Rework Reduction and Quality Cost Analysis of Furniture Production Processes Using the House of Risk (HOR)

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Abstract. — Quality is one of the important factors that makes a company survive in the industrial world. PT. X maintains the quality of its products by conducting quality tests on all products that will be sent to consumers. Although the quality test has been carried out on products, there are still consumers who receive defective products. To reduce product defects, a risk management approach is carried out. Risk management is a method in which organizations can identify problems with a comprehensive and systematic management approach. The method used in this study is Seven tools and House of Risk (HOR). Phase 1 of the House of Risk (HOR) method used to search for risk agents must be prioritized by looking at the value of Aggregate Risk Potential (ARP). Furthermore, the ARP value is used as input for House Of Risk phase 2 to find mitigation strategies that can be applied in the company. Based on the identification of risk events there are 24 risk events in the production process and there are 21 causes of risk (risk agents). The causes of risk that must be prioritized are 10 causes of risk with the highest ARP value of 2699, i.e. the operator ignores the SOP. So that the causes of risk must be prioritized for improvement. Based on the analysis of the quality costs is repair product costs or rework product cost, it is focused on two products is Crb 10123-31 and Crb 01143-79 Ns.

Keywords : Risk Management, Inventory, Aggregate Risk Potential (ARP), House Of Risk (HOR), Mitigation Strategy, Risk Agent, Risk Event, Quality Costs.

1. Introduction

The development of the furniture industry, the companies are required to compete with other companies so that they can survive in the industrial world. One important factor that makes a company able to survive is maintaining product quality so that consumers are satisfied with the products produced by the company.

Remanufacturing as well as quality improvement innovations are important activities to improve sustainability. However, when living side by side in one company, their interactions are not clear. On the one hand, past research found[1]. On the supply-side, a firm carries out advertising to promote its product and product innovation policies that improves product quality. On the demand-side, consumers are sensitive to product price, product quality, and advertising expenditure[2].

Rework is the repeating of an activity (design) at the same scope and abstraction level or the unplanned allocation of resources to fix problems discovered late in a product's development cycle[3]. Rework is redoing tasks in a similar way because inputs or assumptions changed[4]. in reducing
product defects and reworking of course a process is needed. In the process sometimes there are uncertainties that pose a risk.

Risk known uncertainties while uncertainties are unknown risks[5]. Risks can be reduced by the existence of risk management. Risk management refers to a structured process involving actions or activities for the purpose of reducing the chances of the occurrence of such undesirable events and mitigating the effects[6].

In previous research regarding risk management about risk management strategies and residual risk perception in the wine industry. The research was conducted in northeastern Italy. the results of the study state that investment in risk management strategies focuses on managing wine production which has a direct impact [7]. in this research reduce the reworking and cost quality analysis with risk management strategies and the House of risk.

PT. X is a company engaged in manufacturing. The product made by this company is furniture. Furniture products produced by this company are various such as chairs, tables, drawers, beds, sofa beds, wall hangings, and others. Each product produced has different specifications from each other because the company implements the Make to order system, which means the company receives orders from buyers in the production process.

The production process in this company consists of five main parts, namely the inventory section, Central Part Preparation(CPP), white wood and rattan, glass, finishing, packaging. In the production process, products sent to buyers are products that have passed the quality test. Even though the production process has been tested for quality but there are still defective products, it needs to be repaired in the form of reworking. Product defects can be categorized as risks that can disrupt the company.

This research was conducted to help overcome these problems with a risk management approach using the House of Risk (HOR) method. After taking a risk management approach with the HOR method, the next thing to do is to identify the quality costs that must be incurred by the company in terms of this risk.

2. Literature Review

2.1. Risk

Risk is present everywhere, in every aspect of our lives. One example of an industry that poses risks is the construction industry. risk is an inherent element. An effective risk management process does not mean eliminating risk, it is an easier analysis choice[8]. A risk must be identified and analyzed so that it can be minimized and not adversely affect a process[9].

