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Manja Podpecan

Matjaz Maletic
University of Maribor, Kranj, Slovenia

Damjan Maletic
Univerza V Mariboru

Bostjan Gomiscek
University of Wollongong in Dubai, BostjanGomiscek@uowdubai.ac.ae

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Achieving an Effective FMEA: Lessons Learned from a Case Study of the Construction Project

Manja Podpečan
manja.podpecan@gmail.com

Matjaž Maletič
University of Maribor, Faculty of Organizational Sciences, Slovenia
matjaz.maletic@fov.uni-mb.si

Damjan Maletič
University of Maribor, Faculty of Organizational Sciences, Slovenia
damjan.maletic@fov.uni-mb.si

Boštjan Gomišček
University of Maribor, Faculty of Organizational Sciences, Slovenia
bostjan.gomiscek@fov.uni-mb.si

Abstract

Purpose: The aim of the study is to investigate and to understand the practice of implementing the failure modes and effects analysis (FMEA) in an organisational context. Hence, the paper explores the applicability of FMEA to the complex construction project, with an emphasis on the construction process stage of the waste water collection tank. According to the complexity of the construction of the waste water collection tank, it is particularly necessary to adopt a proactive approach to prevent failures.

Methodology/approach: The paper uses a case study approach focusing on the Slovenian construction company. FMEA was applied by a team of three experts covering different perspective of the construction process. Additional data collection methods included interviews and document studies.

Findings: This paper evidenced that FMEA can bring several advantages to the construction industry. It was found that a proactive approach has a potential to contribute to the construction project performance in terms of quality improvement, cost reduction as well as improving the environmental performance. In particular, this paper revealed that FMEA team, especially team leader, plays an important role in achieving an effective FMEA. Alongside the team leader, interviewees outlined the following critical success factors: education and training, selecting an appropriate team, top management support as well as integrating the FMEA in early stages of the project life cycle.

Originality/value – The article presents the results of the case study conducted in an industrial context. The paper provides possible explanations and recommendations for implementing an effective FMEA in the construction industry.

Keywords: Construction industry, wastewater collection tank, FMEA, teamwork, critical success factors

Paper type: Research paper

Introduction

The first step in any quality improvement process is the realisation and acknowledgement by an organisation that something is wrong in an organisation and that it needs to change its culture and system for improvement to take place (Motwani et al., 1994). Nowadays, organisations are concerned with being flexible, responsive and able to adapt quickly to changes according to the necessity of customers (Jaca et al., 2012). In this regard, various quality management tools can be applied to support the actualisation of peoples' intellectual capital to enhance innovation and improvements (Dahlgaard and Dahlgaard-Park, 2006).

Thus, organisations are now faced with a myriad of challenges and there is a strong opportunity and need for quality management tools to take place. As argued by Hagemeyer et al. (2006), the complexity of problem solving requires use of quality tools to assist in the organisation and analysis of information and data surrounding the concern. Moreover, Ahmed and Hassan (2003) argued that quality management cannot be ensured without the application of the appropriate tools and techniques, and firms with greater implementation of these tools and techniques can improve their business results. In particular, the failure modes and effect analysis (FMEA) has been one of the most commonly adopted tool in the new product development process (Thia et al., 2005).

FMEA is an analytical technique used by engineers to ensure all the potential problems have been considered and addressed (Tan, 2003). Unlike many quality improvement tools, FMEAs do not require complicated statistics, yet they can yield significant savings for an organisation while at the same time reducing the potential costly liability of a process or product that does not perform as promised (McDermott et al., 2009). FMEA is known to be a systematic procedure for the analysis of a system to identify the potential failure modes, their causes and effects on system performance (Cassanella et al., 2006). Up to now, the FMEA has been extensively used for the analysis of complex mechanical systems, including software, service automation, and e-commerce (Luo and Lee, 2012). However, despite a wide range of possibilities to utilise the FMEA, there is little evidence that this tool is being effectively implemented in the construction industry.

The purpose of this paper is to contribute to the understanding of how to effectively apply the FMEA in the construction industry. The purpose is hence to contribute to the current knowledge by identifying the possible critical successful factors that influence on an organisation's ability to effectively utilise the FMEA. Drawing from previous studies (e.g. McQuater et al., 1995; Ahmed and Hassan, 2003), one can reveal that quality management tools and techniques require attention in terms of a number of critical success factors, such as management support and commitment, defined aims and objectives for use, effective and planned training, co-operative environment and backup and support from improvement facilitators. Accordingly, Bunney and Dale (1997) suggest that the more complex tools (i.e. failure mode and effects analysis (FMEA)) require the active involvement of the quality function in terms of training and facilitating, which consequently tends to restrict their use to small numbers of people. Moreover, McDermott et al. (2009) assert that the FMEA does take time and people resources.

