APPLICATION OF FAILURE MODE AND EFFECTS ANALYSIS IN THE INDUSTRIAL HOUSEBUILDING INDUSTRY

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ABSTRACT: Failure mode and effects analysis (FMEA) is a well-known method in quality management (QM). Until now only less research is done in the application of quality and process improvement with FMEA in the construction industry. FMEA supports the involvement of experts' information, allows engineers to get contextual information to problems and enables to assess possible failures regarding to their relevance. Reasons for that can be found in the common project based manner of building projects, which do not support the application of FMEA for improvement projects. Industrialised housebuilding, where project-based order fulfilment is combined with process views, starts changing the need for QM-methods in the construction industry. Also because of upcoming use of Building Information Modelling (BIM) concepts a need for appropriate QM-methods is generated, to support the development of usable design standards. In addition it is estimated positive because of the involvement of employees' experiences which is a common source of improvement ideas in construction industry. An FMEA case study is applied during an improvement project in an industrialized housebuilding company to test how well it works for this application. The method is further assessed with a use case as well as by findings of interviewed employees.

KEYWORDS: FMEA, Rework, Quality Management, Industrialized house building, case study

1 INTRODUCTION

It is well known that more than 5 % of the building costs of a building project belong to rework costs on construction site (Taggert et al. 2014) [1]. For a large percentage of rework costs the causes can be found in weak coordination between the involved employees, interface problems and poorly elaborated design (Oakland & Marosszeky 2006) [2]. Strong competition between construction companies is one reason why industrialized housebuilding companies have to face this problem to stay competitive.

Because of the collaborative structure of the building process, with a lot of different employees involved from the beginning of the design phase to construction site assembling, prefabricated housebuilders are vulnerable to interface problems or for failure because of absent context knowledge. Especially in medium and large size companies the absence of a general view of the building process of involved employees contributes to higher fault rates and increased rework on construction site (Meiling et al. 2014) [3], (Gronalt & Grenzfurtner 2015) [4].

The customer individual design, which is an asset of some industrialized housebuilding companies, may support unwanted failure because of weak coordination. Also the high degree of prefabrication at the same time can cause, as a result of weak coordination or bad design standards, in rework on construction site. This rework is absolutely unwanted and results in delay time during the assembling of a building (Gronalt & Grenzfurtner 2015) [4].

To meet those challenges industrialized housebuilding companies have to improve their processes, their quality management as well as their product development. This establishes a need for advanced methods for quality management (QM) and product development in the prefabricated housing industry (Meiling et al. 2014) [3], (Gronalt & Grenzfurtner 2015) [4], (Sandberg et al. 2008) [5].

In the following section we will give an overview of the application of QM in the construction industry under special consideration of the situation in the sector of industrialized housebuilding.

2 LITERATURE REVIEW

practical application in the construction industry, which result in poorly elaborated construction details, repeat new planning of the same construction details, information loss because of interface problems and weak coordination between involved employees and at least in rework as well as loss of effectiveness. Zou et al. (2015) [6] state that most of all interventions to reduce failure and defects in the construction industry base on knowledge and experience based intuition of experts and their subjective estimations. For instance it is not common to use QM-methods to systematically assess failure and there occurrences. According to the experts understanding of building process estimations or taken decisions do not address causes of failure correctly. As result failure occurs second times or other negative effects come to light. Nevertheless a lot of known QM-methods can be used in building companies (Oakland & Marosszeky 2006) [2] and still research is done on their application in construction industry and in particular also for industrialized housebuilding. The application area of used methods and tools reaches from specific use in a part of the building process to a broad application in the whole order fulfilment process. However the focus of applying QM-methods in nearly every approach lies on testing proven methods for typical problems in the construction industry.

For example, Meiling et. al. (2014) [3] described the application of plan-do-check-act method (PDCA) in a continuous improvement approach with the aim to test how well this method works for industrialized housebuilding company. Lundkvist et. al. (2014) [7] assessed PDCA method and continuous improvement in a similar research question. They suggest that the proactive use of this method can be used to reduce both ambiguity and lack of important contextual information. A knowledge based system for rule checking with software support to improve efficiency and effectiveness of prefabricated housebuilders was proposed by Sandberg (2008) [5]. His approach improves the sales and design process. The suggested method is quite reliant to well-developed standards but can reduce individual failure because of a higher degree of standardization.

