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Comparative Study of Risk Assessment Value against Risk Priority Number

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ABSTRACT: Manufacturers have invested billions of dollars implementing Lean principles as a way to maintain and enhance their competitiveness. Even though there are manufacturers that have become industry powerhouses by implementing Lean, there are more examples of those who have not been as successful in achieving the anticipated results. A survey conducted by industry week reveals that about only one-third of U.S. manufacturers consider Lean as their primary improvement program and experts estimate that less than 5% of US manufacturing firms are truly Lean (O'Brien, K., 2003). Most organizations utilize Lean as a way to attain short term cost reductions and adopt a mentality towards short and intermediate term efficiency gains (Smart et al., 2003). This is done to achieve increased profits and return on investments while reducing costs (Banolas, 2007). These approaches have raised questions about sustainability within organizations which implement Lean to reduce costs (Smart et al, 2003). Banolas (2008) and Smalley (2005) define the following four categories as reasons of why Lean does not sustain in organizations.

- Gap of Lean knowledge
- Insufficient Leadership
- Change approach is insufficient
- Insufficient commitment

Sawhney et al(2009) proposed Risk Assessment Value(RAV) to prioritize lean issues. There is no comparative study done between RPN and RAV to prove which is better to prioritize lean issues. This paper represents a comparative study to prove why RAV is better RPN.

I. OVERVIEW OF LEAN

Implementation of Lean principles alone is not sufficient to meet customer's dynamic demands (Yusuf and Adeleye,2002). This paper addresses an organization's "gap of Lean knowledge" by integrating reliability concepts with Lean. Lean system design will be enhanced if it incorporated the fundamental definition of reliability. Lean systems are prone to failure therefore increasing the reliability of Lean system components would enhance the system ability to sustain improvements. IEEE[1] defines reliability as "the ability of a system or component to perform its required functions under stated conditions for a specified period of time"[1] (IEEE: STD 610.12 1990). Sawhney et al applied this basic definition to Lean systems as follows (Sawhney et al., 2009) :

1. The required functions of reliable Lean systems are:
- Materials in the right quantity delivered at the right time at the right location.
- Schedule attained without variance, rescheduling and expediting.
- Equipment should not unexpectedly fail and, if it fails, the repair time should be minimized.
- Personnel must be available and qualified to perform standard operating procedures so that product quality and delivery requirements can be met.

2. The stated conditions of reliable Lean systems are:
- Material availability and quality will vary due to volatile market behavior.

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- Schedule must adapt to meet a customer-oriented market with short term fluctuations in demand.
- Equipment will incur unplanned events, such as extended downtime or performance below the given specification.
- Personnel will incur fluctuations in availability and performance.

3. The specified period of time for a reliable Lean system is defined as the cycle of a system, which depends on the minimum time span associated with material, scheduling, equipment and personnel adherence".

However, the Lean system design has focused primarily on the first component and ignored the second and third component of the Lean system reliability definition. Lean designers do not typically consider the stated conditions. For example, Lean systems are designed based on assumptions such as timely arrival of parts, correct quantity of arrivals, equipment working without failure, all personnel being present, and compliance with established schedules. Therefore, these designs are based on optimal business/ operational condition and not on actual conditions. As a result, Lean systems are unable to function under the realistic business conditions when the system is not designed with that environment in mind.

II. SUMMARY OF LITERATURE

However, practical models that integrate reliability principles mentioned above into Lean design are non-existent (Subburaman, 2010). Sawhney et al (2009) presented a reliability based Lean system methodology that explicitly addresses the second component of the Lean system reliability definition. The contributions of this methodology are outlined below:

1. The focus of the methodology is to force the Lean system designer to define the realistic business conditions and subsequently highlight realistic business conditions that violate the range of conditions assumed by Lean.
2. The methodology categorizes business conditions into four categories: personnel, equipment, material and schedule. Comprehensive Hierarchical Tree Diagrams (HTD) were developed for each category.
3. The methodology prioritized the violations based on a modified Failure Mode Effects Analysis (FMEA). This modified FMEA utilized a Risk Assessment Value (RAV) rather than traditional Risk Prioritization Number (RPN). A summary comparison between RAV and RPN is presented in Table 1.