Seen in this context, the paper focuses on the FMEA team, which is considered as the foundation of the FMEA (McDermott et al., 2009). According to the McDermott et al. (2009), FMEA teams are formed when are needed and disbanded once the FMEA is complete. However, within construction projects teams are often brought in together for the first time and are assigned to the project on a temporary basis (Forgues in Koskela, 2009). Moreover, teams in construction are often coalitions of representatives from various organisations that have different cultures and organisation of work (Forgues in Koskela, 2009). Hence, this paper aims to address these obstacles by presenting the results of a case study of implementing the FMEA within the construction project.

Literature review

FMEA in the construction industry

The construction industry is regarded as one of the main contributors towards a country's economy (Yong and Mustaffa, 2012). From this perspective, the criteria of time, cost and quality as well as other factors such as health and safety, environmental sustainability, technical performance are factors with growing importance for the construction project (Yong and Mustaffa, 2012).

Reflak (2004) stresses that construction can be considered as a continuous process which ultimately results in the final product. Accordingly, the construction involves a design, manufacturing of construction products, construction and/or reconstruction, maintenance of the facility and disposal of the construction waste. In comparison with the traditional manufacturing (e.g. production of consumer goods), the construction is characterised with certain specifics of products and quality management activities that should be considered (Reflak, 2004).

Despite all efforts, many product development projects fail, which consequently leads to the introduction of products that do not meet customers' expectations (Matzler, 1998). Therefore, it is essential to effectively manage new product development process in order to achieve competitive advantage (Chin, 2000). Regarding the construction projects, Reflak (2004) emphasizes the importance of defining the activities across the project lifecycle as well as defining the responsibilities within the quality assurance system. Moreover, Reflak (2004) indicates that quality management among other things includes an accurate identification of direct as well as indirect requirements of different stakeholders. Taking into account the possible negative impacts of the construction facility on the natural environment and safety aspects (Reflak, 2004), it is even more important to eliminate the possible causes of failures in the early stages of the product development process. The latter is consistent with the notion of the FMEA, which strives to eliminate the most important possible causes of failure before their effects are produced, so increasing the reliability of the processes or products created (Sant'Anna, 2012). In this regard, the FMEA has traditionally been split into two areas of attention; design and process FMEA, supporting the later stages of product development (Ginn et al., 1998).

Hence, the FMEA is a systematic way for identification and avoidance of problem in product and process and recognizes the problems and the errors beforehand (Ahmadzadeh, and Sotoodeh, 2011). McDermott et al. (2009) reported that the first step is to identify the failures, followed by the assessment of the effects and risk within a process or product, and elimination or reduction of the failures. Accordingly, the FMEA identifies potential product-related failure modes, the potential effects of the failures on customers, the potential manufacturing or assembly causes, methodologies to reduce the occurrence frequency of the failure modes, and current detection methods of the failure conditions (Tan, 2003).

Construction projects can be extremely complex and fraught with uncertainty. Risk and uncertainty can potentially have damaging consequences for the construction projects. Therefore nowadays, the risk analysis and management continue to be a major feature of the project management of construction projects in an attempt to deal effectively with uncertainty and unexpected events and to achieve project success (Banaitiene et al., 2011). Given the level of complexity of the construction project and the corresponding adaptation of the construction technology, it is even more important to predict the possible failure modes and their effects, and to identify the possible causes at the early stages of product development as well as during the construction. In this regard, the FMEA has been recognised as an opportunity to systematically and proactively investigate possible failure modes and their effects in construction projects (Podpečan et al., 2013).

To sum up, the literature review shows that the FMEA has not been widely studied as a quality management tool in the construction industry. However, a few recent studies (e.g. Podpečan et al., 2013; Murphy et al., 2011) exemplified the possible contributions of the method in the construction sector.

The FMEA process

Product quality and reliability is the most important factor in marketplace competition (Zheng et al., 2010). In order to achieve products' high quality it is particularly important to systematically integrate quality into all stages of product development (Zheng et al., 2010). In the planning and designing phases the organisation can effectively utilise the quality management tools, such as the FMEA. It is recognised that organisation can use quality management tools to integrate the individual efforts of its participants: managers, employers, suppliers, customers (Dudek-Burlikowska, 2011).

