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Assembly Disruptions – Empirical Evidence in the Manufacturing Industry of Germany, Austria and Switzerland

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ABSTRACT: In this paper, we present the results of an empirical study in the manufacturing industry of Germany, Austria and Switzerland with over 100 participants, mainly from the mechanical engineering, automotive and machine tool businesses. The questionnaire-based study yielded original findings in the area of assembly disruptions and the management thereof. Major results include that assembly disruptions are widespread in the industry and lead to extensive economic damages. The reasons, durations and locations of assembly disruptions as well as their character are explored and the need for a new concept of efficient, preventive assembly disruption management is derived.
Keywords: Assembly disruptions, disruption management, empirical study

I. INTRODUCTION

In order to succeed in the competition enforced by the growing globalization of markets, companies face the urgent need to increase flexibility as well as to ensure on-time delivery and to minimize their production costs [1] [2]. A key element of the minimization of production costs is a decrease of assembly costs in spite of simultaneously increasing quality, complexity and customization requirements [3] [4]. A main issue to be addressed for the reduction of production costs and for a secure on-time order completion are disruptions occurring during the assembly process. According to LEHMANN, a disruption is every kind of unintentional deviation from the usual assembly process [5].SCHWARTZadds staff, materials, information or orders as root causes for different kinds of assembly disruptions[6].

According toABUMAIZAR AND SVESTKA, disruptions include machine breakdowns, lacks of material, rush orders and cancelled orders [7]. Although a lot of information about disruption management can be found in the literature and the problem of disruptions is often described, only few empirical studies regarding this issue have been carried out in the production industry. Except studies by LEHMANN and WUENSCHER, which date back several years, little quantification of assembly disruptions can be found in the existing literature. [5] [8]

The study aims to answer three main questions. The first question regards the current situation of companies in the production industry induced by assembly disruptions. Secondly, the study intends to examine the question of how disruptions occur and how they can be characterized. The third question regards disruption management approaches that are already applied in the industry. The study structure has been designed with the purpose of supporting the answer to these questions.

II. PRESENTATION OF THE STUDY DESIGN

In order to fill the date gaps regarding quantified assembly disruptions by describing the reasons for assembly disruptions as well as their impacts and to validate solution hypotheses, an empirical study has been conducted. The study has been carried out in the form of a web-based survey. Participants from Germany, Austria and Switzerland were questioned against the background of several hypotheses within the online-questionnaire. The study design is structured in three consecutive modules. The sample of the study is presented and characterized in the first section. The second module deals with the problem description before some applied solution approaches are presented in the third section (Fig. 1).

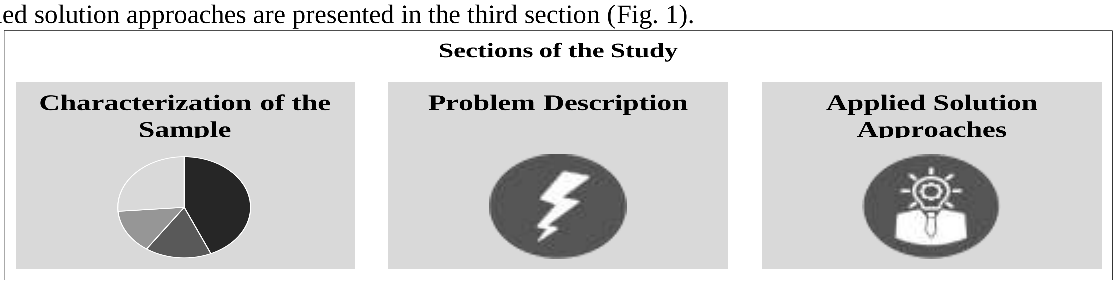

Fig. 1 Study Design: Modules of the questionnaire

The results of this study are presented in the following.

III. PRESENTATION OF THE STUDY SAMPLE

The first part of the questionnaire is intended to characterize the sample of this study. The sample includes 101 participants from numerous companies from Germany, Austria and Switzerland, many of which are internationally operating. The participants hold high positions such as plant manager, production or assembly manager. Due to the large scope of this study, significant results have been derived.

The largest proportion of the participants' companies can be assigned to the mechanical engineering respectively plant engineering industry, automotive industry and machine tool industry. Other participants work for companies in the electrical and aviation industry.

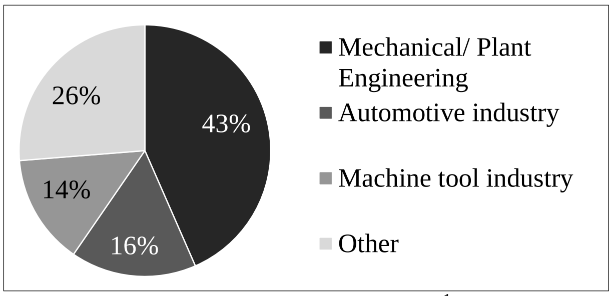

Fig. 2 Represented industries[1]

On average, almost 13,000 members of staff are employed in each of these companies, with an average of about 7,600 employees in the area of assembly. The largest company in the sample employs 360,000 employees. Some other companies employ around 100,000 members of staff.