Criteria	RAV	RPN
Focus	Reliability of Lean	Risk of General Systems
Calculation	$\frac{\text{(Severity *Occurrence)}}{\text{Effectiveness of Detection}}$	Severity*Occurrence*Detection
Range of Scores	.1 to 100	1 to 1000
Justification	Lean design directly impacts Effectiveness of Detection as a means to reduce Severity and Occurrence	Severity, Occurrence and Detection are equal in their impact on risk
Potential Failure Mode	Failure modes are real business conditions that violate Lean assumptions	List of any failure in product or process
Probability of Occurrence (O)	Same as RPN	Same as RAV
Potential Effects	Potential effects are determined from Hierarchical Tree Diagrams developed to support RAV.	Potential effects indicate overall impact and consequences of each failure mode of component or system

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Severity(S)	Same as RPN	Same as RAV
Ability to Detect (D)	Focuses on Effectiveness of Detection: effective use of Lean concepts to detect	Focuses on Detection: general tools to detect

As illustrated in Table 1, the modified FMEA is designed specifically to incorporate second component of the Lean system reliability in designing Lean systems as compared to general traditional FMEA. Specifically, the advantages to the Lean community are as follows:

- Forces designers to systematically consider the business conditions
- Prioritizes Lean System Reliability issues within four easily understood categories
- Focuses in on Lean tools to design mistake proofing on a broader level
- Is supported by a Visual Basic based tool to minimize the tedious calculations and to prioritize Lean failures

The purpose of this paper is to validate the Risk Assessment value (RAV) in an actual manufacturing environment. The case study will include the following steps. The first step will be used to describe the manufacturing process. This manufacturing process was selected because authors have been implementing Lean in the facility for the past four years. The second step will be to design and collect the data required to test RAV against RPN. The third step is to perform the analysis of the collected data utilizing hypothesis testing and Analytic Hierarchy Process (AHP) . The fourth step will be to provide relevant conclusions.

III. CASE STUDY

A metal tube bending process is selected to highlight RAV. The bending process consists of three operational departments; cutting, bending and welding which manufacture a variety of different products. The organization has had a explicit Lean program to improve the process over the past four years. This included training every employee, developing Lean strategies by the Lean council (employees from each department and management) and Lean implementation by the employees. The manufacturing facility today looks and runs quite differently than it did four years ago. This manufacturing process is a Lean system today as defined by Smalley (2005).

However, this manufacturing process continues to face disruptions. Therefore, the focus of this paper is to apply both RAV and RPN to this manufacturing process to predict and prioritize the failures in this Lean manufacturing process. The knowledge base developed for Lean System Reliability (LSR) by Sawhney et al (2009) is utilized to create the initial list of potential failures to evaluate the bending process. Failures are defined as required conditions for the successful operation of the bending process that currently do not exist. These potential failures are categorized under the four critical resources required for Lean; equipment, material, personnel and schedules. The data collection mechanisms included site visits, observations and interviews. However, the primary means of data collection was during a series of interviews when input was provided by a team consisting of members of each department and the management team to a complete list of potential failures. Each time the team indicated that the necessary Lean condition was violated then that condition was treated as a failure. The team completed a FMEA which consisted of all identified failures. In particular, the team focused on three critical pieces of information: probability of failure occurrence, the severity associated with the failure and how effective a system the process had in detecting that failure. The input from the team is the same information that will be utilized to calculate both RAV and RPN. The methodology developed by sawhney et al.,(2009) provides detailed procedure for prioritizing Lean failures. An automated tool was developed to reduce the tedious task of calculating and prioritizing the top Lean failures. A sample screen shot is illustrated in Figure 1.