2.2. Risk Management

Risk management is concerned with planning, identifying, analyzing, responding, monitoring and controlling risk management in an activity [10][11]. Risk management is a process used to identify, measure, ensure, and develop strategies to be used to manage risk[12]. Risk management is able to evaluate and to decide whether a project is worth to carry out with attention to the organizational structure, level of technology, the ability of human resources, financial conditions, the level of production and the level of marketing[13][14]. A risk management activity allows an organization to identify and reduce risks that threaten the achievement of objectives and are part of an effective quality management system[15].

2.3. Quality Risk Management

Quality risk management is a systematic process for the assessment, control, communication and review of risks to the quality of product. Further, QRM concept depends upon the understanding of terms ‘Quality’ and ‘Risk’[16]. Quality risk management is a systematic process for the assessment, control, communication and review of risks towards the quality of product across the product lifecycle[17].

3. Methods
The method used in this study uses a quality risk management approach and the solution is to use the seven tools approach and the House of Risk (HOR) method. The following are the steps in resolving problems with the seven tools and House of Risk (HOR) methods:

3.1 Seven Tools Approach

The seven tools approach used in this study are two, namely histogram and pareto diagram. In this study, the histogram presents data about the frequency of defects in furniture products in each production process. Pareto diagram used to know things that are priorities in quality control [10]. The Pareto chart is a bar graph that shows the data based on the greatest frequency to the smallest. The first bar graph shows the most data as well as its placement is in the far left and so on until the right most data means the least amount [18]. The histogram is called also with frequency distribution diagram. This diagram shows the frequency distribution data are quantitative or qualitative data in the form of a succinct and clear [19][20].

3.2 House of risk

House Of Risk (HOR) is a method developed from the two methods, namely the method of QFD (Quality Function Deployment) and FMEA (Failure Modes and Effects Analysis) that is used to design a framework in managing risk. This method was developed by Geraldin Laudine and Nyoman Pujawan[21]. FMEA (Failure Modes and Effects Analysis) is an effective way to resolve the problem, besides that FMEA is used to determine the potential modes and effect analysis of failure[22][23]. QFD (Quality Function Deployment) is one of the methods successfully used in the process of product design; using the House of quality (HOQ), capable of translating the customer's requirements into design specifications[24].

Data that has been processed using the seven tools approach, the histogram will then be analyzed using the House Of Risk (HOR) method. This method is used to identify the risk of production processes in furniture products to reduce rework products. The following are the stages of House Of Risk (HOR) [21]:

1. Phase 1 HOR
a. Identify risk events (Ei) and risk agents (Aj) in the production process
b. Identify the impact on each Ei variable
c. Determine the rating of the severity value
d. Identify risk factors for each variable Ai
e. Determine the rank of the amount of occurrence
f. Make a matrix of variable correlation relationships Ei and Ai provided that:
0: no correlation, 1: weak correlation, 3: moderate correlation and 9: strong correlation

g. Calculate the value of ARP (Aggregate Risk Potential) from Aj using the formula below:

\[ ARP_j = O_j \times \sum S_i \times R_{ij} \] (1)

h. Determine ARP ratings from each Ai
i. Make a Pareto Aj diagram for priority selection.

| Production Process | Risk Agents (Aj) | A1 | A2 | A3 | ..... | ..... | Am |
|--------------------|------------------|----|----|----|-------|-------|----|
|                    | Severity of risk events (Si) | \( R_{11} \) | \( R_{12} \) | \( R_{13} \) | ..... | ..... | \( R_{1m} \) |
|                    |                   | E1 | E2 | E3 | ..... | ..... | ..... |
|                    |                   | ..... | ..... | ..... | ..... | ..... | \( S_1 \) |
|                    |                   | \( R_{21} \) | \( R_{22} \) | \( R_{23} \) | ..... | ..... | \( R_{2m} \) |
|                    |                   | E2 | E3 | ..... | ..... | ..... | \( S_2 \) |
|                    |                   | \( R_{31} \) | \( R_{32} \) | \( R_{33} \) | ..... | ..... | \( S_3 \) |
|                    |                   | E3 | ..... | ..... | ..... | ..... | ..... |
|                    |                   | ..... | ..... | ..... | ..... | ..... | ..... |
|                    |                   | \( R_{n1} \) | \( R_{n2} \) | \( R_{n3} \) | ..... | ..... | \( R_{nm} \) |
|                    |                   | En | ..... | ..... | ..... | ..... | ..... |
|                    | Occurrence of agent j | O1 | O2 | O3 | ..... | ..... | On |
|                    | Aggregate Risk Potential j | ARP1 | ARP2 | ARP3 | ..... | ..... | ARPm |
|                    | Priority Rank of Agent j | ARP1 | ARP2 | ARP3 | ..... | ..... | ARPm |