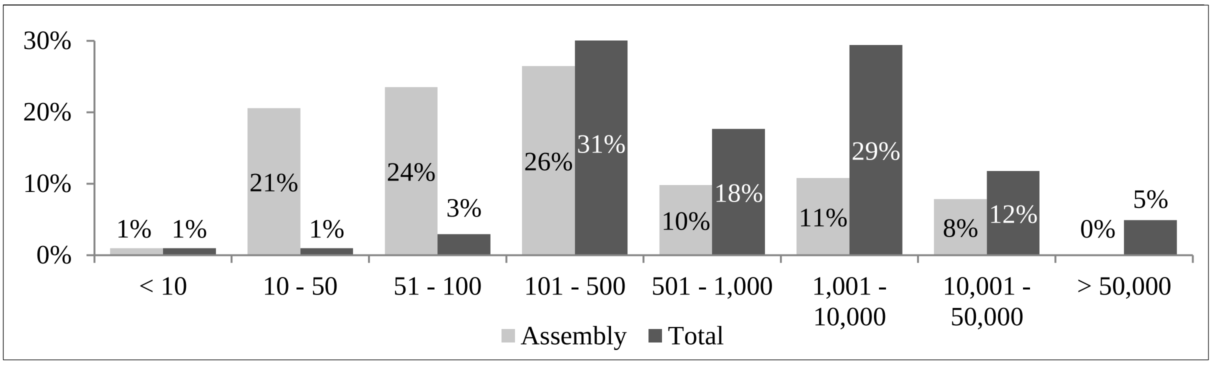

Fig. 3 Number of staff [FTE] in the assembly and in the entire company

To characterize the participating companies in terms of their economic situation, the annual turnover has been taken as a measure (year 2014). Two percent of the participants state an annual turnover between 2 and 10 million €, 21 % between 10 and 50 million € and 77 % above 50 million €.

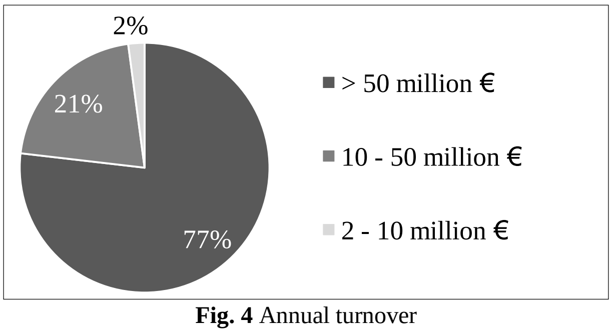

Fig. 4 Annual turnover

[1] If figures do not add up to 100 %, this is due to rounding differences. This applies to several figures in this paper.

It can be derived from these numbers that about one fourth of the sample are ranked among small or medium-sized enterprises (SMEs) which are characterized by an annual turnover below 50 million € based on the SME definition by the European Commission. [9]

The participants further describe the degree of standardization of their companies' products. Only few characterize their products as completely standardized, whereas 39 % classify their products as mainly standardized, 29 % as mainly customized and 24 % as customized.

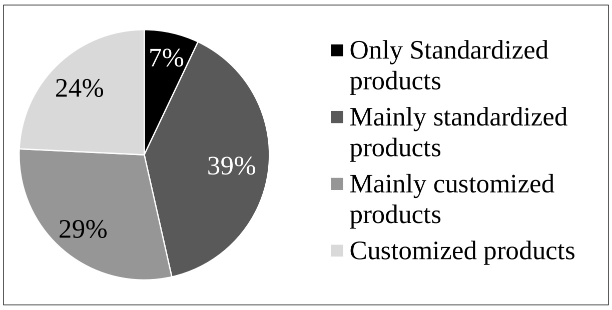

Fig. 5 Degree of standardization of the products

A large diversity can be recognized in the companies' assembly output volumes in 2014. The range reaches from less than ten to more than a million assembled units per year.

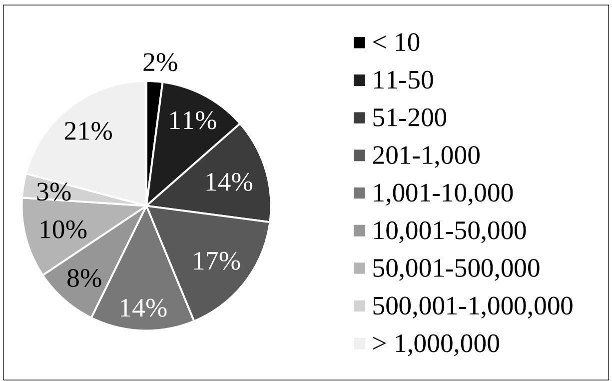

Fig. 6 Assembly volumes [units per year]

The forms of assembly organizations named by the participants reach from group assemblies to production line assemblies, which shows a wide range of assembly practices throughout the represented industries and companies.