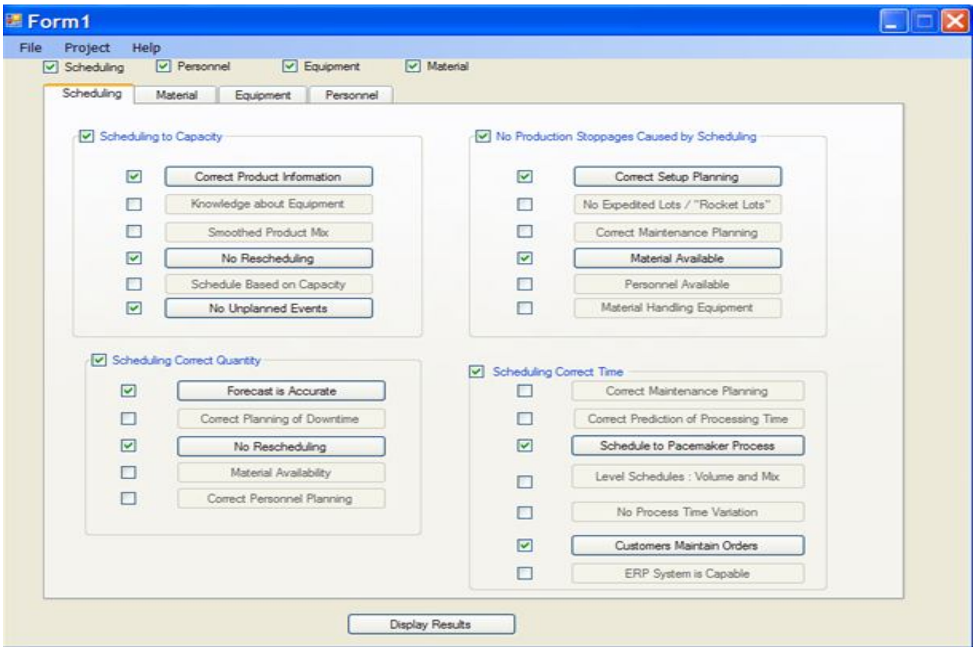

Figure 1 Screen for Operating Conditions for Scheduling

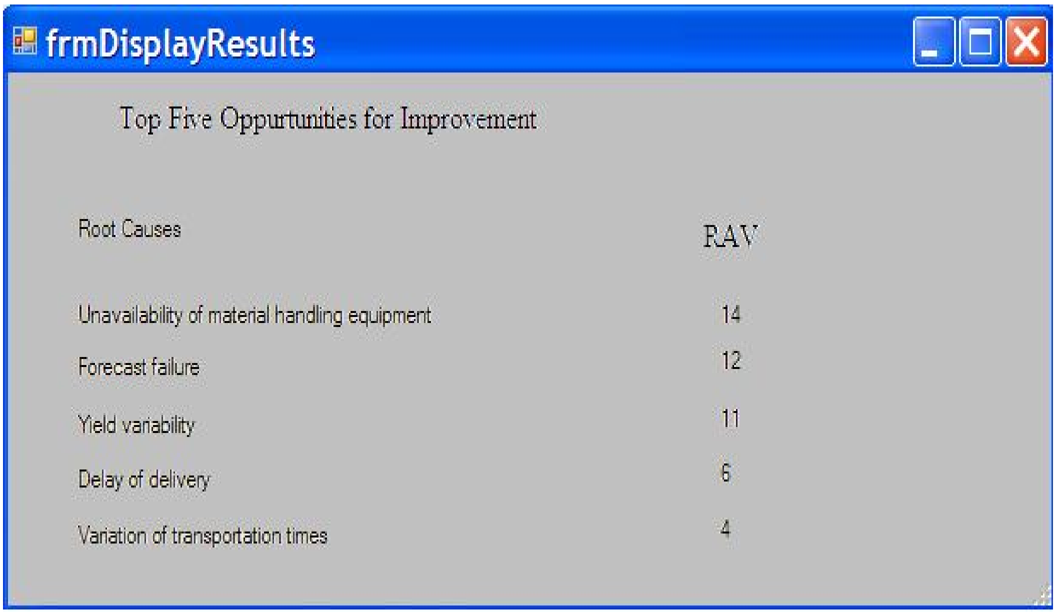

Figure 2 Screen of Final Results

The top thirty five Lean failures is shown in Table 1 of Appendix. It is observed from Table 1, the RAV and RPN ranking is different for each Lean failure. The objective of hypothesis test is to test for significant difference between RAV and RPN ranking in prioritizing Lean system failures. This analysis was executed in two phases. Phase 1 utilized hypothesis testing to determine if the ranking between RAV and RPN is different. Once the results indicated a

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difference between RAV and RPN rankings , phase 2 utilized an Analytic Hierarchy Process (AHP) to determine which approach is a better method to prioritize Lean failures. The purpose of this case study is to draw a comparison between RAV and RPN ranking to conclude better approach that prioritizes risks associated with Lean system.

Phase 1: Hypothesis Testing

Hypothesis testing consists of a pair of statements about unknown parameter that enables one to make a decision whether to accept or reject a statement (Montgomery C. Douglas et al., 2001). The unknown parameter called Null Hypothesis is the first statement denoted by H_0. The second statement called Alternative Hypothesis is a declaration based on the new information denoted by Ha. The process of rejecting or not rejecting the null hypothesis H_0 is called hypothesis testing. The parameters in this case would be RPN and RAV numbers that are calculated by traditional FMEA approach and modified FMEA approach respectively**.** The hypothesis testing procedure outlined by Montgomery (Montgomery C. Douglas et al., 2001) is utilized to perform the test.

