Measurement and Development of Humanware and Technoware Competencies in Order to Meet Pintle Chain Product Requirements in Bandung Manufacture Polytechnic

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Abstract. Politeknik Manufaktur Bandung (Bandung Manufacture Polytechnic) is a polytechnic education that is not only to educate their students, but also manufactures order from customers at its teaching factory. This polytechnic is usually not responsive with the number of reject due to amateur operators from newcomer students. However, customers will be displeased if the reject rate is too high which can cause delay of delivery. At the foundry section, pintle chain is a product that has the highest amount of quantity but the lowest product standard fulfiment. Realizing this problem, it is a strong need to give more focus on quality improvement. The polytechnic considers that bad quality is not only related to low level of humanware (operator) but also related to low level of technoware (machine and equipment). In this research, QFD model was used as a tool for identifying target of improvement of non conforming factors of humanware and technoware using UNESCAP’s technometric model. An improvement was done by implementing new scheduling strategy at foundry unit in order to minimize waiting time from molding to pouring process because of deterioration problem. This strategy provides an opportunity to reduce completion times about 50% and waiting time about 95% compared to the existing scheduling strategy.

Keywords: Humanware, Technoware, QFD, UNESCAP’s Technometric, Scheduling

1. Introduction
To be competitive, improving product quality is a must or at least a product has to meet the standard requirement as the basic level of quality. The standard requirement for a product is considered very important and need to be fulfilled since it was made based on agreement between customers and producers. Standard is aimed at constantly improving industry in order to catch a fast development of technology and innovation that affects the needs of the society [3]. According to International Organization of Standardization (2015), product standard is the most general requirement which contains specifications of a product in term of its characteristics (shape, dimension, material, etc.), methods, processes, and other aspects. If industries can achieve the product standard properly, then the role of standard is effective in providing assurance to society in some aspects. The role of standard includes to compete (development of capability to make competitive advantages), to confirm (guarantee the requirements needed, implied or stated), and to connect (extend the market).
Politeknik Manufaktur Bandung (Bandung Manufacture Polytechnic) is an education institution that is also performing business activities in order to give a real business climate to the students in its teaching factory. Its businesses include various manufacturing services in the field of mechatronics, machining, automation, and foundry. All processes are designed as a flow shop to give as high efficiency as possible. This polytechnic has customer service department that continuously observes how well the products meet their quality standards in order to give excellent service to the customer. Regular shop floor performance observations are performed, including at the foundry unit which at this time has the largest number of quality standard problems.

At the foundry section, pintle chain is a product that has the highest amount of production quantity but the lowest at product standard fulfilment. This product has the rate of returning products about 50% in October - December 2014 and having 649 rejected products of 1564 units. Human resource competencies (categorized as humanware) and capability of equipment or machine (categorized as technoware) are the two main factors that usually make a product miss to meet the standard [2]. In terms of human resources, only few supervisors (actually also as teachers) concerned with the reduction of the number of defects, while the other supervisors tend to maximize learning phase regardless of the number of defect products, thus attention on quality improvement and fulfilling the standard is not exploited sufficiently. In this regard, QFD approach can be used to measure deficiencies of the capabilities of technology (humanware and technoware), so that improvement can be done [4]. In this paper, QFD approach was used as a tool to identify deficiencies of humanware and technoware at the teaching factory. An improvement was then proposed to reduce completion time at foundry shop.

2. Methodology

QFD method uses a matrix approach to relate aspects required in product design as shown in Figure 1. Generally, the QFD method consists of 7 stages, i.e. (i) defining customer requirements, (ii) defining manufacturing process as technical requirements, (iii) create correlation between product requirements and technical requirements, (iv) measuring sophisticated degree of technology’s competencies for fulfilling the standards, (v) measuring actual competencies, (iv) comparing expectation of competencies and actual competences, (vi) calculating technical response’s weight in determining priority of competency’s development.

![Figure 1: A generic QFD matrices [1].](image)

A slight modification of QFD method was done at planning matrix. The requirements in standard document used was considered as the customer needs (in what matrix), while capability of humanware and technoware was considered as the technical responses (how matrix). In the first stage, standard document had been defined and agreed by manufacturer and customer, and it consists of requirements
covering product’s characteristics, method, and process. The total number of standard is 10. After that, expert judgement method was held to determine the weight of each standard requirement by using analytical hierarchy process (AHP). At the second stage, all manufacturing processes are identified comprehensively based on the existing condition at the foundry shop. According to expert’s agreement in production line and customer service representative, there were 9 manufacturing processes identified at the foundry shop. After that, the same expert weighted these manufacturing processes. At the third stage, correlation between technical requirements and customer needs was mapped to form relationship matrix.

At the next stage, measurement of competencies was done only for the process that has correlation with standard requirements using UNESCAP model [5] as formulated in equation (1) and (2).

\[ AKSh_j = \sum_{i \in N_j} W_i \times KSh_i, \]  
\[ AKSt_j = \sum_{i \in N_j} W_i \times KSt_i, \]  

where \( AKSh_i \) is the aggregate of requirement’s competencies of humanware for standard requirement \( j \), \( AKSt_j \) is the aggregate of requirement’s competencies of technoware for standard requirement \( j \), \( KSh_i \) is the expectation of competency’s level of humanware for production process \( i \), \( KSt_i \) is the expectation of competency’s level of technoware for production process \( i \). \( N_j \) is production process that correlates to the standard requirement, \( W_i \) is the weight factor of production process \( i \), and \( j = 1, 2, 3...n \) is the sequence of standard requirements.