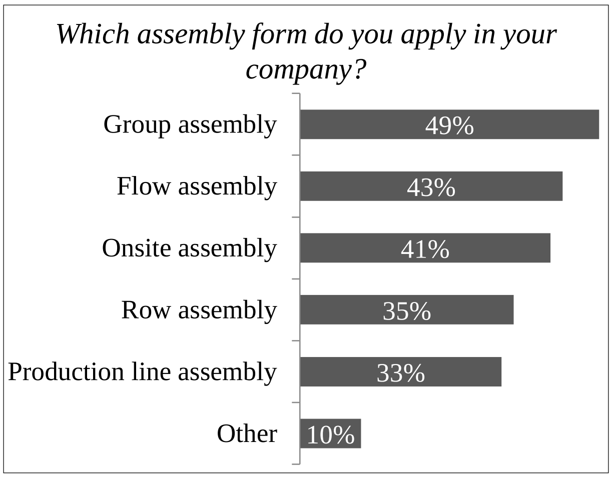

Fig. 7 Assembly forms

IV. CURRENT DISRUPTION SITUATION IN INDUSTRIAL ASSEMBLY

In the second part of the survey, the participants were confronted with questions to analyze whether their companies suffer from assembly disruptions. Further questions aimed at characterizing the disruptions regarding where and how they arise, their duration, whether they can be predicted or avoided and how they are monitored and documented in the companies.

In the beginning, the participants were asked to rate their approval ofthe statement *"Assembly disruptions cause economic losses for our company, e.g. due to additional costs or delays in delivery."*

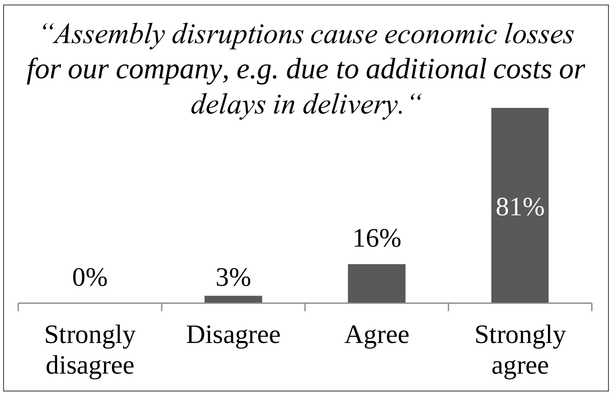

Fig. 8 Rating of economic losses caused by assembly disruptions

It can be seen in Fig. 8that the vast majority of companies (97 %) agree or strongly agree with the statement, which proves that assembly disruptions are a severe economic problem for most companies in the production industry. With these significant results, this study confirms prior findings from the literature, which attest the economic impact of disruptions in the assembly (e.g. [3]).

In the following, the reasons for assembly disruptions in the participating companies were analyzed in a question allowing multiple answers. As can be seen inFig. 9, 92 % of the participants state to have material deficiencies causing disruptions. 54 % respectively 65 % of the participants ascribe assembly disruptions to lacks of capacity and information. Another 19 % name technological problems, environmental influences and quality problems as further reasons.

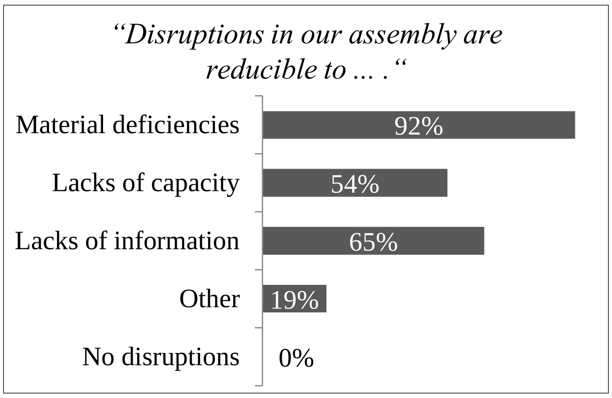

Fig. 9 Reasons for assembly disruptions

Similar results were obtained by LEHMANN in 1992. In his study, which was carried out in a sample of 16 companies, he inter alia evaluated which kind of assembly disruptions occurred. 63 % of the disruptions examined by him were reducible to material-related problems and 18 % respectively 19 % to lacks of capacity and information. [5] The figures differ since LEHMANN evaluated a sample of single disruptions which did not generate multiple answers. Nevertheless, the basic statement endures.

The areas where disruptions can be detected in the companies were investigated next with multiple answers allowed. 95 % of the participants experience disruptions in the final assembly, 73 % in the pre-assembly and only 25 % in a field or onsite assembly. The last value might be due to the fact, that most industrial companies finish their assembly in their own plant, not on the site of the later usage of the product. No participant states not to experience disruptions at all.