Table 1. Phase 1 HOR (Risk Identification).
2. Phase 2 HOR
   a. Arrange mitigation or preventive action (PAk) based on Aj’s priorities
   b. Determine the correlation between Aj and PAk with the following conditions:
      0: no correlation, 1: weak correlation, 3: moderate correlation and 9: strong correlation
   c. Calculate the total effectiveness value of each PAk using the formula below:
      \[ TE_k = \sum (ARP_j \times E_{jk}) \]  
   d. Measuring the level of difficulty in applying PAk with the following scales and conditions:
      3: low
      4: medium
      5: high
   e. Calculate the effectiveness for the difficulty ratio (ETDk) using the formula below:
      \[ ETD_k = \frac{TE_k}{D_k} \]  
   f. Determine PAk priorities based on ETDk values

| Table 2. Stage 2 HOR (Risk Management) |
|----------------------------------------|
| Preventive action (PAk)               |
| To be treated risk agents (Aj)        |
| Relationship between mitigation actions and to be treated risk agent |
| ARP1 | ARP2 | ARP3 | ARP4 | ARP5 |
| A1  | E11  |      |      | ARP1 |
| A2  |      |      |      | ARP2 |
| A3  |      |      |      | ARP3 |
| A4  |      |      |      | ARP4 |
| A5  |      |      |      | ARP5 |
| Effectiveness of action k             |
| TE1 | TE2 | TE3 | TE4 | TE5 | TE6 | TE7 |
| Degree of difficulty performing action k |
| D1  | D2  | D3  | D4  | D5  | D6  | D7  |
| Effectiveness to difficulty ratio     |
| ETD1 | ETD2 | ETD3 | ETD4 | ETD5 | ETD6 | ETD7 |
| Rank of priority                      |
| R1  | R2  | R3  | R4  | R5  | R6  | R7  |

Si = level of impact of a risk (risk severity) Oj = risk insurance event rate
Rij = risk event correlation relationship with risk agent j ARPj = Aggregate Potential risks from risk agents j
TEk = the value of the effectiveness of each mitigation action k
Ejk = Relationship between risk agent correlation j and risk mitigation k ETDk = effectiveness against the ratio of difficulties
TEk = The total effectiveness of the action k Dk = The level of difficulty taking action

3.3 Analysis of Pareto’s Chart
In this study, Pareto diagram is used to indicate the classification of data from left to right based on the percentage order of the value of ARP (Aggregate Risk Potential) in House Of Risk (HOR). The biggest percentage will be improved by conducting phase 2 HOR, which is looking for strategies for the proposed risk mitigation steps.

3.4 Quality Cost Analysis
In the analysis of the cost of this quality that will be calculated is the cost of failure from within (internal), namely the cost of rework (reprocessing). Costs to be calculated include material costs, direct labor costs and overhead costs.

4. Result
Process at PT. X. Based on observations there are some defects produced during the production process in the period 2017. The following is a breakdown of data on furniture products ordered by Braxton during the 2017 period:
Figure 1 shows the defects in furniture ordered by Braxton buyers during the 2017 period. Of the several types of disability, the most common disability was poor sanding from 51 defective findings and too much glue or putty from 44 defective findings. Based on this problem it is necessary to take action so that defective products are reduced so as to satisfy customers and can reduce complaints from customers. To overcome this problem will be done by identifying risks in each production process that can lead to defective products.