In another approach by Gronalt and Grenzfurter (2015) [4] user experience is introduced in the development processes of industrial housebuilders to get better standards for planning of buildings. Through the support of a proposed development process with UXD elements well elaborated standards are developed. Those support employees in the building process to take decisions with a more general view and enables reduction of interface problems.

Also the upcoming application of BIM technologies, which may contribute to reduction of failure and rework, needs elaborated design standards as a base for planning buildings (Issa & Olibina 2015) [8]. BIM and BIM related technologies try to support user along the life cycle of a building to optimize planning, construction and management of buildings with software support. At least this method will contribute to a reduction of failure Zou et al (2015) [6]. Therefore design standards like details, rules and so on are used. The quality of those standards in many cases directly influences the planning results. To develop and assess design standards good QM-methods and development processes are necessary. For a successful implementation of BIM the following conditions are important:

- effective communication within the company,
- appropriate management of experience and multidisciplinary knowledge and
- collection and evaluation of essential knowledge on time (Zou et. al. 2016) [6].

To support the implementation of BIM practices which support those requirements like good development processes, applicable tools and methods for development as well as QM are quite necessary (Kokkonen & Alin 2016) [9]. Each of that research emphasises the importance of a general view on the building process and the need for introducing contextual information to failure or defects to reduce rework significantly and improve efficiency of building processes. FMEA will support this request, if experts from the different departments of a company were involved in the FMEA team (Tietjen et. al. 2011) [10], (Li et al. 2014) [11].

In the following section we will present FMEA in the application of prefabricated housebuilding. Also the method and it’s general use is described. Our aim was to analyse if this method is a useful tool to reduce failure rate, interface problems and at least rework costs in industrialized housebuilding under current challenges in the housebuilding industry.

3 METHODOLOGY

FMEA is a well-known method, which is used in many companies for R&D or QM to analyse risks of a product or process. It is quite common to use it in six sigma projects as well as in development processes to improve the reliability of products. Additionally FMEA is popular because of the effective documentation of possible failure, their causes and how to avoid those, which enables to store and provide this knowledge for future (Oakland & Marosszeky 2006) [2], (Werdich 2012) [12], (Tietjen et. al. 2011) [10] and (Li et al. 2014) [11]. Werdich (2012) [12] and Tietjen et. al. (2011) [10] distinguish between two approaches of FMEA. A first approach is applying FMEA preventive during the development of a product which allows reducing the risk of breakdown of a product or component at a very early stage of product development. An FMEA during the product development represents a quality assurance to avoid expensive failure related costs in later stages like rework on construction site. A second approach of FMEA can be seen as a method to find and initiate corrective actions in the case of detected failure on the product or process. This application area provides the opportunity to analyse detected failure systematically. A typical application example for this approach is using an FMEA during a six sigma project. Six Sigma is a QM approach which uses a number of QM methods, like
statistical process control, Ishikawa diagrams or FMEA, in a defined order to systematically reduce and avoid failure.

The approach of FMEA has a lot of advantages for quality management and for product development. Below we summarized some advantages of FMEA, which are relevant for improving building or development processes in the prefabricated housing industry:

- FMEA uses the experiences and expertise from employees of different departments to identify the importance of failure or potential failure systematically by discussing and structuring the problem (Oakland & Marosszeky 2006) [2].
- FMEA gives the involved experts from the different departments of a company a general view on the processes or the applications of the products and allow a project manager to find comprehensive solutions for problems (Li et al. 2014) [11].
- FMEA enables to find functional interrelations and possible failure in an early step of their occurring. Thus failure related cost can be reduced.
- FMEA enables to analyse the risk of fall out of a product, a component or a process on the state of the art.
- FMEA can be used as a knowledge base which allows focusing on actions for improving development processes and building processes in the long term.
- FMEA effectively documents potential failure, functional interrelations between those as well as their influence on the quality of products or processes and saving action strategies.
- The documentation enables to save the know-how about failure and functional interrelations for long term use in a company (Werdich 2012) [12], (Tietjen et. al. 2011) [10].