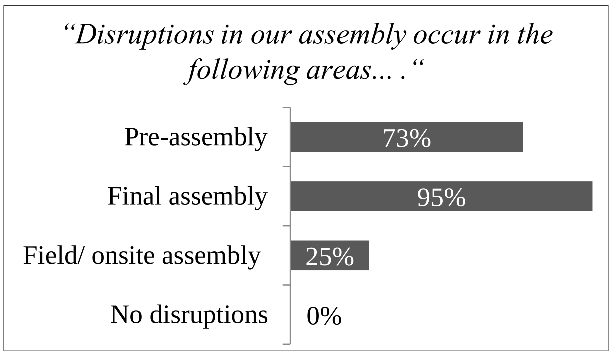

Fig. 10 Areas of disruptions

Again, the data collected by LEHMANN substantiate these results. He found that the majority (62 %) of the examined disruptions in his study arose in the final assembly, 28 % in the pre-assembly and 10 % in a field or onsite assembly. [5]

LEHMANN further worked out the duration of the regarded disruptions. In his sample, 48 % of the disruptions lasted longer than four hours, whereas a small majority of the disruptions (52 %) lasted for a shorter period of less than four hours. [5]

The results of our study show that the duration of disruptions has decreased significantly compared with his findings. 65 % of the sample characterize the average duration of their assembly disruptions as “short (< 4 hours)” and only 35 % as “long (> 4 hours)”.

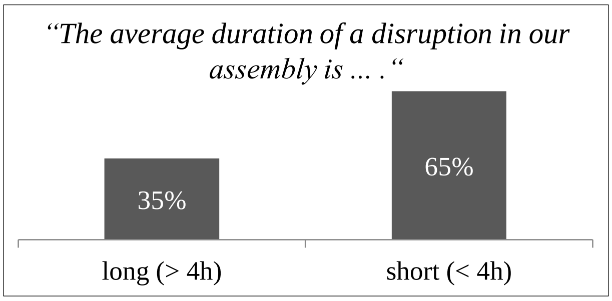

Fig. 11 Average duration of assembly disruptions

These findings suggest that the majority of assembly disruptions that companies have to deal with only last for a relatively short time.

The importance of the duration of occurring disruptions can be measured by the induced economic losses. It was found that participants who describe their assembly disruptions as “long (> 4h)” rather tend to agree to the fact that assembly disruptions cause economic losses than those who describe their disruptions as “short (< 4h)”.

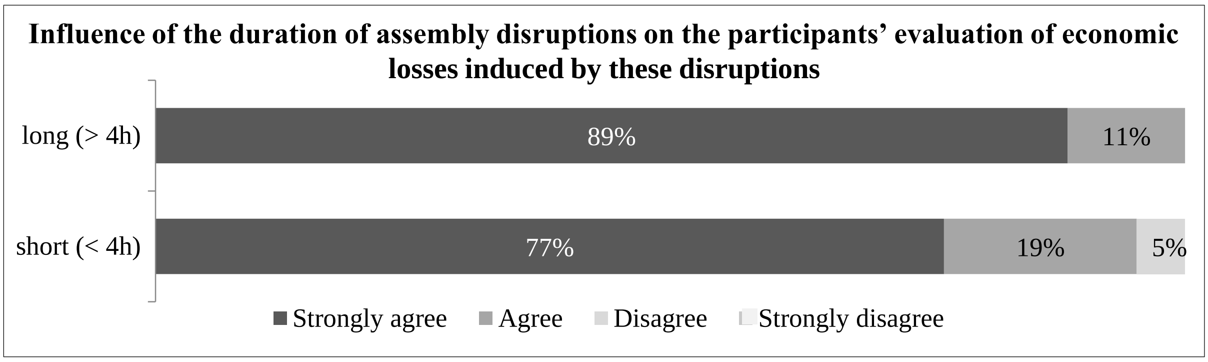

Fig. 12 Evaluation of economic losses due to assembly disruptions depending on their duration

In the next question, the participants were confronted with the statement *"Theoretically predictable or even avoidable disruptions occur in our assembly.”*as this information about a disruption can be beneficial in terms of finding promising disruption management solutions. The answers show that a high proportion of assembly disruptions can be predicted and therefore potentially avoided. 72 % of the participants agree (24 % strongly) to the statement whereas 28 % disagree (2 % strongly).