Step 1: Determine the parameter of interest

The critical task in this method is to determine if there is any difference in means of RPN and RAV numbers. Hence, the parameter of interest in this approach will be μ_1 and $\mu_{2,}$ the mean of the RPN numbers and RAV numbers.

$\mu_{1\,=}$ mean of RAV numbers.

μ_2 = mean of RPN numbers.

Step 2: Define the null hypothesis, H_0

There is no difference in the means of RPN and RAV numbers. For a given Lean failure, RPN and RAV values have same ranking.

H_0: $\mu_{1=}\,\mu_{2.}$

Step 3: Define the alternative hypothesis, H_a

The means of RPN and RAV numbers are not equal. For a given failure, RPN and RAV values have different ranking.

H_a: $\mu_{1\neq}\,\mu_{2.}$

Step 4: Specify the significance level, α

The significant level is set at 0.05 for this case study.

Step 5: Test for Normality

Figure 7 and 8 provide a summary of the normal distribution test performed on RPN and RAV numbers respectively. RAV and RPN numbers were tested using JMP (Sall et al., 2005). The p value of normality test is significant to determine whether data fits normal distribution. If p value> 0.05 then RPN numbers and RAV numbers follow normality. From these figures, the p value determined from the Shapiro - Wilk test is <.0001 (Sall et al., 2005). This proves that RAV and RPN numbers do not fit the normal distribution.