Those advantages of FMEA can be used to improve products and processes in the prefabricated housing industry. To show this a case study was done. The approach was supported by a medium size industrialized housebuilding company, which normally builds about 200 family homes a year. We introduced FMEA in the company during an improvement project. The moderation of the FMEA was done by one of the scientists, who have technical experiences in the area of industrialized housebuilding. The FMEA was executed on the basis of (Werdich 2012) [12] and (Tietjen et. al. 2011) [10]. The formation of the FMEA team was done accorded to the management under consideration of all necessary departments. The choice of the team members was done very carefully under consideration of members from the different companies departments, because a broad team formation enables the possibility to include a lot of views to questions and allows the team to get a general view of problems (Tietjen et. al. 2011) [10]. The team consisted of two construction workers, a site manager, a material requirement planner, a production manager, a planning engineer, a development engineer, a purchasing manager and a head of department.

To work on the improvement project four FMEA group meeting took place. The formulation of the fundamental problems was done in the beginning of the improvement project outside of FMEA group meetings. Therefore workshops with employees for different departments as well as subcontractors were done. Also information from customer service was involved. The collected information to potential failure was used during the FMEA group meetings. Each group meeting took place as a moderated work shop. To analyse and evaluate the problems tools and techniques like cause and effects analyse or 5-Why-method were used. In this way failure causes, failure modes and failure effects were worked out for each problem. Also for each failure preventive actions and detection action for the current state were noted. In a next step the severity of the failure, the probability that a failure occurs and the probability of failure detection were assessed. As guidance to assess severity (S), probability of occurrence (P) and probability of failure detection (D) the grading scheme by (Tietjen et. al. 2011) [10] was used. For each problem the FMEA group determined evaluation points from 1 to 10 for each one of the three indexes. Whereby a high number represents an unfavourable estimation and a low number the opposite. The determination of the indexes during the group meetings must be seen as subjective estimations of experts (Werdich 2012) [6]. Out of those indexes a Risk Priority Number (RPN) was calculated to evaluate the importance of a failure. Therefor the following formula (1) was used (Werdich 2012) [12], (Tietjen et. al. 2011) [10]:

\[ RPN = S \times P \times D \] (1)

RPN = Risk Priority Number
S = Severity of an failure
P = Probability of an failure occurs
D = Detection (Probability of failure detection)

RPN helps to systematically estimate the necessity of improvements for a failure mode. Failure with a RPN below 100 normally can be neglected. For failure with a higher RPN improvements should be intended (Tietjen et. al. 2011) [10].

As all indexes are subjective estimations of experts it is helpful if the moderator checks the plausibility of the results with the FMEA group. Nevertheless RPN can be used to take statements about importance of processing improvement projects to failure modes (Werdich 2012) [12].

In a last step actions to avoid and detect those failures which improve the current status were worked out for failures with a high priority. Also the improved state has to be assessed in the same way as the current state to evaluate suggested improvement actions. Usually most of improvement actions lead to significant improvements of RPN. If suggested improvement action do not show RPN below 100 or won’t fulfil requirements of group members it is useful to look for alternative improvement actions (Werdich 2012) [12].
Finally all results are documented in an FMEA-sheet for further use and for each of the found improvement actions responsibilities and the time horizon for implementation have to be defined. The results from the FMEA we found during our improvement project were used in the company for improvement projects. In the following section we will describe examples the results of applying an FMEA in an improvement project.

4 USE CASE

With the problem of rework and unproductive time a typical representative case which occur on each construction sites will be presented. Efforts to reduce rework are an important subjects to improve competitiveness of construction industry. In this use case FMEA is chosen to cope with this task.

We evaluated the FMEA approach on the overall housebuilding processes. Case examples from our project partner, an industrialized house building company, show the value of this method for improving the product development as well as processes including the coordination between employees in the building process.

During our case study the method was used to reduce failure and non-productive time as well as resulting costs which appear in the plant and on construction site. In the course of the project problems out of this subject area were processed, whereby employees in the different departments formulated lists with fundamental problems befor the project start. Also information about defects from customer service was used. During the four FMEA-meetings those failure lists were processed. Failure were analysed, ranked relating to their importance by using RPN and improvement suggestions were found. Out of 53 failures which were discussed during the group meetings 38 improvement suggestions concerning to preventive or detecting actions were found. Some of those contribute to improvements of same failure. Fore nine failure modes which were assessed with a low RPN the experts in the team don’t see any importance to improve something.