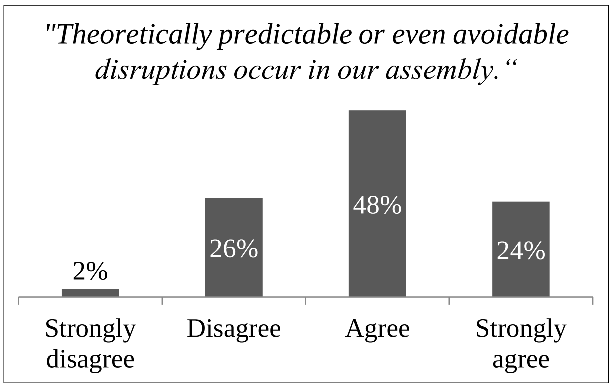

Fig. 13 Assembly disruptions that can be predicted or even avoided

The repetition of assembly disruptions over time in a similar way is likely to increase the predictability of assembly disruptions. Thus, the proposition "*In our assembly, disruptions occur which repeat in a similar way.*" was presented in the survey in order to enquire the level of repetition with which disruptions arise. 79 % of the participants confirm that disruptions repeating in a similar way can be found in their assembly (33 % strongly) whereas 21 % disagree with the statement.

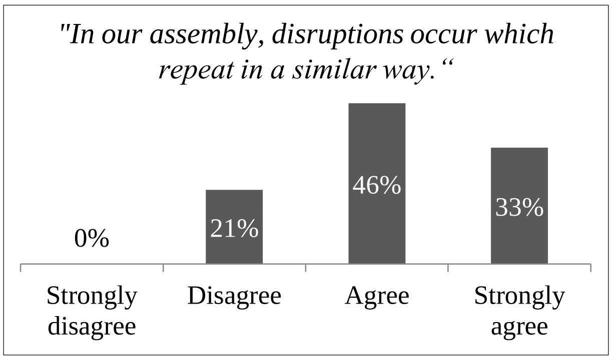

Fig. 14 Similar repetition of disruptions

These results suggest that a high proportion of assembly disruptions is caused by lasting problems instead of random environmental influences. The reduction of the frequency of disruptions has been described as a critical element of a successful disruption management in the literature before (e.g. [10]). This underlines the significance of these findings, as the recognition of repeating disruptions is a promising approach to this aim.

A profound knowledge and an explicit documentation of processes respectively parts, that are critical with regard to assembly disruptions, are described as the groundwork for a successful disruption management in the literature [3]. Therefore, the participants were asked for their degree of consent with the statement *"Critical processes respectively parts are known and explicitly documented in our company."*

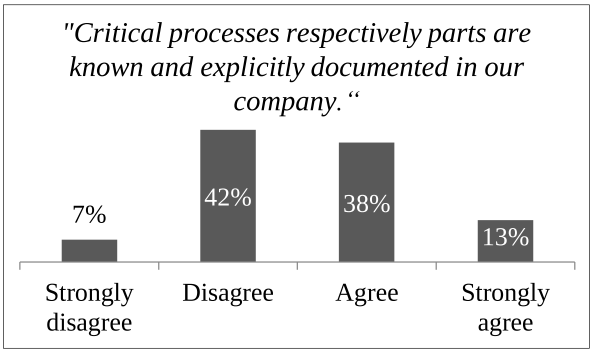

Fig. 15 Knowledge and documentation of critical processes and parts

The results reveal a potential for improvement regarding the monitoring of the elements of the assembly process that are vulnerable to disruptions.

In the last question of the second part of the questionnaire the proposition *"Due to limited planning capacities, not all processes respectively parts in our company can be monitored regarding possible future* *disruptions."* was presented in order to determine a possible reason for why the monitoring of processes is still worthy of improvement.

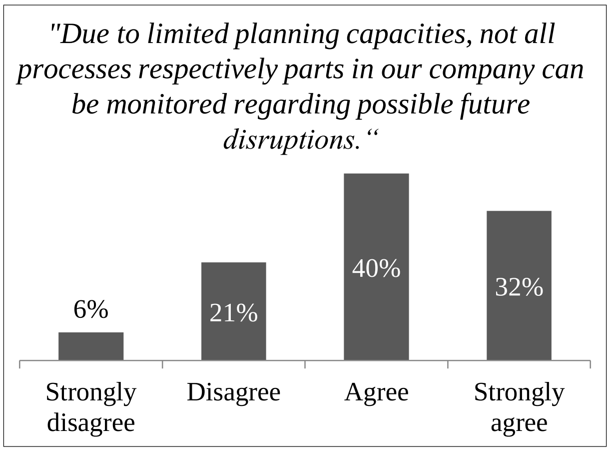

Fig. 16 Restrictions to the monitoring of processes due to limited planning capacities

The results as shown in Fig. 16 suggest that limited planning capacities inhibit a complete monitoring of processes.

V. DISRUPTION MANAGEMENT APPROACHES AND EVALUATION BY PARTICIPANTS

The third part of the questionnaire addresses solutions and improvement approaches the participants already apply in their companies within the scope of assembly disruption management.