FMEA is a preventative approach used to design product and processes which assure that both design and manufacturing quality objectives consistently meet customer requirements. The method aims to avoid as many potential failures as possible by identifying them and taking appropriate mitigating actions in all stages of product development. The results of the FMEA can be utilized to prioritize efforts for preforming design modification and process improvements which can reduce failures and risk. FMEA can be applied to all stages of a product life cycle (Zheng et al., 2010).

Vindoh and Sanhos (2012) defined the process of the FMEA through broad stages: (1) Specifying possibilities, (2) quantifying risk, (3) correcting high risk causes and (4) re-evaluation of risk. Furthermore, based on the literature review, Dudek–Burlikowska (2011) summarized the stages of the FMEA in four categories, as follows:
1. Qualitative analysis;
2. Quantitative analysis;
3. Drawing up the plan of preventive action;
4. Supervision of preventive duties.

Figure 1 illustrates the general procedure of the FMEA process. The first phase consists of breaking the product or process into the key component (McDermott et al., 2009). The actions in the second phase contain the identification of potential failure modes, potential effects and potential causes of failure modes. Subsequently, the calculation and ranking of risk priority numbers (RPN) is followed. Additionally, the recommendations of corrective actions and the modifications of the design are proposed. At the end of the procedure, the FMEA report can be obtained and the required actions should be completed to reduce the number of the potential failure modes to the minimum. Afterwards, organization can verify to what extent previous actions reduced the RPNs.

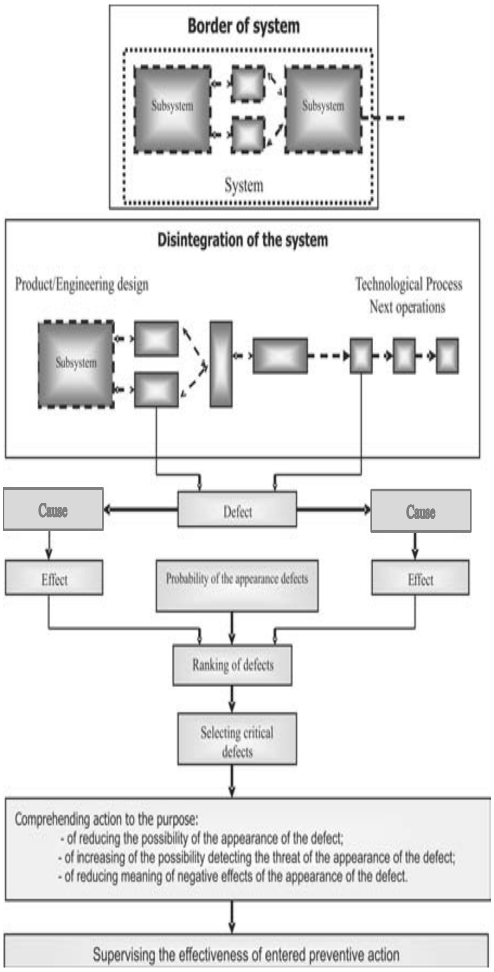

Figure 1. Stages of the FMEA method (Dudek-Burlikowska, 2011, adopted from Hamrol and Mantura (2005))

In order to successfully implement the FMEA, organization should consider the following success factors that are critical to the process of the FMEA (Carlson, 2012):

- Understanding the basics of the FMEA and Risk Assessment;
- Applying key factors for effective FMEA;
- Providing excellent FMEA facilitation;
- Implementing a "best practice" FMEA process.

Although one person typically is responsible for coordinating the FMEA process, all FMEA projects are team based. The purpose for an FMEA team is to bring a variety of perspectives and experiences to the project (McDermott et al., 2009). The issues and the challenges related to the FMEA and teamwork are discussed in the following section.

FMEA and teamwork

Recognition that efficiency of an organisation depends on the ability of employees to participate through the diversity, strongly supported the expansion of teamwork (Praper, 2001). According to the Praper (2001), teamwork is necessary when the working task exceeds one functional expertise. In response to mounting expectation for greater productivity, more organizations are adopting team-based structures. The tenet of teamwork is based on a belief individuals of the teams will bring knowledge, and experience to the workplace (Chan et al., 2003). Team-based structures in the workplace are a necessity for many organisations, and in other organisations they provide a viable alternative to individually-based work. Teams have become ubiquitous in the modern workplace with an increasing number of companies shifting from individual-based work tasks to team-based ones (Honts et al., 2012). Therefore, teams are expected to enable a higher amount of adaptability, productivity, and creativity than any individual employee can offer, and to provide more complex, innovative, and comprehensive solutions to organizational problems (Savelsbergh et al., 2008).