This risk identification is done by interviewing companies, namely the quality control division and the production department. The following are risks that can interfere with the furniture manufacturing production process:

**Table 3. Account of Risk Events**

| Section              | Activity | Risk Event                                                                 |
|----------------------|----------|-----------------------------------------------------------------------------|
| Central Part Preparation | Kiln Dry | There is a broken wooden                                                   |
|                      |          | There is a curved wood                                                     |
|                      | Sizing   | There is a wooden eye                                                       |
|                      |          | the dimensions of the wood that does not comply with the specification     |
|                      |          | There is a difference in color while the joining of wood                   |
|                      |          | wood cracked when the process of connecting a wood                         |
| Rotan Process        | Bending  | There are variations in color rattan                                        |
|                      |          | results of untidy matting                                                  |
|                      |          | There are nails that look on the outcome of the Assembly                   |
| Glass Process        | Shaping  | the surface of the glass edges uneven                                       |
|                      |          | Series of glass not precision                                              |
|                      | Assembling | the results of the assembly that is not strong                           |
|                      |          | the results of the assembly which is not presentable                       |
|                      |          | There is material which breaks                                             |
|                      |          | the connection is not flat and legs shake                                  |
|                      | Assembling | There are uneven surfaces                                                  |
|                      |          | installation of components that are wrong so the way it works is problematic|
|                      |          | components not aligned                                                     |
|                      |          | the color of the wood is not the same                                      |
| Wood Process         | Assembling | the product surface is rough                                              |
|                      |          | the brightness of colors exceeds or is less than the specifications         |
|                      | Sanding  | there are irregularities of color                                          |
|                      | Colouring | There are a variety of colors on one piece                                 |

After identifying risk events, then identifying the causes of risk is done by interviewing the company, namely the head of the QC department. The following identifies the causes of risk in all risk events which will be explained in table 2 below:
Table 4. End of risk Recap (Risk Agent)

| Risk Agents                                                                 | Code |
|----------------------------------------------------------------------------|------|
| Negligence of the operator                                                | B1   |
| Don’t pay attention to the arrangement of wood and kiln dry               | B2   |
| Raise the temperature too fast                                            | B3   |
| The position of the assembly which is not payed                           | B4   |
| The operator ignores the SOP                                              | B5   |
| The lack of communication when revision pictures                          | B6   |
| Repeated checking is not done                                             | B7   |
| Pressure does not correspond to the type of wood                           | B8   |
| Don’t pay attention to the kind of hard or soft wood                      | B9   |
| The blade on the aus cut machine                                          | B10  |
| Types of rattan which is not the same                                     | B11  |
| Size per part part no precision                                           | B12  |
| The size of the dowel is not appropriate                                  | B13  |
| The awarding of the glue less many                                        | B14  |
| The lack of communication with revision pictures                          | B15  |
| Pressure on the engine claim is too large                                 | B16  |
| Less expert operators                                                     | B17  |
| Wind pressure down on the spray tool                                      | B18  |
| Spray the dirty tool                                                      | B19  |
| Mixing colors                                                             | B20  |
| Existence of step color skipped                                           | B21  |

Each risk event will be assessed for its severity. The severity shows how big the impact is. While each cause of risk will be assessed based on the criteria for the occurrence or how often these failures occur. Furthermore, an assessment of the correlation between the incidence of risk and the cause of risk is carried out. The three assessments will be used as input to find the value of the Aggregate Risk Potential (ARP). The result of Risk Aggregate Potential Value (ARP) is:

