RISK ANALASIS USING EXTENDED SAFMEA METHODOLODY ON EXAMPLE OF INCUBATED COMPANIES

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Abstract: *The paper examines the use of the Failure Modes and Effect Analysis (FMEA) methodology – in variant of statistical FMEA (SAFMEA) on the risk factors of incubated technological companies. Each risk factor were evaluated by mentors / management of chosen business incubators by using the Severity, Likelihood, Detection (conventional) and Influence of mentor (enhanced) parameters. The results are shown in different perspective – by using risk priority number* (*RPN) indexes, risk matrix and risk map. As the most significant risk factor was identified Funding issues - cash flow (followed by Customer acquisition issues and Funding issues – capital). However the results also show very high level of variance within the answers of the respondents. The paper also examines the impact of the enhanced nonconventional parameter (Influence of mentor) on the RPN index results where it was identified that some risk factors (such as Issues with business model) can be substantially reduced by the influence of the mentor / consultant.*

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JEL Classification: *D81, M13.*

Introduction

Risk management deals with identification, assessment and prioritization of risks and its main role is to minimalize impact of the negative scenarios. The paper is trying to apply the SAFMEA risk analysis on the risk factors identified within business incubators. Firstly the FMEA (in variant of SAFMEA) methodology is described along with the explanation of business incubation process where risk analysis is performed. In the next part, the methodology of the research is showed followed by the results of the SAFMEA methodology. In the final part, the discussion and conclusions are settled.

1 Theoretical background

1.1 Failure Modes and Effect Analysis (FMEA)

Failure Modes and Effect Analysis (FMEA) is widely used for detection of accidents and risk analysis – like similar methods such as HAZOP (Hazard and operability of Study) or What if method (Kubíčková, 2009). It is applied to discover and to eliminate potential failures (Hu-Chen, 2013). FMEA is used for summarization of risk information which is presented to the management (Stamatis, 2013). The conventional FMEA methodology uses three main parameters – Severity (*S*), Occurrence (*O*), and Detection (*D*). (Mohsen, 2016). Some authors such as Tichy uses different naming for parameters – Severity (*Sv*), Likelihood (*Lk*) and Detection (*Dt*), however the meaning is the same. The parameters are used for calculation a risk priority number (*RPN*) as it is shown in the formula (1) (Tichy, 2006). All parameters are described on a scale from 0 to 10 where 10 is the

highest. That makes RPN_{min} = 1 and RPN_{max} = 1000 (Lipol, 2011). It is common that RPN = 125 is considered as a limit for the calculated risk as high (Tichy, 2006).

$$RPN = Sv * Lk * Dt \tag{1}$$

The significant advantage of FMEA methodology is in its variability. Three former parameters can be extended with other parameters – frequently by parameters such as Fear (*Fr*) or vulnerability (*Vr*). The reason of parameter enrichment is that FMEA methodology would more reflect specific conditions where risk analysis is performed. Formula for calculation RPN_{ex} is as shown in (2), nevertheless the FMEA enrichment is possible due to its results are relative number (ie. not absolute) (Tichy, 2006).

$$RPN_{EX} = Sv * Lk * Dt * NewParam \tag{2}$$

The usability of FMEA methodology is broad – from the original use in industry quality risk analysis, over project management, to investment risk assessment and the outcome of the analysis could be in different forms – from simple table to risk maps (Januska, 2015) using only some of the parameters (ie. to identify level of importance of the risk there are only used parameters *Lk* and *Sv*). (Korecky, Trnkovsky, 2011)

FMEA methodology also have its drawbacks in real-world situations (Liu et al., 2012). Mostly recognized limitations are that different combinations of *Sv*, *Lk*, *Dt* can produce the same RPN therefore some risk significance can be lost (Mohamed & Robinson, 2010). Moreover, some authors argue that formula for calculation RPN is questionable, mathematical number RPN is not continuous and it is sensitive to variations in risk factor evaluation (Geum et al., 2011; Liu et al., 2011; Mohsen, 2016).

Another major weakness is that FMEA is based on prerequisite that values of parameters are set by experts in consensus. However, this is mostly impracticable in the team of experts. Therefore, the methodology called Statistical FMEA (SAFMEA) was developed to find statistical evaluation of the multiple responses (Tichy, 2006). The process of gathering source data is similar to FMEA methodology and it consists of filling SAFMEA-E form by all participating experts.