In teamwork the problems are usually enlightened in several ways and in this way more ideas come up than one individual only may bring up, as a team has a larger experience pool than the single individual and team members can inspire one another to show more creativity (Dahlgaard et al., 1998). Likewise in many other disciplines, effective teamwork is essential in quality management field as well. For instance, the implementation of the self-assessment is a team-based activity which requires several people with an in-depth knowledge in different areas, such as: Human resource, business analysis and process management (Chen and Jang, 2011).

Consistently with the above discussion, one can highlight the importance of teamwork in the FMEA process as well. Although one person is usually responsible for coordinating the FMEA process, the FMEA is by its nature team based. The purpose of the FMEA team is to bring variety perspectives and experience to the project (McDermot et al., 2009). Seen in this context, teamwork is critical to the success of the FMEA process. The team to perform the FMEA should include customers, manufacturing engineers, test engineers, quality engineers, reliability engineers, product engineers, and sales engineers (Teng and Ho, 1996). Hence, in the FMEA approach, the diversity and ability of the team are the most important considerations, followed by training for the team members (Chin et al., 2008).

Team forming and building is particularly important in the construction sector, because the success of a project is to a great extent dependent on the team performance (Raiden et al., 2004). An example of good practise in relation to team management in the construction sector can be found in the work of Matesi (2007). Author reported that a company established weekly meetings (named as BUILD - Building, Understanding through Initiatives in Learning and Development) where team evaluates scheduling with its trade groups, discusses about the scope of the work, performs a review of completed work, and identifies activities that are coming up (Matesi, 2007).

In fact, it would be inappropriate to establish a permanent FMEA team because the composition of the team is dictated by the specific task or objective. In cases where several FMEAs are needed to cover one process or product, it is a good practice to have some overlap of the members between the teams, but there also should be some members who serve on only one or two of the teams to ensure a fresh perspective of the potential problems and solutions (McDermott et al., 2009). According to McDermott et al. (2009), the best size for the team is usually four to six people, but the minimum number of people will be dictated by the number of areas that are affected by the FMEA

McDermott et al. (2009) underline the importance of appropriately qualified team of experts in order to be able to undertake a comprehensive review of the process. With this widespread growth of work teams, it becomes increasingly important for organizations to accurately analyze the characteristics needed for an individual to be an effective team member (Honts et al., 2012). With regard to the effective implementation of the FMEA, literature (e.g. McDermott et al., 2009) emphasises the significance of obtaining a basic understanding of the FMEA steps by all team members, prior conducting the FMEA. However, extensive training is not necessary if team members have previous experience working on problem-solving teams (McDermott et al., 2009).

Research setting: a case study of applying an FMEA in the construction project

Waste water collection tank

The construction project of the Blok 6 at thermal power plant TE Šoštanj included a construction of an underground wastewater collection tank, facility with grates and docking shaft. The dimensions corresponding to the wastewater collection tank layout are: 17.50 m x 25.10 m to 26.90 m. The minimum primary height of the tank is 9.85 m with the local deepings of 12.25 m. The wastewater collection tank was built on the principles of the white tub, while the supporting structures were designed of reinforced concrete. The collection tank is located between the existing cooling tower and the existing dining area, south of the import ramp near the headquarters of TE Šoštanj (Podpečan et al., 2013).

The empirical context

The FMEA was selected to identify potential risk areas in the construction of the wastewater collection tank. Potential areas where failures were expected to be occurring in high frequencies were the subject of the analysis.
The major sources of data collection included: (1) Analysis of documentation, (2) observation of the real situation, (3) interviews with those who were responsible for the design and construction of wastewater collection tank.

The preliminary FMEA was performed by a cross-functional and multi-disciplined team consisting of three experts that were responsible for different phases of design and construction of wastewater collection tank. Additionally, the first author of this paper was also part of the FMEA team.

Prior to conducting the FMEA, generic evaluation criteria for each of the three rankings of severity, occurrence, and detection were established. The FMEA process was documented using an FMEA worksheet (a summary of the results is presented in Table I). The conventional steps (McDermott et al., 2009; Gomišček and Marolt, 2005) of the FMEA were followed, starting with the product and the construction process review. In the following, potential failure modes were brainstormed and potential effects of the failure were identified. In addition to assessment of the severity (S), occurrence (O), detection (D), potential causes/mechanisms of failure were identified. Once the FMEA team completed the FMEA worksheet, a cutoff RPN (a value of 30), where any failure modes with an RPN above that point are attended to, was determined. Actions were proposed to reduce the severity, occurrence, and detection rankings.