The first question in this part deals with methods respectively tools applied in the represented companies in order to eliminate or to deal with disruptions. Multiple answers were allowed and a diversity of practices has been identified. 74 % of the participants state that a spontaneous respectively intuitive approach to handling disruptions is applied in their companies. 73 % indicate to have defined escalation stages in place and 68 % try to prevent disruptions based on experiences. Reactive respectively preventive IT-based disruption management are named by 62 % respectively 53 % of the participants. Only 26 % indicate the keeping of a disruption logbook. Further 9 % name individual methods including specialized teams or processes in their disruption management.

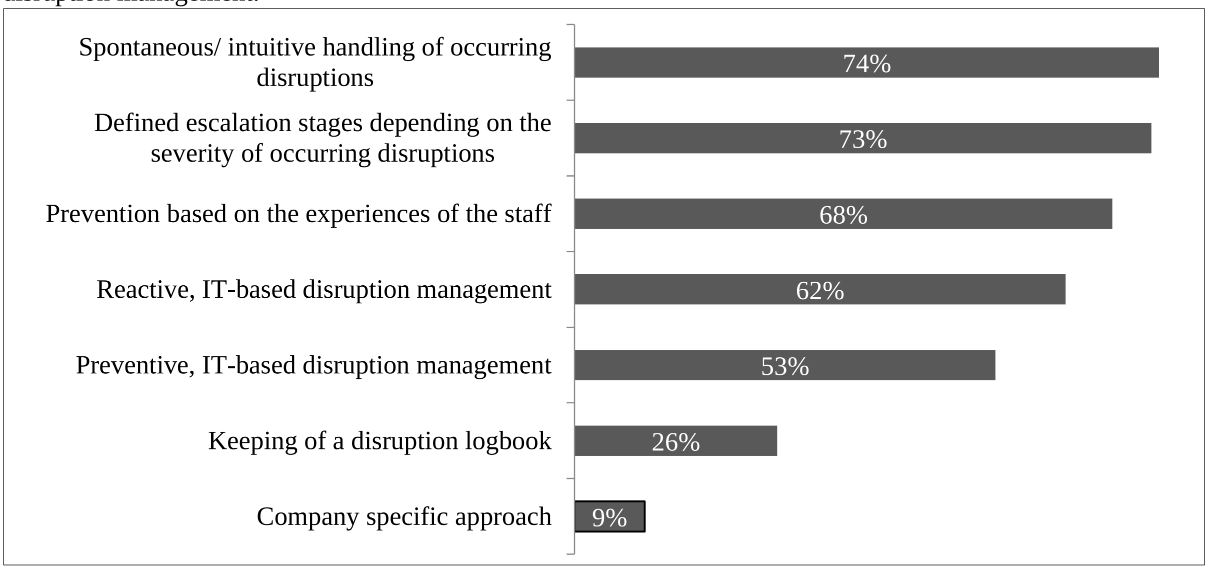

Fig. 17 Methods and tools applied within the scope of assembly disruption management

In the following question, the participants were asked to evaluate the average utility of their methods and tools applied to reduce disruptions and their impacts with regard to the belonging cost incurrence. Although the majority (64 %) consider the utility of their approaches to be (rather) high, the remaining 36 % reveal efficiency problems in the current disruption management of their companies.

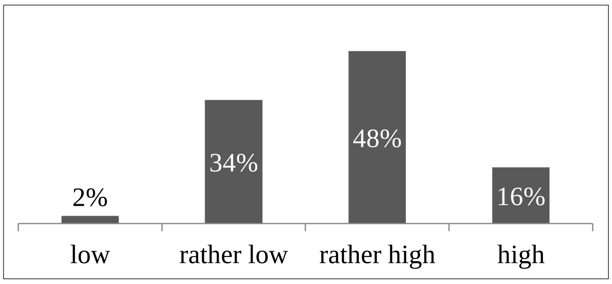

Fig. 18 Evaluation of the average utility of methods and tools within the disruption management

In order to differentiate this evaluation depending on the applied methods within the disruption management, the correlation between selected disruption management approaches and the evaluation of their utility has been measured.