The documentation of the results with the FMEA-sheet was useful for further processing of the improvement suggestions as well as for controlling of implementation of those. Not each of the found improvement suggestions could be processed, even though a general view on the failure was generated during the FMEA meetings. About 10 improvement suggestions won’t be implemented. Reasons therefore may be found in technical modifications or changes in processes which effect the improvement suggestions, inconsistently implementation and in two cases misjudgements during the team meeting. In the last to cases those persons who were responsible for a part of these failures were not in the team. All in all we estimate, that the found improvement suggestions were quite elaborated, even though not all of those will be implemented. In order to show the findings an illustrative improvement example which was carried out during the FMEA meetings is presented in the following section.

4.1 PROTECTION OF WINDOWSILLS

One of those failures who reached a high RPN was defects on windowsills. To show the potential of FMEA we will present this failure example for evaluating the method and for providing an impression for its practical use.

Windowsills are components that are installed in a certain amount in each family home. Typically it consist of a coated metal plate with two end pieces. The costs of such a windowsill comprises between €8,- to €15,-. Despite of the low material costs windowsills are important components which are used to protect walls against moisture entrance. Because of this principal function it is clear why joints to facades must be executed exact.

A subsequent exchange on construction site in the consequence of damage is normally very cost expensive because of additional trips to construction site and time-consuming rework. Also the execution of joints to facades after plastering of those is difficult. An exchange of a windowsill on site could further lead to the possibility of weak points. However this failure occurred very frequent. One typical example of a damaged windowsill is shown in figure 1.

![Figure 1: Example of a mechanical damage of a windowsill](image-link)

During the FMEA this failure was analysed because customer service, construction site workers and site manager told that defects on windowsills occur very frequently. They estimated that at nearly each fifth to sixth building one windowsill have to be changed. This was a quite high probability of occurrence. The FMEA team analysed the failure in detail by using the FMEA procedure.

The failure effect for this failure the team defined quite fast as Costs for rework on windowsills. In most cases this work was executed by customer service in a very late phase of the building process. Additionally time delay to the point of risk transfer to customers was determined because customers avoid accepting much rework after they are responsible for a building.

For the further investigation of this failure possible defects were summarized during the discussion. Typical found defects were scratched surfaces, dents and unwanted discrepancies in the surface. To find the causes for the found defects cause and effects analysis
was used. During this analysis the team found the following possible reasons for failure occurrence:

Scratched Surfaces
- Pulling cable on construction site
- Workers use windowsills to go outside
- Delivery with defects by supplier
- Improper remove of plaster material residues

Dents
- Hits during loading in the plant
- Hits during unloading on construction site
- Hits from tools or material which is falling down during assembling of the building
- Disassemble of scaffolds

Unwanted discrepancies in the coat surface
- Use of aggressive solvents
- Adhesives which diffuse in the coat surface
- Production failure of suppliers

Some of those failure occurred because of improper working, whereby team members told that in some cases it isn’t possible to prevent from those. Two possible defects occurred because of a missing or imprecise incoming goods inspection of windowsills.

During further analysis the process was analyzed from receiving of windowsills up to last rework actions executed by customer service. In figure 2 the original process with possible actions of failure detection as well as possible causes for the defects is shown.

![Figure 2: Possible actions of failure detection as well as possibilities of failure occurrence in the process](image)

The analysis shows that the detection of defects was quite too late, because each kind of possible failure will be found after plastering of façade. An earlier detection of failure was rare and was based on coincidence. As cause of the late failure detection the late removing of the foil cover was found. Because of the high degree of possibilities of failure occurrence also the weak protection of windowsills through foil covers was determined. The original protection of windowsills is shown in figure 3. The used foil cover was definitely not constructed to prevent from hits. It could prevent from slight scratches in the surface, but when high mechanical stresses work on the foil cover prevention from scratches isn’t possible. Although other defects can appear very slight if only the foil cover was used as protection.

![Figure 3: Original protection of windowsills](image)

The knowledge exchange in the team during this phase of the FMEA is a big advantage for improving processes as well as technical details. During the project it became evident, that the team members got a more general view of the building process, because the intra-departmental knowledge was supplemented by those of other departments. For example without the knowledge exchange in the FMEA-team no one comes to mind that the protection of windowsills is insufficient. Found failure modes, failure effects and failure causes from this stage of the FMEA were transferred to the FMEA-sheet. For the current state of the failure also existing preventive actions as well as detecting actions were noted. For each failure severity (S), probability of failure occurrence (P) as well as probability of failure detection (D) were assessed by the team and in the following the RPN was calculated.