Table I. An example of FMEA results

Potential failure modes	Potential effect of the failure mode	Potential causes of the failure mode	RPN 1	RPN 2	RPN 3	Average
Incorrect drilling process according to the soil.	Collapse of soil between the concrete.	Incorrect application of protective tubes.	**3**	**12**	**8**	**8**
Improper armature.	Strength of the construction is not adequate.	Delivered armature is not suitable.	**4**	**24**	**8**	**12**
Incorrectly tied armature.	Strength of the construction is not adequate.	The stirrup is missing.	**12**	**24**	**42**	**26**
		The spiral is missing.	**20**	**36**	**28**	**28**
		Spacers are missing.	**48**	**36**	**8**	**31**
		Design and construction requirements for installation of armature are not properly followed.	**8**	**32**	**16**	**19**
Collapse of soil during the concrete construction process.	Strength of the construction is not adequate.	Protective tubes for borehole are not used.	**3**	**18**	**42**	**21**
Incorrectly built concrete.		Improper use of the assembly tube.	**24**	**6**	**8**	**13**
Improper concrete mixtures.		An error occurred while ordering concrete mixtures.	**6**	**7**	**16**	**10**

Furthermore, a post hoc analysis included semi-structured interviews, mainly to provide better insight into the effectiveness of using the FMEA in the construction sector. The research question which underlined the analysis was: *What are the main success factors in applying the FMEA?*

Analysis and discussion

The results indicate that the FMEA is an important component of quality management in the construction industry. Accordingly, Murphy et al. (2011) evidenced that FMEA is a user-friendly risk assessment tool which can be used for business case analysis or post-project reviews, to assess potential risks to innovation in construction projects. Seen in this context, Stiller and Woll (2011) argue that preventive quality methods like the FMEA include the definition of preventive measure to ensure the avoidance of manifestation of risk.

Finding failure modes and analysing the effects of the failures can also be used in the construction sector as a systematic preventive approach (Nielsen, 2002). The FMEA can be applied at different stages of a project. In this context the two main approaches are suggested (Murphy et al., 2011): the functional FMEA (at the design stage) and the hardware FMEA (at the as-built stage). The research work reported in this paper is focused on the implementation of the FMEA in the construction project aiming to identify possible deficiencies that might hinder an effective implementation of the method. In fact, very few companies have employed the FMEA technique and sustained its authentic benefits (Devadasan et al., 2003), suggesting that the FMEA is often not implemented to the fullest extent.

Drawing on the findings (Podpečan et al., 2013), it is argued that the FMEA is an effective and systematic approach of improving the quality of the construction of the wastewater collection tank. Several benefits were identified of applying the FMEA in the construction project, such as: (1) FMEA can be considered as a way to involve key team members during the vital phases of the whole construction project lifecycle; (2) Outcome of the FMEA is a list of recommendations to reduce overall risk, to improve project quality, to reduce cost, and to avoid possible delays in the construction process.

Despite the benefits discussed above, several opportunities for improving the effectiveness of the FMEA raised up during the process of the FMEA and upon a post-hoc qualitative analysis (presented in Table II), as discussed in the reminder of this section. The results particularly seem to stress the following:

- Team members faced difficulties in estimating the rates of factors associated with the calculation of an index called risk priority number (RPN) (see differences between estimates in Table I). According to the Devadasan et al. (2003), calculation of RPN makes the FMEA process complex, but does not assure any accuracy in estimating the mode and effect of the failures.
- Our findings support one of our study's central propositions about the role of the FMEA team in achieving an effective outcome of the method. Typically the construction project involves cross-functional team (even with members of different organisations), which alongside the complexity of the construction environment, makes it even more difficult to establish a proper team which possesses the skills to effectively implement the FMEA.