The procedure for calculation of SAFMEA results is as follows. Firstly, in every row *j* (ie. For every risk factor) for every expert *k,* values RPN_{jk}^{E} are calculated as it is shown in (3).

$$RPN_{jk}^{E} = SV_{jk}^{E} * Lk_{jk}^{E} * Dt_{jk}^{E} \tag{3}$$

Therefore, for every row *j* it will be calculated n_e expert values. Then for every row j it is calculated mean values of index RPN^{E} as shown at (4).

$$mRPN_{j}^{E} = \frac{\sum_{k} RPN_{jk}^{E}}{n_e} \tag{4}$$

If $n_e \geq 5$ it is calculated standard deviation of variance.

$$sRPN_j^E = \left(\frac{1}{n_e - 1}\sum_k \left(RPN_{jk}^E - mRPN_j^E\right)^2\right)^{\frac{1}{2}}, s > 0 \tag{5}$$

If $n_e \geq 5$ it is recommended to calculate estimated distribution quantile.

$$qRPN_j^E = mRPN_j^E + sRPN_j^E \tag{6}$$

Finally, the results (risk factors) is filled table where all risk factors have their $qRPN_j^E, mRPN_j^E, sRPN_j^E$ identified. Moreover, the results can be divided into three tables:

- Sorted by $mRPN_j^E$
- Sorted by max SV_{jk}^E
- Sorted by $qRPN_j^E$

1.2 Business incubators and incubation process

Business incubator is defined as "an organization managed by specialized professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions". (IASP, 2014)

The purpose of business incubator is to provide facility, finance consultancy, advices from experts, comprehensive information and business development. (Carter and Jones-Evans, 2006) The main roles of business incubator are "play an incubator role, nurturing the development and growth of new, small, high-tech firms, facilitating the transfer of university know-how to tenant companies, encouraging the development of faculty-based spinoffs and stimulating the development of innovative products and processes." (Koh, et al., 2003) The role of the business incubator can be more useful as the small and medium enterprises are facing higher risk intensity (Belás, 2015) despite of the fact that small and medium enterprises are skeptical towards risk management in general (Mikusova, 2015)

The incubation process is divided into three main stages:

- **Pre-incubation phase** represents activities such as supporting entrepreneur with developing business idea, business model and business plan. Typically, it is followed by first assessment of the idea and initial couching.
- **Incubation phase** is characterized by support to incubated company in order to help it transform from start-up to expansion stage. The incubation program is set for fixed time (usually 3 years) and it includes activities such as mentoring, direct coaching, facility rent for reduced fees and providing access to
- **Post-incubation phase** are activities for company which successfully completed incubation program – such as couching with first issues the company have to face after leaving the incubator.

(European Commission, 2010)

2 Methods

The first aim of the contribution is to identify significance of major risk factors (issues) of incubated companies by using extended FMEA methodology.

The risk factors which incubated companies may face were set firstly. The aim of the paper is not to examine nor dispute risk factors (issues) of incubated companies, therefore the risk factors were taken over from existing literature. According to Wang there were 20 risk factors identified (such as cash flow issues, new customer acquiring issues, regulation issues etc.) (Wang, 2016). These factors were used to create SAFMEA-E form where respondents are asked to set level of Severity (*Sv*), Likelihood (*Lk*), Detection (*Dt*) and enhanced parameter Influence rate of mentor (*Me*)– on the scale from 1 to 10.

The second aim of the paper is to compare traditional SAFMEA to the situation where conventional parameters are extended of the fourth parameter Influence rate of mentor. The new parameter is introduced to the conventional parameters because of the significant role of the mentor on risk management in incubated companies. For this case the calculation of $mRPN_j^E$ has to be modified as shown in (7) by including the Influence rate of mentor parameter (*Me*) to the formula. The rest of the SAFMEA methodology remains identical. All calculation made by extended SAFMEA is marked by index ^{EX}.

$$RPN_{jk}^{EX} = SV_{jk}^{E} * Lk_{jk}^{E} * Dt_{jk}^{E} * Me_{jk}^{EX} \tag{7}$$

The web-based questionnaire was sent to the business incubators' mentors who are in direct mentoring relationship with incubated companies. The questionnaire contained matrix of set risk factors and SAFMEA parameters to fill by respondents. The expected result is a set of filled SAFMEA-E forms and then by using the SAFMEA methodology, the output in form of SAMFEA-T table is generated.