The high risk priority numbers made an improvement of the current state necessary. But also the team was sure that a reduction of this failure is necessary, before the RPN was determined.

To reduce the risk of failure occurrence as well as to raise the probability of failure detection improvement actions were carried out. At least three of those were implemented. Those are removing foil cover from windowsills during an incoming goods inspection, protection of windowsills with a panel and sensitize employees for potential reasons of defects. An incoming goods inspection where the protective foil is removed from the windowsills contributes to a reduction of production failure on the part of suppliers. Also an adequate protection of windowsills with a panel reduces risk of damage from common stresses. Because of this reason most possibilities of failure occurrence were reduced to a minimum remaining risk. To support reduction of possibilities of failure occurrence trainings and information initiatives for employees are intended.

The recommended actions for improvement were assessed with FMEA-indexes. The calculated RPN showed an improvement from the current state to the improved state if those actions will be realized.
The results of the FMEA were documented in an FMEA-sheet. One example of such documentation is shown in figure 4. In this figure you can see the documentation for our use case. The documentation of essential parts of the findings of FMEA was also emphasized by the team members as big advantage of this method. This enables the controlling of implementation of improvements as well as an easy understanding of findings. During implementation of found recommended actions different board materials for windowsill protection were tested. As best board for this use a fiberboard was found which arise as by-product of industrialized housebuilding and cause no material costs. Also the time and costs required for cutting and assembling are less than for rework. The new protection of windowsills is shown in figure 5.

Due to the improvement of windowsill protection with the recommended actions, although possibilities for failure detection and failure occurrence changed compared to the initial situation. The improved situation is shown in figure 6. Detection of failure which are in the part of supplier takes place in an early stage of the process, because foil covers are removed during incoming goods inspection. Possibilities of failure occurrence are reduced to a minimum remaining risk. Additionally protective boards have to be assembled in the plant.

Based on the implementation of recommended actions less defects concerning to windowsill damages occurred after application of FMEA. The positive effect of failure reduction was seen for all failure where improvement suggestions were well implemented.

### 5 FINDINGS & DISCUSSION

After the project a qualitative survey with all project members and other employees was made. Statements out of those interviews should give an impression of applying FMEA in an industrialized housebuilding company. During the FMEA-meetings a quite productive climate was recognized which enabled constructive working without big quarrels. The good climate in the team was also headed as good conditions to work on elaborated solutions for improving the processes. The
uncomplicated cooperation enabled the understanding of positions from different departments, although different interests were presented. But the FMEA meetings no principal questions or personal disagreements were to solve. This was a quite big advantage for this improving project as well as for applying FMEA during those. All statements must be seen under this conditions. Despite of those the statements refer to applying of FMEA in a construction company to reduce failure and rework. Independent of our situation a good climate in the team must be seen as a precondition of successful application of FMEA as it is also for other methods where people have to work together in teams (Werdich 2012) [12].

5.1 ANALYSIS OF FAILURE & RISK EVALUATION

The analysis of failure during application of FMEA in a construction company, where in most cases solving of problems is based on experience (Zou et. al. 2016) [6], was assessed as an improvement to common situations of failure reduction. Because of its experience based character the method was perceived as useful supplement to present approaches. This was emphasized from a planning engineer:

\[ \text{FMEA is a method with a good mixture of tools to enable a systematical reduction of failure. Especially the use of experts experiences to find solutions in combination with systematical procedure contribute to useable improvement suggestions. Causes of failure as well as effects of improvement actions are well considered. Somebody from a department, who only can take decisions on his own experience, won't be able to recognize causes of failure as well as we did.} \]

Also the detailed analysis of failure and the examination of failure causes one FMEA-team member saw as an advantage of this method.