Table II. Summary of results gathered in interviews with FMEA team members (TM)

Category	Subcategory	Relevance	Illustrations
Effectiveness of the FMEA	FMEA team leader	Very important	TM1: […] All factors are important to successfully implement the FMEA. TM2: […] I would outline the FMEA team leader as the most important success factor, mainly in terms of facilitating meetings as well as to ensure that team is progressing toward the completion of the FMEA.
	Education and training	Very important	
	Selecting the proper team	Very important	
	Top management commitment	Important	
	FMEA case study workshop	Important	
Quality management tools – training programs	e.g. FMEA	Very important	TM1: […] Of course, it would be essential to upgrade knowledge and skills in relation to QM tools. TM2: […] Yes, it definitely would be important to provide more training in QM tools; however, a lack of time might be an issue.
A contribution of the FMEA to problem solving	Identification of potential defects, effects and causes	Important	TM1: […] Yes, but is necessarily to obtain an involvement and support from project management. TM2: […] Yes, but in construction project we are often faced with time pressure, which could be an obstacle to fully engage in the FMEA process.
FMEA performance	Quality performance	Important	TM1: […] Yes, I consider the FMEA as beneficial to improve project performance. TM2: […] Yes, it could contribute to the construction project performance. However, it is important to conduct the FMEA in the early stage of a project.
	Cost reduction		
	Environmental performance		
	Society acceptance		

TM – team member

Lack of management commitment, lack of training/skills, lack of involvement of key team members, and lack of understanding of the method are the main factors that influence the success of the implementation of the FMEA as reflected in our study. One of the most important enabling factors identified in this study were the commitment and involvement of all key project team members. In particular, team members that were involved in the interview highlight several factors as being important to the effective implementation of the FMEA. From their standpoint, FMEA team leader is the most important factor in terms of facilitating meetings as well as to ensure that the team's efforts are coordinated. McDermott et al. (2009) defined a team leader or facilitator as a person who is well trained in the FMEA process and can easily guide the team through the process as they are actually performing the FMEA.

Alongside the FMEA team leader, process experts (e.g. design engineer) play an important role in FMEA team by the means of bringing tremendous insight to the team performance (McDermott, et al., 2009). Furthermore, prior studies (e.g. Savelsbergh et al., 2008) provide evidence that team learning behavior, team leadership behavior, and goal clarity are indeed expected to be important predictors of team performance.

The case study has exemplified how important it is to involve key project team members and to ensure that they have basic understanding and knowledge about the FMEA. In addition, expert knowledge and expertise are required to provide consistent rankings. Ideally, everyone on the FMEA team would agree on the severity, occurrence, and detection rankings. In all likelihood, however, there will be some disagreements due to each team member's unique perspective of the process or product (McDermott et al., 2009).

Nonetheless, the results of the interviews indicate that the education and training is recognised as an essential element of an effective implementation of the FMEA. However, extensive training is not required for team members, but is desirable to have some experience with understanding by solving similar problems and the FMEA, before the start of the project (McDermott et al., 2009). In addition, interviewees stressed the importance of understanding on how to use supplementary problem solving tools to manage project more successfully.

Hence, success of the use of certain quality management tools depends on the proper quality management training program of all individuals who are engaged in the implementation of specific tools (Clegg et al., 2010) as well as to consider the critical success factors (e.g. management support and commitment, an environment that encourages the constant improvement and other issues), regardless of the quality management approach (Dahlgaard and Dahlgaard-Park, 2006).

Overall, the results of the qualitative study indicate that the FMEA has a potential to improve quality, reduce cost as well as to improve sustainability aspects of the wastewater collection tank. In this context the FMEA can benefit in reducing the project risk in terms of avoiding the undesired events that can range from delay, excessive expenditures, and unsatisfactory project results for the organization, society, or environment (Shenhar et al., 2002).

Conclusion

This paper presented a case study of applying the FMEA method in real environment of a construction project. In this context, the FMEA is considered to be more than just preventive quality management tool, and is in practice also a communication tool that enables synergistic value of teamwork and in doing so enables a company-wide cross-functional and multi-disciplinary team effort. The specific benefit of the FMEA as evidenced in this case study, is the ability to look at the product and process development problem solving, perhaps more objectively and systematically.

To summarise, in order to attain the potential benefits from the implementation of the FMEA, organisation should:

- Take actions to demonstrate top management commitment,

- Provide education and training,
- Establish proper team of skilled and experienced members and
- Assign the FMEA facilitator or team leader.

This case showed that the effectiveness of the FMEA is particularly dependent on the team leader whose responsibility is to facilitate and coordinate the FMEA team effort.

Furthermore, the results of the case study revealed that team members recognise the applicability of the method and its potential benefits. In the context of the implementation of the method, team members stressed the importance to implement the method in the early stage of the construction process. Additionally, interviewees also stressed the need to find the synergies between the FMEA and other quality management tools, which would be helpful to exploit the potential benefit of the method to even greater extent.