The questionnaire was sent to 30 selected mentors by email. However due to time consuming nature of the SAFMEA form, only 10 respondents filled the questionnaire. That makes the return rate 33%, which can still be considered as high. The respondents are consisted from management of business incubators (20%) and mentors/consultants working in the business incubators (80%).

3 Problem solving

The results from the filled SAFMEA-E forms are shown in the Table 1. The results show interesting outcomes. In the situation when conventional SAFMEA is used (ie. values of $mRPN_j^E$), the most significant perceived risk is 4. Funding issues – cash flow, followed by 15. Leadership and product alignment. The lowest significance is perceived 17. Legislation and regulation issues (the ranking is shown in the column Rank^E). On the other hand when enhanced SAFMEA is calculated (ie. by adding parameter of Influence rate of mentor) the results (and risk factor's significance) change. The risk factor 16. Partnership issues becomes the most significant risk. It is due to mentor's limited impact on this risk factor. It is followed by 4. Funding issues – cash flow. This shows that mentor can have positive impact on managing this risk factor. Like before, even in the case of expanded SAFMEA the 17. Legislation and regulation issues are perceived as risk factor with lowest significance (the ranking of extended FMEA is shown in the column Rank^{EX}).

Another beneficial view is which risk factors changed their position the most. The most positive influence of mentor is in the risk factor 6. Issues with business model from the

position 7 to the position 14. The second most significant change was observed in the risk factor 19. Issues with hiring and keeping employees. In this case the rank changed from position 15 to 9. It is due to low possibility of positive influence by mentor.

Tab. 1: SAFMEA-T table made from responses in SAFMEA-E forms

Risk factor	$mRPN_j^E$	$mRPN_j^{EX}$	Rank^E	Rank^{EX}
1. Building product issues	237	905	4	7
2. Customer acquisition issues	148	591	13	17
3. Funding issues - capital	167	824	11	8
4. Funding issues - cash flow	346	1870	1	2
5. Issues with building the team	230	1302	5	3
6. Issues with business model	212	688	7	14
7. Over capacity (Too much to do)	123	486	17	18
8. Revenue issues	187	1137	9	5
9. Minimum viable product issues	118	634	18	15
10. Staying focused and disciplined	153	719	12	11
11. Product market fit issues	222	742	6	10
12. Critical mass issues	198	983	8	6
13. Business scaling issues	145	701	14	12
14. Problem solution fit	128	473	16	19
15. Leadership and product alignment	295	1141	2	4
16. Partnership issues	281	1949	3	1
17. Legislation and regulation issues	79	254	20	20
18. Propagation product issues	182	699	10	13
19. Issues with hiring and keeping employees	139	818	15	9
20. Technology issues	86	610	19	16

Source: Author

Other important part of SAFMEA methodology is to calculate estimated distribution quantile which gives view on index randomness (it applies when ne $\geq$ 5). The results are shown in the Table 2. For better understanding, for every risk factor, the coefficient of variation is calculated. As it is possible to see in the results the responses vary significantly across experts. As mentioned in the theoretical review, the main prerequisite for FMEA methodology is based on the consensus amongst experts. However, the results show that responses can vary distinctively. In comparison between conventional SAFMEA and expanded SAFMEA – 30% of risk factors show lower variability in case of conventional SAFMEA.

Tab. 2: SAFMEA-T table with variance calculations

Risk factor	$mRPN_j^E$	$sRPN_j^E$	$qRPN_j^E$	$mRPN_j^{EX}$	$sRPN_j^{EX}$	$qRPN_j^{EX}$	V^E	V^{EX}
1. Building product issues	237	129	366	905	448	1353	54%	49%
2. Customer acquisition issues	148	58	206	591	258	849	39%	44%
3. Funding issues - capital	167	76	243	824	445	1269	46%	54%
4. Funding issues - cash flow	346	122	468	1870	1068	2938	35%	57%
5. Issues with building the team	230	160	390	1302	1026	2328	70%	79%
6. Issues with business model	212	130	342	688	415	1102	61%	60%
7. Over capacity (Too much to do)	123	56	179	486	329	815	45%	68%
8. Revenue issues	187	90	277	1137	690	1827	48%	61%
9. Minimum viable product issues	118	47	164	634	283	917	40%	45%
10. Staying focused and disciplined	153	98	251	719	416	1135	64%	58%
11. Product market fit issues	222	130	352	742	258	1000	58%	35%
12. Critical mass issues	198	75	273	983	238	1221	38%	24%
13. Business scaling issues	145	36	181	701	217	919	25%	31%
14. Problem solution fit	128	157	285	473	295	768	123%	62%
15. Leadership and product alignment	295	140	435	1141	577	1718	48%	51%
16. Partnership issues	281	104	385	1949	1401	3350	37%	72%
17. Legislation and regulation issues	79	35	114	254	88	342	45%	35%
18. Propagation product issues	182	58	240	699	363	1062	32%	52%
19. Issues with hiring and keeping employees	139	40	178	818	417	1235	29%	51%
20. Technology issues	86	42	128	610	352	962	49%	58%