Table 5. The order of ARP from the largest to the smallest

| No  | Code | Risk Agents                                                                 | ARP  | ARP   |
|-----|------|------------------------------------------------------------------------------|------|-------|
| 1   | B5   | The operator ignores the SOP                                                | 2699 | ARP5  |
| 2   | B1   | Negligence of the operator                                                  | 1909 | ARP1  |
| 3   | B4   | The position of the assembly which is not payed                            | 979  | ARP4  |
| 4   | B2   | Don’t pay attention to the arrangement of wood and kiln dry                 | 272  | ARP2  |
| 5   | B7   | Repeated checking is not done                                               | 602  | ARP7  |
| 6   | B10  | The blade on the aus cut machine                                            | 552  | ARP10 |
| 7   | B12  | Size per part part no precision                                             | 472  | ARP12 |
| 8   | B14  | The awarding of the glue less many                                          | 379  | ARP14 |
| 9   | B17  | Less expert operators                                                       | 323  | ARP17 |
| 10  | B20  | Mixing colors                                                               | 308  | ARP20 |
| 11  | B13  | The size of the dowel is not appropriate                                   | 285  | ARP13 |
| 12  | B16  | Pressure on the engine claim is too large                                   | 238  | ARP16 |
| 13  | B9   | Don’t pay attention to the kind of hard or soft wood                       | 218  | ARP9  |
| 14  | B21  | Existence of step color skipped                                             | 207  | ARP21 |
| 15  | B6   | The lack of communication when revision pictures                           | 204  | ARP6  |
| 16  | B8   | Pressure does not correspond to the type of wood                            | 190  | ARP8  |
| 17  | B3   | Raise the temperature too fast                                              | 184  | ARP3  |
| 18  | B11  | Types of rattan which is not the same                                       | 132  | ARP11 |
| 19  | B19  | Spray the dirty tool                                                        | 130  | ARP19 |
| 20  | B18  | Wind pressure down on the spray tool                                        | 144  | ARP18 |
| 21  | B15  | The grant is too much glue                                                  | 125  | ARP15 |

6
Based on table 5, it can be seen that the ARP value from highest to lowest. The risk cause of the operator ignoring the SOP has the highest ARP value of 2699 while giving too much glue has the lowest ARP value of 125.

![Figure 2. Pareto ARP diagram](image)

Based on Figure 4, it can be seen which causes of risk should be prioritized based on the Pareto diagram concept. If the company wants to overcome the problem by 80%, there are 10 types of risk causes that must be prioritized, namely the operator ignores the SOP, operator negligence (human factor), assembly position is not considered, does not pay attention to the wood arrangement in the dry kiln, no longer checked, the knife cut using, the size of each part is not right, less glue, the operator is less skilled and mixes the wrong color.

In phase 2 of the HOR, the search for mitigation strategies or preventive measures is carried out. This strategy is used to reduce the occurrence of risk causes so that risk events will decrease as well. In determining mitigation strategies, this is adjusted for the identified risk causes. Based on interviews with production parties, 16 strategies for mitigation proposals were obtained, namely as follows:

| Table 6. Summary of proposed mitigation strategies |
| --- |
| **Preventive action** | **Code** |
| Do the training or training to operator | PA1 |
| Provide socialization SOP | PA2 |
| Conduct performance assessment for the operator | PA3 |
| Provide briefings to the operator every morning | PA4 |
| Conduct evaluation work each work before it ends | PA5 |
| Design a workplace that is comfortable and safe for the operator | PA6 |
| Create work orders for each sheet of the operator | PA7 |
| Do some checking every once an hour | PA8 |
| Make the wood setup in the SOP kiln dry | PA9 |
| Makes engine maintenance schedule daily, weekly and monthly | PA10 |
| Create a work instruction to cut machines | PA11 |
| Make archive documents maintenance | PA12 |
| Improve the system of workers’ acceptance | PA13 |
| Create a sample panel colors for finishing operator | PA14 |
| Give instructions pengecetan each item products | PA15 |
| Inline check periodically in the finishing area | PA16 |

Furthermore, an assessment of the correlation between the causes of risk and the proposed mitigation strategy is carried out. This assessment is carried out by the company, namely the head of the QC department. The ARP value of the 10 priority causes of risk and the correlation value between
the causes of risk and the proposed mitigation strategy is used as input to determine the value of total effectiveness.

Furthermore, an assessment is carried out to assess whether the strategy is difficult or not applied in the company by determining the value of the degree of difficulty. This assessment is done by giving a questionnaire to the company that is an expert in their field, namely the head of the QC department. The total effectiveness value and degree of difficulty are used to calculate effectiveness to difficulty ratio (ETD). The highest mitigation proposal strategy with effectiveness to difficulty ratio (ETD) is the output of phase 2 HOR, which means that the strategy can be applied in the company to be used to reduce the causes of risk. The following is a recapitulation of the results of ETD value calculations:

Table 7. Recapitulation of ETD values

| Code | Proposed mitigation strategies | ETD       |
|------|--------------------------------|-----------|
| PA2  | Provide socialization SOP      | 27035.07  |
| PA4  | Provide briefings to the operator every morning | 27035.07 |
| PA8  | Do some checking every once an hour | 27035.07|
| PA5  | Conduct evaluation work each work before it ends | 20276.3 |
| PA3  | Conduct performance assessment for the operator | 19447.89|
| PA1  | Do the training or training to operator | 19282.88|
| PA10 | Makes engine maintenance schedule daily, weekly and monthly | 18885.06|
| PA9  | Make the wood setup in the SOP kiln dry | 17677.23|
| PA7  | Create work orders for each sheet of the operator | 16089.54|
| PA14 | Create a sample panel colors for finishing operator | 15717.83|
| PA15 | Give instructions pengecetan each item products | 15717.83|
| PA16 | Inline check periodically in the finishing area | 14856.39|
| PA13 | Improve the system of workers’ acceptance | 13055.08|
| PA12 | Make archive documents maintenance | 12543.13|
| PA11 | Create a work instruction to cut machines | 12391.5 |
| PA6  | Design a workplace that is comfortable and safe for the operator | 3437.094|

Table 7 shows the ETD value of all proposed mitigation strategies. Based on ETD calculations, it is known that the strategy that has the highest ETD value is three, namely providing socialization of SOPs and quality standards to operators, giving briefings to operators every morning and checking every hour with ETD values of 27035.07 meaning that these three strategies can be applied in the company to reduce the causes of risk.

Furthermore, an analysis of quality costs, costs are carried out. The quality costs to be analyzed in this study are internal failure costs, namely the cost of product repairs (product rework). In analyzing the cost of repairing this product based on the cost of the material used for product repairs, direct labor costs in accordance with the length of time worked on product repairs and factory overhead costs, namely the cost of electricity usage if the repair uses a machine. The following are the results of calculating quality costs for each type of disability:
Table 6. Results of calculation of quality costs

| Type of reject      | Type of product | Crb 01143-79 Ns | CRB10123-31 |
|---------------------|-----------------|----------------|------------|
| Wood eye            | Rp30,141        | Rp26,694       |
| Discolouring        | Rp46,967        | Rp40,073       |
| Fingerpoint         | Rp10,012        | Rp10,357       |
| Laminate            | Rp15,763        | Rp13,956       |
| Dimention           | Rp144,307       | Rp144,997      |
| Material Split      | Rp146,123       | Rp144,136      |
| Poor Assembly       | Rp106,181       | Rp106,181      |
| Door/Drawer alignment | Rp42,842     | Rp43,182       |
| Colour variation    | Rp81,972        | Rp83,465       |
| Rough finish        | Rp124,169       | Rp126,007      |
| Glossy top coat     | Rp30,114        | Rp30,114       |
| Color deviation     | Rp247,958       | Rp246,182      |
| Poor sanding        | Rp11,692        | Rp12,382       |
| Too much glue/putty | Rp19,788        | Rp19,788       |
| Marking process     | Rp15,283        | Rp15,973       |

5. Conclusion

Based on the Aggregate Risk Potential (ARP) calculation and analysis using the Pareto diagram, there are 10 causes of risk that must be prioritized for improvement and looking for mitigation strategies, namely the operator ignores the SOP with the largest ARP value, which is 2699, operator negligence (human factor), assembly position, do not pay attention to the arrangement of wood in the dry kiln, not checked again, the knife on the cutting machine is worn out, the size of each part is the wrong part, lack of glue, the operator is less skilled and mixing color is wrong. The mitigation proposal strategy used to minimize the occurrence of risk causes that can cause risk events there are 16 strategies proposed with 3 proposed strategies that have the highest ET_D value namely providing SOP socialization and quality standards to operators, providing operator briefings every morning, and checking every hour. Quality cost analysis is focused on two products, namely Crb 10123-31 and Crb 01143-79 Ns. For example, the total repair cost for Crb 10123-31 products caused by wood defects is Rp 26,694 while on Crb product is 01143-79 Ns, the total repair cost is Rp. 30,141. This research provides results not only in a qualitative calculation but also calculates the cost of each improvement process. this will help the company about the costs. this is different from previous research using only qualitative calculations.

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