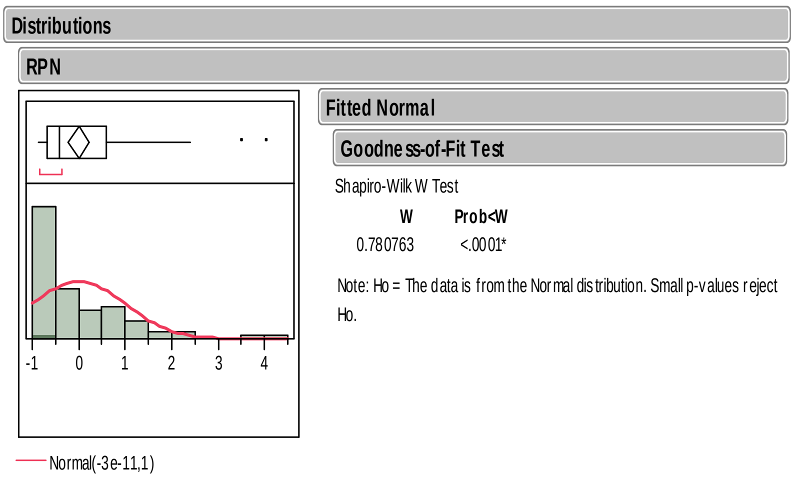

Figure 4 Test for Normality of RPN Numbers

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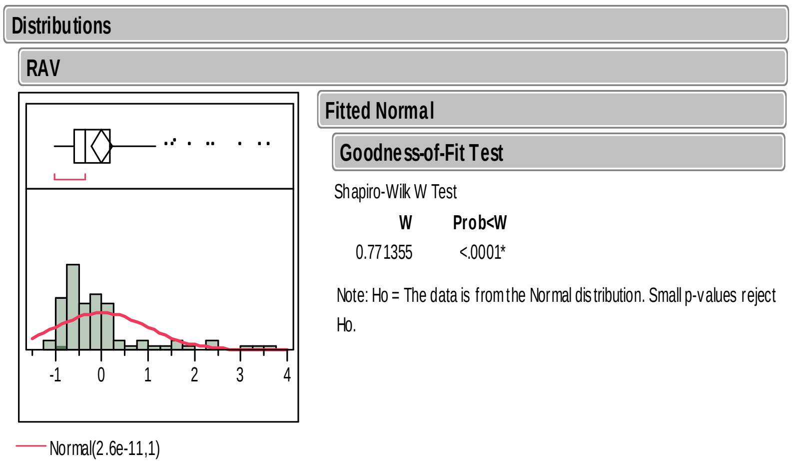

Figure 5 Test for Normality of RAV Numbers

Step 6: Non parametric rank F- test

When the distributions of error terms do not follow normality, a nonparametric test is used to perform hypothesis testing (Kutner et al., 2005). The assumption of continuous distribution is the requirement to perform this test. It was assumed that two samples followed continuous distribution. This test provides the basis for differences in means assuming that the shapes of two samples are identical.

In this step, the F_R* and F test statistic model developed in Microsoft Excel is assessed to accept or reject null hypothesis. As a result F_R* and F test statistic value for RAV and RPN numbers is calculated. If $F_R^* \leq F(1-\alpha; r-1, n_T - r)$ null hypothesis is accepted and if $F_R^* > F(1-\alpha; r-1, n_T - r)$ alternate hypothesis is accepted. Table 2 in the appendix shows the F_R* and F test statistic calculated for RAV and RPN numbers. The F_R* test statistic value is defined as ratio of MSTR to MSE. Equation 2 show the mathematical formula used for calculating F_R*.

$$F_R^* = MSTR/MSE \qquad (2)$$

Where,

$$\text{Treatment Mean Square (MSTR)} = \frac{\sum n_i(\overline{R}_i. - \overline{R}..)^2}{r-1} \qquad (3)$$

$$\text{Error Mean Square (MSE)} = \frac{\sum\sum(R_{ij} - \overline{R}_i..)^2}{(n_T - r)} \qquad (4)$$

Where,

$$\overline{R}_{i.} = \frac{\sum_j R_{ij}}{n_i} \qquad (5)$$

$$\overline{R}.._{.} = \frac{\sum\sum R_{ij}}{n_i} = \frac{(n_T+1)}{2} \qquad (6)$$

Equation 3 and 4 represent the mathematical formula for calculating MSTR and MSE utilizing equation 5 and 6. The F statistic value is calculated from tables using equation 7.