Source: Author

FMEA methodology has major drawback in RPN index. It is because the RPN index cumulates three (or in case of extended version - four) parameters together. Therefore, there could occur combination of parameters where significant information is lost.

The solution of this drawback can be eliminated by using risk matrix or risk map diagram. Risk matrix is showing the risk factors in context of mean value of Severity (*Sv*) and mean value of Likelihood (*Lk*). The risk matrix ignores parameters Detection (*Dt*) and Influence rate of mentor (*Me*). (Hnilica, 2009) Risk matrix in Table 3 identifies the most significant risk as 2. Customer acquisition issues, 3. Funding issues – capital and 4. Funding issues - cash flow. The lowest significance (ie. in white area) is risk factor Problem solution fit.

Tab. 3: Risk matrix

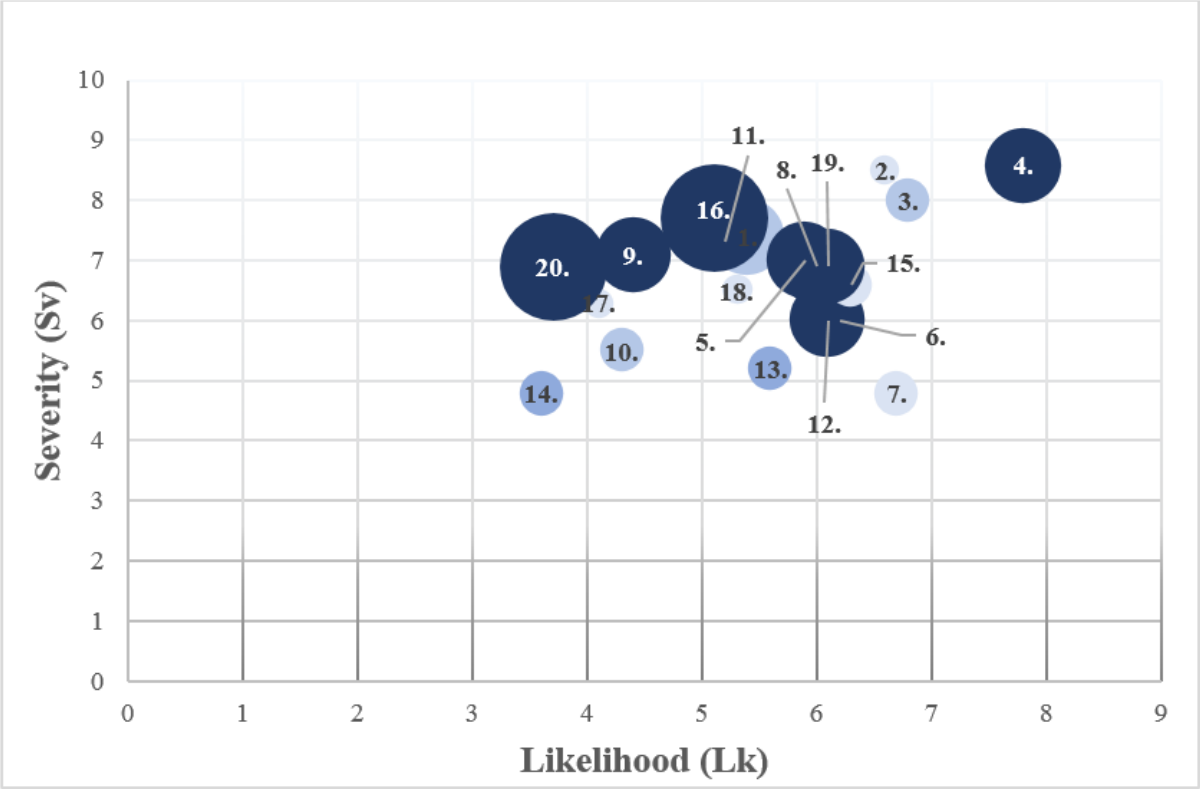
Likelihood (*Lk*)	**Severity (*Sv*)**				
	0-1,99	2-3,99	4-5,99	6-7,99	8-10
8-10					
6-7,99			**(7);**	**(6); (8); (12); (15); (19);**	**(2); (3); (4);**
4-5,99			**(10); (13);**	**(1); (5); (9); (11); (16); (17); (18);**	
2-3,99			**(14);**	**(20);**	
0-1,99					