Compared to the initial situation also the realization of improvements is perceived as an opportunity to systematical reduce failure, like it is told from a planning engineer:

\[ \text{The determination of improvement actions enables us a much more target orientated reduction of problems.} \]

The indexes severity, probability of occurrence and probability of detection of failure as well as RPN, which is calculated out of those, supports employees with suitable estimations based on the risks that originates from a failure. This helps employees, despite of their limited knowledge, to choose improvements which contribute to a bigger success of the company. Otherwise it can appear that improvement suggestions will be implemented which may have a smaller benefit for the company or cause disadvantages. Especially in construction industry, where many people from different departments have to work together to fulfil orders, different perceptions are common and contribute to misjudgements. Because of that reason FMEA-indexes may support employees in their improvement decisions as the head of department in our team told us:

\[ \text{The assessment of failure concerning to their severity, probability of occurrence and probability of detection is favorable. It provides clarity to the significance of a failure and the effects of improvements even though RPN is only the subjective estimation of the FMEA team. So risks can be classified more easily in a systematical way.} \]

5.2 GENERAL VIEW ON THE BUILDING PROCESS & CAUSE AND EFFECT RELATIONSHIPS

The group discussions during FMEA which enables the team members to get a general view of the building process were seen as one of the biggest advantages of this method. Cause and effects of failure and improvement suggestions will be understood more easily from participants. Especially impacts on processes with a lot of different involved employees in the divided order fulfilment process get more visible. The group discussion and the systematical approach of FMEA enable the participating employees to find common understandings to problems. A planning engineer told us:

\[ \text{The group discussion as well as definition of failure modes, failure causes and failure effects during FMEA enabled us to understand causes and effects of failure as well as from recommended improvement actions. Especially for me participation from employees from the different departments was really important because it allows me to get a more general view of the building process.} \]

\[ \text{Because of the corporate decision making we were able to communicate our results in the company in a common language. This avoids misunderstandings.} \]

The discussions in the group are important to understand functional interrelations. Erroneous developments can be avoided by understanding cause and effects relationships. Also improvement actions as well as new design standards will be discussed more comprehensive. Therefore facilitated decision making get possible and outcomes are easier applicable. A planning engineer and a material requirement planner emphasised:

\[ \text{With FMEA failure could be seen from a broader perspective. Hence, it becomes possible finding a suitable solution. Temporary solutions will be avoided.} \]

The general view on problems also enables to reduce interface problems between departments. Interfaces will be defined more precisely. During an FMEA meeting found improvement suggesting usually take interfaces in count.

Additionally also capacity scheduling will be considered easier which is also a contribution to a more comprehensive decision making. Possible capacity constrains are in most cases departmental specific knowledge. This expertise support decision making quite well. The involvement during FMEA is enabled quite well because of interdepartmental exchange during the meetings.
5.3 COOPERATION & COMMUNICATION

As benefit beside the found improvement suggestions, an improvement of the communication of the team members was seen. This effect was seen as quite positive for communication and cooperation in the company, because it doesn’t restrict only on the improvement project. In many cases of day to day business cooperation inside the company was improved. One FMEA team member told it as follows:

Now it is much easier for me to talk to people from another department when I have a question or a problem with something. Because I know to whom I can talk about my problem and I know he will give me an answer based on his expertise and experiences. On those I can count.

Another team member told that "since the beginning of the project I have less fear to communicate difficulties or own failure because other employees understand my point of view more easily than before the project.

5.4 KNOWLEDGE EXCHANGE

The improved cooperation in the following of FMEA application enables that skills and expertise knowledge of employees got more visible for each one in the company. This was also communicated from more employees, inside and outside the FMEA team, as big advantage. The exchange of expertise knowledge and experiences increased during the improvement project. Working on concrete problems, which concerns employees from different departments enables gaining new knowledge and experiences. A construction site worker told us:

Knowledge exchange increased since the improvement project. Employees from other departments contact us more often to discuss for example different alternatives of design and involve us in planning decision if we are concerned. We see that our experiences and expertise knowledge is quite important for the company.

But we also get a bigger insight in processes, the knowledge and structures of other departments. Because of this reason it is easier for us to understand decision, which contribute to a better success of our company but for example lead to less attractive work on construction site.

Also the effective way of documenting knowledge was seen as advantage for knowledge exchange in the company as well as for further use for staff training. This was also confirmed by a development engineer:

A further use of results of FMEA will be enabled because of the effective documentation of knowledge. These findings will be used for implementation of improvement actions, to comprehend agreements, to control state of improvement suggestions as well as for further use in development projects or for staff training. I see it as a knowledge base for further use.