$$F(1-\alpha; r-1, n_T - r) \qquad (7)$$

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Where,

- α - Significance level
- (r-1) - Degree of freedom 1
- (n_T -r) - Degree of freedom 2

Step7: Accept or Reject the null hypothesis
This step is used to determine whether the means of RPN and RAV numbers are significantly different from each other. Table 2 in the appendix shows the results of non parametric rank F test performed on the means of RAV and RPN numbers at 95% significance level. It can be observed that F_R*> F (1-α; r-1, n_T -r) thereby rejecting the null hypothesis. This implies that the means of RAV and RPN numbers are not equal. Thus it can be concluded that means of RAV and RPN numbers are statistically different. Hence the question arises which of these two approaches will be a better approach to rank Lean failures?

Phase 2: Decision making with the Analytic Hierarchy Process (AHP)
Many problems in engineering involve decision making when the situation faces multiple objectives. Thomas Saaty's Analytic Hierarchy Process (AHP) is a powerful tool utilized to make such decisions. In this research, the objective of AHP is to determine which of these approaches: traditional RPN or RAV approach is better method to prioritize Lean risks. The approach follows the Saaty's procedure as described by Winston (2004).

The objective of AHP process is to determine the best approach to prioritize Lean failures. The criteria used to choose the objective is based on probability of occurrence; severity and effectiveness of detection. The hierarchy modeling for prioritizing Lean failures is shown in Figure 1.

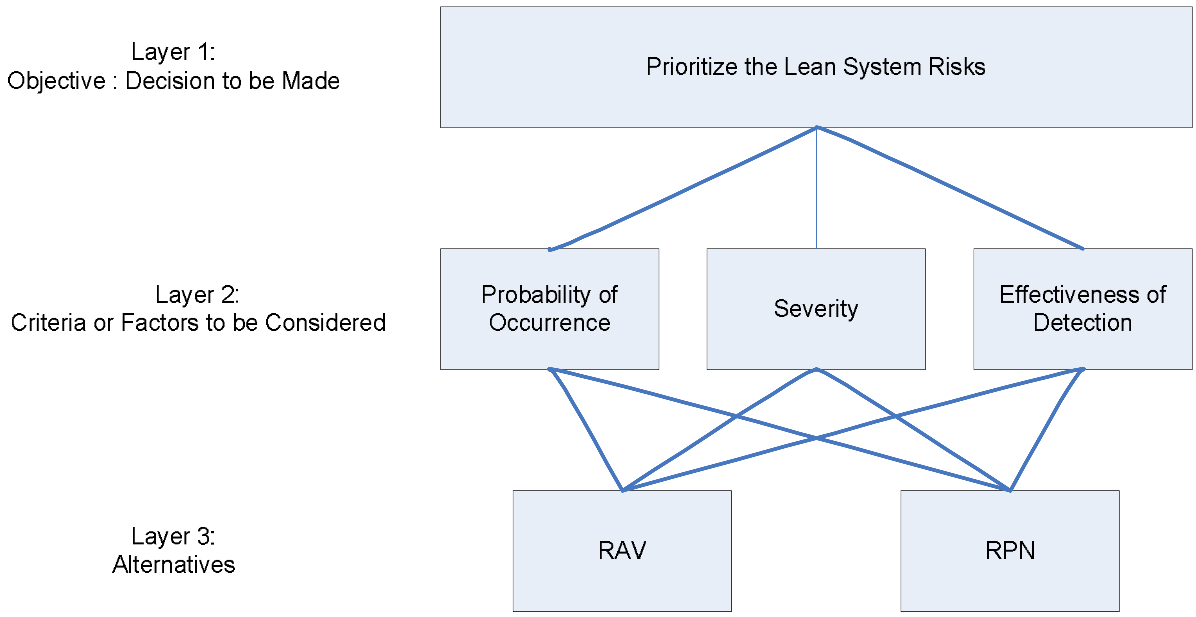

Figure 6 Hierarchy Modeling to Prioritize Lean Failures

Layer 1 focuses on setting the objective of the structure. This layer selects the most needed approach for prioritizing Lean system risks. Layer 2 comprises of probability of occurrence, severity and effectiveness of detection which are the

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factors or criteria that influenced the selection of most needed approach. Layer 3 emphasizes on prioritizing alternatives to implement the better approach for ranking Lean failures. This level consists of RAV, RPN. The needs for these alternatives are determined based on the criteria in Layer 2 (Sawhney et al., 2009).

