new ones, can be used for determining the impact of the interventions by comparing the evolution of the KPIs of the workers directly affected by the interventions and the KPIs of the workers who are not affected by them. As with CAs, the consideration of a control group of workers may help to determine the existence of external factors modifying the impact of the interventions. However, in case of efficiency, in this project log data analysis will be used for determining the biases due to the learning processes of the introduced artefact handle and/or the performance of the artefact.

The study by Lacueva et al. [6] contains the definition of several measurements which can be used for determining the quality of the systems and their information which can be obtained from the logged data. In other words, log data can be used for validating the artefacts' complementarily to the CAs. These measurements could be general, i.e. use of the system, or particular for a given kind of system, i.e. number of contributing workers to a knowledge management system.

Impact analysis and validation processes are thought to be used through all the project life. While validation of artefacts will be linked to a particular intervention, the impact assessment process is going to be executed at given points of time. It does not mean that impact analysis is going to be a continuous process; it means that the measurements are going to be considered longitudinal. For example, when CA tools are applied, measurements will be gathered at given points of time, before the interventions or after a period a given intervention have time, they will be repeated with each intervention.

Because the questions are linked to the impact dimensions, current measurements will provide insights about whether the desired effects are achieved or not. These insights will be based on the comparison of the impact assessment before the intervention (or the beginning of the project) with the results after the intervention considering the use of a control group of workers for being able to determine bias due to external factors.

CAs will support the analysis of the impact dimensions which are related with worker's JS and their innovation and problem-solving skills. TAs will be required for measuring the impact interventions have in productivity. Together with the use of control groups, TAs used for measuring impact will validate the assumptions that F4W improvements are due to the project intervention.

5 CONCLUSION

As a theoretical contribution of this study, we present an evaluation framework that supports the evaluation process in a project which is characterized by a wide range of different companies and IS solutions that are developed to be deployed in these companies. The framework allows for embracing this variety by combining the state-of-the-art research of available tools and provides indicators that enable a wide impact measurement of the new digital solutions in smart factories.

The approach provides us with indicators that are valid for all use cases of the project but it also leaves room for case specific measurements. This implies that, when it comes to quantify the results in order to compare them adequately, the company- and solution-specific conditions have to be considered. Some of them, as for example a change of job satisfaction in percent can be analyzed project-wide while others, like descriptions of changes work processes should be regarded separately. Due to the underlying conditions as described in section 2, it was important to find an appropriate trade-off between generalization and specialization. Generalization, on the one hand, is important in order to get comparable data across all cases [29]. Specialization, on the other hand, is needed, in order to receive meaningful evaluation results [41].

However, because sometimes the expected effect would not be achieved, validation tools will help to determine the possible causes. This might result either in improvements of the software, the addition of new functionalities or the creation of new artefacts. Because the validation framework links different kinds of IS quality measurements with impact dimensions and after the execution it will provide a set of real measurements relating them to obtained impact, it is expected that the framework could also be used for determine which are the aspects to consider when evaluating the introduction of a given system.

6 ACKNOWLEDGMENTS

This study has received funding from the European Union's Horizon 2020 research and innovation program under Grant Agreement n° 636778.

7 REFERENCES

[1] UNIDO, the United Nations Industrial Development Organization, 2013, Emerging trends in global manufacturing industries, Vienna, Austria, 90 p.

[2] Kannengiesser, U., Neubauer, M., Di Francescomarino, C., Dragoni, M., Ghidini, C., Heininger, R., 2015, Worker-Driven Improvement of Processes in Smart Factories, Mensch und Computer 2015 – Workshopband.

[3] Zuehlke, D., 2010, SmartFactory–Towards a factory-of-things, Annual Reviews in Control, 34, 129-138.

[4] Barrett, M., Davidson, E., Prabhu, J., Vargo, S. L., 2015, Service innovation in the digital age. MIS Quarterly, 39, 1, 135-154.

[5] Xu, J. D., Benbasat, I., Cenfetelli, R. T., 2013, Integrating Service Quality with System and Information Quality: An Empirical Test in the e-Service Context, MIS Quarterly, 37 (3), 777-794.

[6] Lacueva, F.J., Mayo, S, Heinrich, P., Moertl, P., Hannola, L., 2016, Project Deliverable 6.1: Evaluation Framework, Project FACTS4WORKERS: Worker-Centric Workplaces in Smart Factories.

[7] Mörtl, P., Schafler, M., Lacueva, F.J., 2016, Worker Characteristics moderate the Impact of Socio-technical Workplace Interventions on Job Satisfaction. In: Weyers, B. & Dittmar, A. (Hrsg.), Mensch und Computer 2016 – Workshopband. Aachen: Gesellschaft für Informatik e.V.

[8] Smith, P. C., 1969, The Measurement of Satisfaction in Work and Retirement: A Strategy for the Study of Attitudes. Chicago, IL: Rand McNally.

[9] Hannola, L., Heinrich, P., Richter, A., Stocker, A., 2016, Sociotechnical challenges in knowledge-intensive production environments, XXVII ISPIM Conference, June 19-22, 2016, Porto, Portugal.

[10] Gerhard, D., Dumss, S., Rosenberger, P., 2016, Project Deliverable 5.1: Blueprint Architecture and Integration Plan. Project FACTS4WORKERS: Work-Centric Workplaces in Smart Factories.

[11] van Saane, N., Sluiter, J., Verbeek, J., Frings-Dresen, M., 2002, Reliability and validity of instruments measuring job satisfaction - a systematic review. Occupational medicine, 53 (3), 191-200.

[12] Spector, P. E., 1985, Measurement of Human Service Staff Satisfaction: Development of the JS Survey. American Journal of Community Psychology, 13 (6), 693-713.