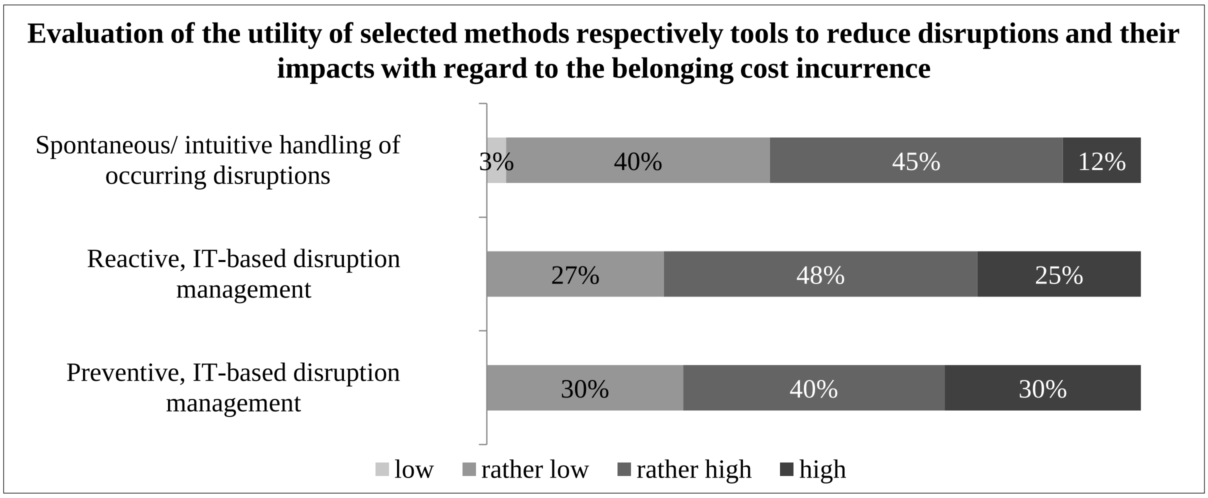

Fig. 19 Correlation of applied disruption management approaches and the evaluation of their utility

A significantly higher share of high evaluations can be found among those with a preventive disruption management approach compared with reactive or even spontaneous approaches. In other words, companies, which focus on preventing assembly disruptions are more satisfied with the efficiency of their efforts than other companies, which handle assembly disruptions in a reactive manner.

In order to further investigate the differences between these different approaches, the participants were asked how they evaluate the potential of preventive disruption management (e.g. [3]) in contrast to reactive disruption management (e.g. [11], [12]). Although a high proportion of participants evaluates their reactive approaches to be successful within disruption management before, a significant majority (88 %) of all study participants assesses the potential of a preventive disruption management higher than that of the reactive approach.

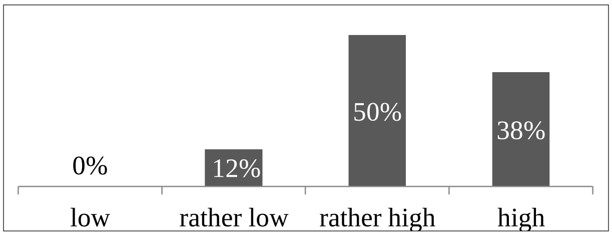

Fig. 20 Evaluation of the potential of preventive disruption management in comparison with reactive disruption management

Next, the participants were asked to give their opinion on whether their resources could be used more efficiently and disruptions could be prevented if there was transparency about actually critical processes respectively parts. The majority (87 %) agrees with this proposition whereas only 13 % disagree.

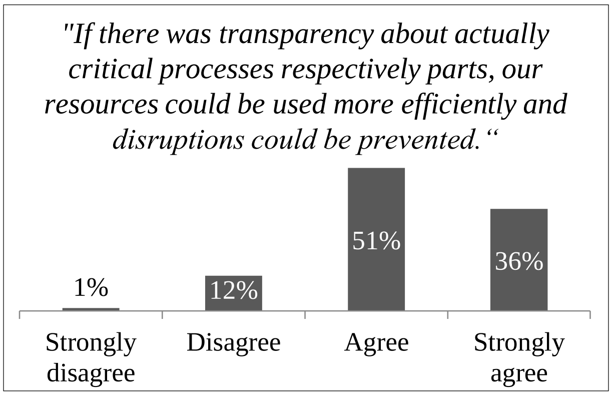

Fig. 21 Transparency about critical processes and parts

Based on this question, it was investigated to which extent the participants' consent with the statement *"If there was transparency about actually critical processes respectively parts, our resources could be used more efficiently and disruptions could be prevented."* is depending on their knowledge and documentation of critical processes respectively parts (Fig. 15).