Figure 6 shows the hierarchy modeling for prioritizing Lean failures. The elements are RAV, RPN. In this paper, only prioritization of Lean risks and its three factors: probability of occurrence, severity and effectiveness of detection will be illustrated in detail. The pair-wise comparisons start from this level. The value for these pairwise comparisons between the criteria is established based on justification for modified FMEA approach illustrated by Sawhney et al., (2009). As a result, the following assumptions are made:

- Effectiveness of detection is more important than probability of occurrence.
- Probability of occurrence is more important than severity.
- Effectiveness of detection is very strong indicator of system failure than severity.

AHP is used to decide which one of these two approaches should be in priority to rank Lean system risks. This module is designed in order to determine the most suitable approach to prioritize Lean risks for a given Lean environment based on three criteria considered.

IV. RESULTS

Table 2 shows the priority vector values for effectiveness of detection is 0.738, probability of occurrence is 0.168 and severity is 0.094. It means that company should place its priority firstly on effectiveness of detection.

Table 2 Pair Wise Comparison Matrix and Synthesis of Results for Overall Weighing Analysis

Weighing Analysis	Effectiveness of Detection	Probability of Occurrence	Severity	Priority Vector
Effectiveness of Detection	1	3	7	0.738
Probability of Occurrence	1/3	1	5	0.168
Severity	1/7	1/5	1	0.094

Table 3-5 depict the priority vector values for each of alternatives. Table 3 shows the priority vector values for RAV is 0.84 and RPN is 0.16. Table 4 shows the priority vector values for RAV is 0.25 and RPN is 0.75. Table 5 shows the priority vector values for RAV is 0.25 and RPN is 0.75.

Table 3 Determining the Scores of an Alternative for Effectiveness of Detection

Aspect	RAV	RPN	Priority Vector
RAV	1	5	0.84
RPN	1/5	1	0.16

Table 4 Determining the Scores of an Alternative for Probability of Occurrence

Aspect	RAV	RPN	Priority Vector
RAV	1	1/3	0.25
RPN	3	1	0.75

Table 5 Determining the scores of an Alternative for Severity

Aspect	RAV	RPN	Priority Vector
RAV	1	1/3	0.25
RPN	3	1	0.75

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Based on the results from Tables 3-5, Table 6 provides the summary of the AHP priority vectors for each of modules and sub modules.

Once the weighing values for the three criteria and scores of alternative for each criterion is determined, it is necessary to establish overall priorities to achieve the objective. Table 7 shows the results of overall priorities of RAV and RPN in order to determine the better approach for prioritizing Lean risks. It can be observed from Table 7 that the overall priority for RAV is greater than RPN. Therefore it is concluded that RAV is better approach to rank Lean failures. From Table 7, it can be seen that the company should focus to implement RAV approach because of the highest priority vector of 0.68.