5.5QM & IMPROVEMENT IN INDUSTRIALIZED HOUSEBUILDING

FMEA is a standard method in six sigma as well as continuous improvement projects. For this reason also the usability of FMEA during those improvement projects in industrialized housebuilding industry is important. The interviews with employees from our project partner confirmed that this method is also a quite suitable method to support OM and improvement projects in this industry. This was highlighted from the head of department during our interview:

In my opinion FMEA fits well to the needs of QM in construction industry. The use of this method will contribute to efficiency enhancement of industrialized housebuilding companies because of reduction of rework.

The effectiveness as well as the usability of this method in QM of industrialized housebuilding was also emphasised by the development engineer:

FMEA provide a quality control in industrialized housebuilding which enable a reduction of rework as well as a more efficient work for plant and construction site workers. Occurring errors will be analysed systematically concerning to failure causes. This isn’t as matter of course.

Concerning to IT based methods of BIM which could contribute to improvement of efficiency of construction industry, also a support for this technologies was assumed. Especially to improve mapping of processes and construction standards in BIM-systems and to get more reality based planning solutions this method was seen as an opportunity to support BIM implementation on the user side. The development engineer told us concerning to this topic:

The use of FMEA can also contribute to improvement of BIM if it is used for supporting development of design and construction standards.

5.6 REQUIRED TIME & PERSONNEL REQUISITES

The time required to apply this method was considered disadvantageous. Compared to common improvements in construction industry were in most cases less people were involved, more time for meetings must be provided. This requires a rethinking of common view concerning to improvement of processes and design standards.

Additionally the collaborative structure of the building process with employees on different locations was seen as a disadvantage for using this method. This complicates the agreement of FMEA meetings. A construction site worker told us:

It is difficult to participate in meetings if the construction site where you work is located far away from the plant were the meeting takes place.

This difficulties to participate on meetings were also seen by site managers and other construction site workers. The participation of both groups is essential for
well elaborated improvement suggestions why a reduction of this problem is quite important. Because of this reason it is recommended to prepare meetings well to enable effective work during the meetings. Also we recommend to prefer less meetings during the project because otherwise searching for appointments will influence FMEA negative.

6 CONCLUSION

In this paper the well-known QM-method FMEA was applied in an improvement project in the area of industrialized housebuilding. The aim was to reduce rework and unproductive time caused by failure. Because of this reason the application of FMEA during an improvement project was accompanied. As findings the output of well implemented improvement actions is determined. Out of 53 failures which were discussed during FMEA 38 improvement suggestions concerning to preventive or detecting actions were generated. 28 of those were implemented successful and contribute to a reduction of potential failure and relating rework. Out of the treated failure one example which comprises damages on windowills is picked out to present the practical application of the method. Therefore this case is analyzed from the beginning where failure mode and failure effects are defined. During the further application of FMEA cause and effects analysis were used to analyze the failure in in its details, which enables to take statements about failure causes and actual actions of failure prevention as well as failure detection. While the further analysis severity, probability of failure occurrence and probability of failure detection are determined an out of those RPN was calculated. Those is used to assess the failure concerning to its risk. To improve the current state recommended actions for failure detection and prevention are formulated and assessed. After successful application of FMEA and implementation of recommended action a reduction of windowill damages and the related rework is determined.

To gain statements to the application of FMEA from project members and employees a qualitative survey was made. We found that project members appreciate the systematically proceeding and the discussion culture during the FMEA meetings which allowed getting a more general view of the building process. The discussion culture during FMEA enabled the employees to contribute their experience and technical expertise. Also insights in the working situation of the colleagues were generated for all employees. After the FMEA some employees determined that they understood requirements of other employees much better than before. Also some employees outside the project group told that the results of the FMEA and discussions with project members enable to get a more general few of the building process, which contributes to less failure in their opinion. As disadvantage the required time for application was seen. Also the involvement of construction site workers was to organize difficult because they are regularly situated on different sites outside the plant and when the assembling of a building starts they are typically indispensable.

All in all FMEA is an appropriate method to reduce failure and relating rework and costs in industrialized housebuilding industry. It will contribute to improve processes and construction standards and will at least support six sigma or continuous improvement projects as well as BIM technologies.

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