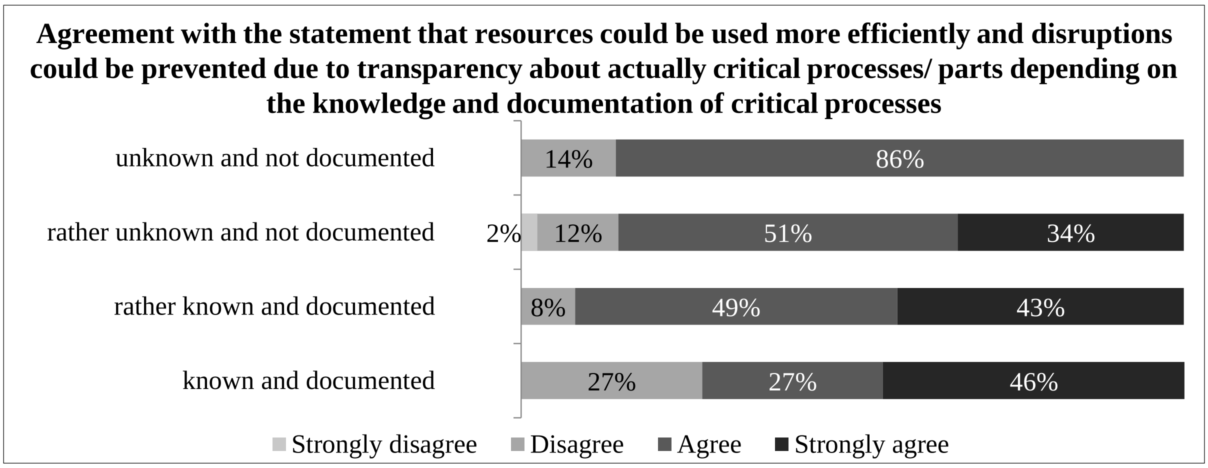

Fig. 22 Influence of the knowledge and documentation of critical elements on the efficiency of the use of resources and the possible prevention of disruptions

It can be derived fromFig. 22, that the consent with the proposition increases with the knowledge of critical process elements and with their explicit documentation.

Rephrasing this finding in simple terms, the companies, which know and document critical processes, realize that resources can be used more efficiently and disruptions can be prevented. Those who do not have the transparency do not share this view, as it is a hypothetical question for this part of the sample.

For a quantification of the anticipated benefits through the transparency of critical processes respectively parts, the participants were asked to estimate the saving potential in the case of transparency in relation to the total assembly costs. The boxplot method has been applied in order to compute a measure of dispersion of the participants' ratings without including the extreme potential outliers [13]. Fig. 23displays in a boxplot the range of estimations ignoring the highest outliers (50 %, 80 %, 80 %), which are symbolized by circles. The average estimate amounts 15.2 %, suggesting a significant economic potential in the monitoring of process elements critical to disruptions. 59 % of the participants estimated this potential between 10 % and 30 % and the range of estimations reached from 1 % up to 80 %.

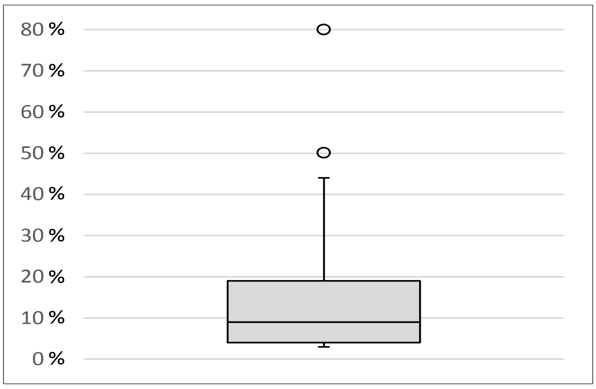

Fig. 23 Rating of the cost reduction potential of total assembly costs presented in a boxplot

It has been shown, that not all processes can be monitored due to limited planning capacities (compare Fig. 16). The next proposition was presented with the aim to examine, if at least an ongoing monitoring respectively treatment of *critical* processes respectively parts was possible. The consent of 79 % of the participants shows, that these critical process elements can be monitored or treated with regard to disruptions.

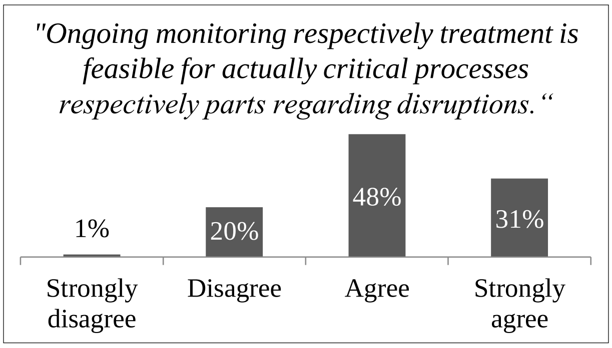

Fig. 24 Possibility of an ongoing monitoring respectively treatment of actually critical processes

This suggests that a promising approach for assembly disruption management might be to focus on identifying these disruption-critical factors and concentrating prevention efforts on them.

VI. CONCLUSION AND OUTLOOK

An empirical study in the manufacturing industries of Germany, Austria and Switzerland with more than 100 participants has been performed in 2015 and 2016 with the aim to reveal new statistical data and findings with regards to assembly disruption management. Not only is the topic of disruptions widespread in the assembly of industrial companies in large parts of Europe, but it also causes massive economic damages to these companies.

It was confirmed that a high number of disruptions can theoretically be forecasted or even prevented, and that many disruptions reoccur in an exact or similar way as before. This leads to the question on why companies do not prevent disruptions. The study reveals that the planning capacities are not sufficient to deal with every disruption and process in the same way, but that the critical processes have to be focused. Even in the case of only dealing with critical processes the saving potentials amount to about 15 % of overall assembly costs.

Based on these results, an approach for efficient preventive disruption management is being developed by the authors, which has been first described conceptually in 2015 and is being refined to be published in 2017 [3].

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