Table 6: Summary of AHP priority vectors for each of modules and sub modules

	Priority Vector	**Alternatives**	**Priority Vector**
Effectiveness of Detection	0.74	RAV	0.83
		RPN	0.17
Probability of Occurrence	0.17	RAV	0.25
		RPN	0.75
Severity	0.09	RAV	0.25
		RPN	0.75

Table 7 Overall Priorities

Criteria	Effectiveness of Detection		Probability of Occurrence		Severity	
Weighing	0.74		0.17		0.09	
Alternative	RAV	RPN	RAV	RPN	RAV	RPN
Priorities	0.83	0.17	0.25	0.75	0.25	0.75
Overall Priorities						
RAV	0.68					
RPN	0.32					
Conclusion - RAV is better						

V. CONCLUSIONS AND RECOMMENDATIONS

The visual basic based RPLS tool developed for RAV calculation eliminates any additional effort needed by the end user. The contributions of this research are as follows:

- Developed RPLS tool to automate modified FMEA.
- A case study was conducted to compare RAV and RPN numbers for the four critical resources of Lean.
- Determined RAV as better method to prioritize Lean risks

Further research could be carried out incorporating neural networks to develop a more robust decision model. The relationship within the HTD's will be established by determining the logic between nodes. The following are areas for further research

- Validated weighing values for probability of occurrence, severity and effectiveness of detection would enhance the RAV calculations based on Lean experts input.
- All the four resources can be surveyed among more industries to determine its practicality.

In the automated RPLS tool, Lean controls for all the potential root causes can be determined.

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REFERENCES

1. Smart, P. K., Tranfield,D., Deasley,P., Levene,R., Rowe,A and Corley.J (2003), "Integrating 'Lean' and 'High Reliability' Thinking", Proceedings of the Institution Mechanical Engineers, Vol. 217, No. 5, pp.733-739
2. Booth, C and Harmer,M. (1995), "Agility, the future for ceramic manufacturing", Ceramic Engineering Science proceedings, Vol 16, No.1, pp 220-225
3. Banolas, R. (2007), " An approach to Lean Transformation", Lean Enterprise Institute
4. Yusuf, Y.Y and Adeleye. (2002), " A Comparative Study of Lean and Agile Manufacturing with a related Survey of Current Practices in the UK" , International Journal of Production Research
5. O' Brian, K (2003), Value Chain Report- Focused approach for implementing Lean, Industry week, www.industryweek.co
6. Smalley, A (2005), Basic Stability is Basic to Lean Manufacturing Success, Lean Enterprise Institute,
7. Lean Enterprise Institute. (2008), Survey of Lean Community, available at: http://www.lean.org/WhoWeAre/NewsArticleDocuments/Obstacles_addendum_release08.pdf (accessed 24 April 2009)
8. Weick, K. E. (1987), "Organizational Culture as a Source of High Reliability", California Management Review, pp.112-127
9. Sawhney,R., Subburaman.K., Sonntag,C., Capizzi.C., Rao.P.V (2009), " A Modified FMEA Approach to Enhance Reliability of Lean Systems", accepted to International Journal of Quality and Reliability Management
10. IEEE Std 610.12-1990, IEEE Standard Glossary of Software Engineering Terminology, Institute of Electrical and Electronics Engineers, 1990.
11. Womack, J.P., Jones, D.T., and Roos, D. (1990). *The machine that changed the world*. Rawson Associates, New York, NY
12. Biazzo,S., and Panizzolo,R. (2000). "The assessment of work organization in Lean production: the relevance of the worker's perspective", Integrated Manufacturing Systems, Vol.11 No.1, pp 6-15
13. Forza,C. (1996). "Work organization in Lean production and traditional plants: what are the differences?", International Journal of Operations and Production Management, Vol.16 No.2, pp 42-62
14. Scherrer-Rathje,M., Boyle,T.A., Deflorin, P. (2009), "Lean, take two! Reflections from the second attempt at the Lean Implementation", Business Harizons, Vol 52 Issue 1 pp. 79-88, available at: www.sciencedirect.com (accessed April 22, 2009)
15. Forrester, R. (1995). "Implications of Lean manufacturing for human resource strategy", Work Study, Vol. 44 No.3, pp.20-24
16. Meier, D. (2001), "The Reality of Lean Manufacturing – Brief Article", available at: http://findarticles.com/p/articles/mi_m0FWH/is_3_113/ai_72117362 (accessed 26.August 2008)