Source: Author

As it is evident from the risk matrix, the impact of some parameters are ignored. Risk map diagram has mean value of Likehood (*Lk*) of every risk factor is placed on one axis and mean value of Severity (*Sv*) on the other. Moreover, the size of circle of risk factor is represented by mean value of Detection (*Dt*). (Fotr, 2012) To get the size of the circle the values of $\min SV_{jk}^{E}$ and $\max SV_{jk}^{E}$ was identified and the interval between them was divided into four sizes of the circle. In the case of the four parameters, the different color was used to distinguish between different levels of the Influence rate of mentor (*Me*) parameter. The risk map diagram was formed from the responses of the SAFMEA-E forms. The result is shown in Figure 1.

Risk map shows that the risk factor with highest significance is 4. Funding issues - cash flow. The second most significant are 2. Customer acquisition issues, 3. Funding issues – capital and 4. Funding issues - cash flow. It is very interesting to observe that risk matrix shows these three risk factors with the same significance, but risk map provides more comprehensive results. It is possible to see, that risk factor 4. Funding issues - cash flow is has also high risk in detection and low ability of influencing of mentor. On the other hand, two rest risk factors (2. and 3.) are identified with lower detection risk and with better influence by mentor – therefore their overall risk significance is lower. This information can be vital for risk analysis and further steps made by management.

Fig. 1: Risk map showing risk factors in context of FMEA parameters



Source: Author

4 Discussion

The paper shows the possibility of using SAFMEA methodology in risk analysis of incubated firms in the business incubator. Moreover it compares two possible outcomes of the analysis – risk matrix and risk map. When compared to the study where risk factors were gathered (Wang, 2016) where the author used simple three level ranking system (ie. identifiying 1st , 2nd and 3rd most significant challenge) SAFMEA methodology brings more comprehensive and objective outputs for management than said study.

It was interesting to discover, that there is no simple and free for use software solution for calculating SAFMEA methodology therefore all calculations had to be made manually in MS Excel. Moreover it creates the possible space (gap) for further development.

Conclusion

FMEA methodology is easy to use and well established methodology for identification and evaluation in risk management. The recent use of FMEA methodology is from industrial field to project / strategic management. The paper examines the 20 different risk factors of incubated companies in business incubators by using FMEA methodology (in variant of SAFMEA methodology) by calculating responses from mentors.

Firstly the paper compares the RPN indexes of risk factors in the conventional SAFMEA methodology and enhanced SAFMEA (by adding parameter influence by mentor). It clearly shows that some risk factors (6. Issues with business model and 19. Issues with hiring and keeping employees) shifted significantly in the overall ladder of risk factors' RPN indexes. It is explained by the fact that mentor of business incubator can considerably change risk importance by careful coaching.

The results using risk matrix shows that the most significant risk factors are 2. Customer acquisition issues, 3. Funding issues – capital and 4. Funding issues - cash flow. The results using risk map shows that risk factor 4. Funding issues - cash flow has higher significance by adding to the analysis the parameters Detection (*Dt*) and Influence by mentor (*Me*).

Overall it is possible to state that SAFMEA methodology is producing comprehensive results which could be displayed in the form of table, risk matrix or risk map. The methodology (and results) gives to management/mentors complex tool for risk analysis of the incubated companies.

Downside of the SAFMEA methodology that all calculations were made by using the MS Excel as there are no free and easy to use software solution for calculation all necessary formulas. However, it makes space for further improvement and development.

There could be long discussion on the topic of which method to use for risk analysis however FMEA is well known for its adaptability, reusability and spread amongst management. As it was shown in risk matrix and risk map, the practical advantages of FMEA is also in rich possibilities of results presentation. These are practical reasons why business incubators in the role of primary investor should consider SAFMEA as their primary tool for risk analysis and management. Moreover, SAFMEA is already used in comprehensive risk studies around different field, such as traffic risk analysis, automotive or project management where different opinions of the experts are demanded. Due to incredible adaptability of SAFMEA methodology the application is very wide and almost limitless.

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