[13] Smith, P.C., 1967, The development of a method of measurement for JS: The Cornell Studies, E.A. Fleishman (Ed.) Studies in personnel and industrial psychology (343-349), Homewood, IL: Dorsey.

[14] Hackman, J., R., Oldham, G. R., Janson, R., Purdy. K., 1975, a New Strategy for Job Enrichment. California Management Review, Vol 17 (4), 57-71.

[15] Davis, F.D., Bagozzi, R.P., Warshaw, P.R., 1989, User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. Management Science, 35 (8), 982-1002.

[16] Legris, P., Ingham, J., Collerrette, P., 2003. Why do people use information technology? A critical review of the technology acceptance model. Information & Management, 40, 191-204.

[17] Awa, H.A., Ojiabo, O.U., Emecheta, B.C., 2014, Integrating TAM, TPB and TOE frameworks and expanding their characteristic constructs for e-commerce adoption by SMEs, Journal of Science & Technology Policy Management, 6, 76-94.

[18] Venkatesh, V., Brown, S. A., Bala, H., 2013, Bridging the Qualitative-Quantitative divide: Guidelines for conducting mixed methods research in information systems, MIS Quarterly, 37 (1), 21-54.

[19] DeLone, W.H., McLean, R., 2003, the DeLone and McLean Model of Information Systems Success: A Ten-Year Update, Journal of Management Information Systems, 19 (4), 9-30.

[20] Holsapple, C.W., Lee-Post, A., 2006, Defining, Assessing and Promoting E-Learning Success: An Information Systems Perspective. Decision Science Journal of Innovative Education, 4 (1), 67-85.

[21] Angeletou, A., Garschall, M., 2013, T&T Net, Deliverable 3.1: Pilot Assessment and Evaluation Plan.

[22] Rettig, M., 1994, Prototyping for tiny fingers, Communications of the ACM, 37 (4), 21-27.

[23] Brooke, J., 1996, SUS-A quick and dirty usability scale, Usability evaluation in industry, 189 (194), 4-7.

[24] Finstad, K., 2010, The usability metric for user experience, Interacting with Computers, 22 (5), 323-327.

[25] Voss, K. E., Spangenberg, E.R., Grohmann, B., 2003, Measuring the hedonic and utilitarian dimensions of consumer attitude, Journal of Marketing Research, 40 (3), 310-320.

[26] Hashemi M., Herbert J., 2015, Baran: An Interaction-centred User Monitoring Framework, Proceedings of the 2nd International Conference on Physiological Computing Systems, 52-60, ESEO, Angers, Loire Valley, France.

[27] Setz, C., Arnrich, B., Schumm, J., Ehlert, U., 2010, Discriminating stress from cognitive load using a wearable EDA device, IEEE Transactions on Information Technology in Biomedicine, 14 (2), 410-417.

[28] Steinhueser, M., Herzog, C., Richter, A., Hoppe, U., 2015, A Process Perspective on the Evaluation of Enterprise Social Software, Proceedings of the 2nd European Conference on Social Media, 429-436.

[29] Gable G.G., Sedera D., Chan T. (2008), Re-conceptualizing information system success: the IS-Impact Measurement Model, Journal of the Association for Information Systems, 9(7), 377-408.

[30] Richter, A., Heidemann, J., Klier, M., Behrendt, S. 2013, Success measurement of enterprise social networks, the Wirtschaftsinformatik 2013, Leipzig, Germany.

[31] Heinrich, P., Richter, A., 2015, Project Deliverable 1.1: Captured and structured practices of workers and contexts of organizations, Project FACTS4WORKERS: Worker-Centric Workplaces in Smart Factories.

[32] Denner, J., Heinrich, P. Heldman, C., Richter, A., 2015, Project Deliverable 1.2: First version of requirements of workers and organisations, Project FACTS4WORKERS: Worker-Centric Workplaces in Smart Factories.

[33] Wong, K.Y., Tan, L.P., Lee, C.S., 2013, Knowledge Management performance measurement: measures, approaches, trends and future directions, Information Development, 31 (3), 239–257.

[34] Behrendt, S., Richter, A., Trier, M., 2014, Mixed methods analysis of enterprise social networks, Computer Networks, 75, 560-577.

[35] Sidi, F., Panahy, P. H. S., Affendey, L. S., Jabar, M. A., Ibrahim, H., Mustapha, A., 2012, Data quality: A survey of data quality dimensions, IEEE International Conference on Information Retrieval & Knowledge Management (CAMP), 300-304.

[36] Batini, C., Cappiello, C., Francalanci, C., Maurino, A., 2009, Methodologies for data quality assessment and improvement, ACM computing surveys (CSUR), 41 (3), 16.

[37] Cardoso, J., Sheth, A., Miller, J., Arnord, J., Kochut, K., 2004, Quality of service for workflows and web service processes, Journal of Web Semantics: Science, Services and Agents on the World Wide Web, 1 (3), 281-308.

[38] Lettner, F., Holzmann, C., 2012, Automated and unsupervised user interaction logging as basis for usability evaluation of mobile applications, Proceedings of the 10th International Conference on Advances in Mobile Computing & Multimedia, ACM, 118-127.

[39] Nunamaker Jr, J. F., Briggs, R. O., Derrick, D. C., Schwabe, G., 2015, The last research mile: Achieving both rigor and relevance in information systems research, Journal of Management Information Systems, 32 (3), 10-47.

[40] Venable, J. Pries-Heje, J., Baskerville, R., 2012, A comprehensive framework for evaluation in design science research, International Conference on Design Science Research in Information Systems, Springer Berlin Heidelberg, 423-438.

[41] Seddon, P. B., 1997, A respecification and extension of the DeLone and McLean model of IS success, Information systems research, 8 (3), 240-253.