A certain number of methodological weaknesses can be identified in our approach. For instance, we remained limited to the perspective of identifying key success factors by involving only three experts in our qualitative study. As such, the primary aim of this study is not to draw generalising conclusions that are valid in all contexts and organisations, but on a project in the construction. Furthermore, the investigation of several cases should make the study more robust than just studying a single case, which would further increase the possibility to generalise the results. Therefore, we strongly suggest that one needs to put in a precaution when drawing implications of this result.

References

Ahmed, S. and Hassan, M. (2003), "Survey and case investigations on application of quality management tools and techniques in SMIs", *International Journal of Quality & Reliability Management*, Vol. 20 No. 7, pp. 795-826.

Ahmadzadeh, F. and Sotoodeh, D. (2011), "To Reach Knowledge Management Goals with Failure Mode and Effect Analysis", *Canadian Journal on Scientific and Industrial Research*, Vol. 2 No. 9, pp. 307-310.

Banaitiene, N.; Banaitis, A.; Norkus, A. (2011), "Risk management in projects: peculiarities of Lithuanian construction Companies", *International Journal of Strategic Property Management*, Vol. 15 No. 1, pp. 60-73.

Bunney, H.S. and Dale, B.G. (1997), "The implementation of quality management tools and techniques: a study", *The TQM Magazine*, Vol. 9 No. 3, pp. 183–189.

Carlson, C.S. (2012), "Lessons Learned for Effective FMEAs", 2012 Annual RELIABILITY and MAINTAINABILITY Symposium, available at: http://www.reliasoft.com/pubs/2012_RAMS_lessons_learned_for_effective_fmeas.pdf

Cassanelli, G., Murab G., Fantinia F., Vanzib M. and Planoc B. (2006), "Failure Analysis-assisted FMEA", *Microelectronics Reliability*, Vol. 46, pp. 1795–1799

Chan, C.A.C, Pearson, C. and Entrekin, L. (2003). "Examing the effecta of internal and external team learning on team performance", *Team Preformance Management*, Vol. 9, No. 7/8, pp. 174-181

Chen, C.K. and Jang, J.Y. (2011). FACT: A Comprehensive Business Excellence Model. In, Jaca, C. (Ed.), *14th Quality Management conference on Quality and Service Sciences. Procee-*

dings of 14th QMOD Conference, Servicios de Publicationes Universidad de Navarra, Pamplona, pp. 413-437.

Chin, K.S., Chan, A., Yang, J.B. (2008), "Development of a fuzzy FMEA based product design system", *The International Journal of Advanced Manufacturing Technology*, Vol. 36, pp. 633–649.

Chin, K.S. and Pun, K.F. (2000), "A strategic review of product development direction for Hong Kong manufacturing industries: proactive versus reactive?", *International Journal of Operations and Quantitative Management*, Vol. 6 No. 2, pp. 79–97.

Dahlgaard, J.J. and Dahlgaard-Park, S.M. (2006), "Lean production, six sigma quality, TQM and company culture", *The TQM Magazine*, Vol. 18 No. 3, pp. 263-281.

Dahlgaard, J.J., Kristensen, K. and Kanji, G.K. (1998), *Fundamentals of Total Quality Management: Process Analysis and Improvement*, Nelson Thorne, Cheltenham.

Devadasan, S.R., Muthu, S., Samson, R.N. and Sankaran, R.A. (2003), "Design of total failure mode and effects analysis programme", *International Journal of Quality & Reliability Management*, Vol. 20 No. 5, pp. 551-568.

Dudek-Burlikowska, M. (2011), "Application of FMEA method in enterprise focused on quality", *Journal of Achievements in Materials and Manufacturing Engineering*, Vol. 45 No. 1, pp. 89-102.

Forgues. D. and Koskela L. (2009), "The influence of a collaborative procurement approach using integrated design in construction on project team performance" *International Journal of Managing Projects in Business*, Vol. 2 No. 3, pp. 370-385

Ginn D.M., Jones D.V., Rahnejat H. and Zairi M. (1998), "The QFD/FMEA interface", *European Journal of Innovation Management*, Vol. 1 No. 1, pp. 7– 20.

Hagemeyer, C., Gershenson, J.K. and Johnson, D.M. (2006), "Classification and application of problem solving quality tools. A manufacturing case study", *The TQM Magazine*, Vol. 18 No. 5, pp. 455-483.

Hamrol, A. and Mantura, W. (2005), *Quality Management. Theory and Practice*, PWN, Warsaw, (in Polish).

Jaca, C., Viles, E., Mateo, R. and Santos, J. (2012), "Components of sustainable improvement systems: theory and practice", *The TQM Journal*, Vol. 24 No. 2, pp. 142 – 154.

Luo, S.H. and Lee, G.G. (2012), "Applying failure mode and effects analysis for successful knowledge management", Total Quality Management & Business Excellence

DOI:10.1080/14783363.2012.733263

Matesi, A. (2007), Team Building*, Professional Builder*, 72(13), 42-50.

Matzler, K., Hinterhuber, H. H. (1998), "How to make product development projects more successful by integrating Kano's model of customer satisfaction into quality function deployment", *Technovation*, Vol. 18 No. 1, pp. 25–38.

McDermott, R.E., Mikulak, R.J. and Beauregard, M.R. (2009), *The Basics of FMEA,* 2nd Edition, Tylor & Francis Group, New York, NY.

McQuater, R.E., Scurr, C.H., Dale, B.G. and Hillman, P.G. (1995), "Using quality tools and techniques successfully", *The TQM Magazine*, Vol. 7 No. 6, pp. 37-42.

Motwani J. G., Frahm M. L. and Kathawala Y. (1994), "Quality Training: The Key to Quality Improvement", *Training for Quality*, Vol. 2 No. 2, pp.7–12.

Murphy, M., Heaney, G., and Perera, S. (2011), "A methodology for evaluating construction innovation constraints through project stakeholder competencies and FMEA", *Construction Innovation*, Vol. 11 No. 4, pp. 416–440.

Podpečan, M., Maletič, M. and Gomišček, B. (2013), "Failure mode and effects analysis (FMEA) as a tool for quality management in construction", *Gradbeni vestnik*, Vol. 62, pp. 54-60.

Raiden, A.B., Dainty, A.R.J. and Neale, R.H. (2004), "Current barriers and possible solutions to effective project team formation and deployment within a large construction organisation", *International Journal of Project Management*, Vol. 22, pp. 309–316.

Reflak, J. (2004), Zagotavljanje kakovosti v procesu gradnje [Quality assurance in the construction process], in Škraba, B. (Ed.), *Družba, prostor, graditev*, IZS, Ljubljana, 19. 5. 2004, pp. 185–189.

Sant'Anna, A. P. (2012), "Probabilistic priority numbers for failure modes and effects analysis", *International Journal of Quality & Reliability Management*, Vol. 29 No. 3, pp. 349-362

Shenhar, A.J. (2001), "One size does not fit all projects: exploring classical contingency domains", *Management Science*, Vol. 47 No. 3, pp. 394-414.

Stiller, C and Woll, R. (2011), "Reflexion of various perspectives of prevention – What Quality Management can learn from?", in Jaca, C. (Ed.). *14th Quality Management conference on Quality and Service Sciences. Proceedings of 14th QMOD Conference*, Servicios de Publicationes Universidad de Navarra, Pamplona, pp. 1653-1663.

Tan, C.M. (2003), "Customer-focused build-in reliability: a case study", *International Journal of Quality & Reliability Management*, Vol. 20 No. 3, pp. 378-397.

Teng, S.H. and Ho, S.Y. (1996), "Failure mode and effects analysis An integrated approach for product design and process control", *International Journal of Quality & Reliability Management*, Vol. 13 No. 5, pp. 8-26.

Thia, C.W., Chai, K.H., Bauly, J. and Xin, Y. (2005), "An exploratory study of the use of quality tools and techniques in product development", *The TQM Magazine*, Vol. 17 No. 5, pp. 406-424.

Vinodh, S. and Santhosh, D. (2012), "Application of FMEA to an automotive leaf spring manufacturing organization", *The TQM Journal*, Vol. 24 No. 3, pp. 260-274.

Yong, Y. C. and Mustaffa N. E. (2012), "Analysis of factors critical to construction project success in Malaysia. *Engineering, Construction and Architectural Management*, Vol 19 No. 5, pp. 543-556.

Zheng, L. Y., Liu, Q. and McMahon C. A. (2010), "Integration of process FMEA whit product and process design based on key characteristic", in Huang, G.H., Mak, K.L. and Maropoulos, P.G. (Eds.), *Proceedings of the 6th CIRP-Sponsored International Conference on Digital Enterprise Technology. Advances in Intelligent and Soft Computing*, Springer-Verlag, Berlin, Vol. 66, pp. 1673-1686.