At the fifth stage, the measurement was done for actual competencies of foundry shop at the teaching factory. Production supervisor and human resources division measured the average of competencies in each process by using UNESCAP model [5] as shown in equation (3) and (4).

\[ AKIh_j = \sum_{i \in N_j} W_i \times KIh_i \]  
\[ AKIt_j = \sum_{i \in N_j} W_i \times KIt_i \]  

where \( KI \) is the level of actual competencies, so that \( AKIh_i \) is the aggregate of actual competencies of humanware for standard requirement \( j \), \( AKIt_j \) is the aggregate of actual competencies of technoware for standard requirement \( j \). \( KIh_i \) is the actual competency’s level of humanware for production process \( i \), \( KIt_i \) is the actual competency’s level of technoware for production process \( i \). At the sixth stage, planning matrix is constructed to compare \( AKS \) and \( AKI \) by setting \( AKS \) equal to goal and then do normalization. At the last stage, gap percentage was calculated in each process which was used as priority consideration in performing improvement.

### 3. Implementation

Processes that are defined as technical requirements consists of 9 processes; each has the weight as follows, i.e. (i) melting metal 21.5%, (ii) molding 3.8%, (iii) sand recycling 25.1%, (iv) pouring 9.3%, (v) blasting 3.6%, (vi) finishing 7.9%, (vii) core making 17.7%, (viii) shaking out 7.7%, and (ix) tensile test 3.5%. The elements of product standard and their weights are shown in Table 1.

| Pintle Chain Product’s Requirements | Weight |
|------------------------------------|--------|
| i. Target of material composition 3.8 - 4.2% C, 1.6-2% S, <0.6Mn, 0.8-1.2% Cu, FCD 700 | 19.51% |
| ii. Final product should be free from sand defect | 15.21% |
| iii. Dimension should be in range or within 1-1.5 mm | 14.49% |
| iv. There is no defect at assembly pintle chain (between shaft and hole). | 13.83% |
| v. Final product should be free from cold shuts | 10.54% |
| vi. Surface’s rigidity should be 450 RMS | 9.25% |
| vii. Final product should be free from blowholes | 7.33% |
| iii. There is no tied-sand in final product | 4.12% |
| ix. It has inoculation treatment and Mg Treatment | 3.86% |
| x. Final Product should pass the tensile test | 1.85% |
Then, the mapping of correlation matrix is done by using four indicative scales, i.e. 0 (no correlation), 1 (minimum correlation), 3 (medium correlation), and 9 (strong correlation). The result is shown in Table 2.

| Table 2. Matrix of Correlation
|---------------------------------|
| **Product Standard of Pintle chain** | **P1** | **P2** | **P3** | **P4** | **P5** | **P6** | **P7** | **P8** | **P9** |
| Dimension | Range: 1-1.5 mm | 9 | 3 | 0 | 0 | 1 | 0 | 9 | 3 | 0 |
| Material | Composition 3.8-4.2% C, 1.6-2%S, <0.6 Mn, 0.8-1.2% Cu, FCD 700 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 1 |
| Metal Treatment | Inoculation treatment and Mg Treatment | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 1 |
| Surface’s rigidity | 450 RMS | 9 | 3 | 1 | 1 | 1 | 1 | 9 | 1 | 0 |
| Blasting | No tied-sand in final product | 1 | 0 | 0 | 3 | 9 | 0 | 1 | 0 | 0 |
| Defect free | | 9 | 9 | 1 | 9 | 1 | 0 | 9 | 0 | 0 |
| | Free from sand defect | 9 | 0 | 1 | 9 | 1 | 0 | 9 | 0 | 0 |
| | Free from cold shuts | 9 | 3 | 1 | 3 | 0 | 0 | 9 | 0 | 0 |
| | Free from blowholes | | | | | | | | | |
| Test | Pass the test | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 9 | 0 |
| Assembly | No defect | 9 | 3 | 0 | 0 | 0 | 3 | 3 | 0 | 0 |

Two expert with more than 20 years working experience (as supervisor and head of quality control) were asked to measure the competencies level (actual and expectation) of humanware and technoware. The level of industrial or actual competence is below the standard requirements. The $AKI_h$ proportion (aggregate of industrial competence of humanware) that are more or equal to $AKS_h$ (aggregate of standard competence of humanware) is only 9%. And for technoware, the level of industrial competence is also below the standard requirements. The proportion of $AKI_t$ that are more or equal to $AKS_t$ is only 15% (as shown in Figure 2).

![Figure 2. Level of competence of (a) humanware and (b) technoware.](image)

For the humanware, the process of making a mold has the biggest gap percentage compare to other, with the value of gap is 50% with the following reasons:

- Minor causes: The operator fails (i) to observe the pattern of a mold which is worn out, (ii) to change with the new pattern, and (iii) to warrant that there will be no damage of the mold when the mold is being transferred by the crane.
- Major causes: the resin to bond of the sand has been deteriorated.

According to previous technological studies, the weak bond of the sand’s mold produces defects including sand erosion, and blowholes. These defects are considered as the major weakness of the teaching factory in the production of the pintle chain. Based on the shop floor observation, this weakness can be solved if there is no waiting time between molding process and pouring process, but the fact the waiting time is high an varies from one day up to one week. Long waiting time makes the bond deteriorate. Further analysis found that long waiting time is caused by the operator's schedule procedure since the procedure misses to consider the deterioration of resin to bond sand’s mold. Accordingly, finding optimal solution that relates deterioration of resin to bond sand’s mold and operator scheduling.
For the technoware, it can be concluded that the level of technology for core making, molding, pouring, shaking out, and sand recycling are lower than the required standard. In general all machines or equipments are old, more than 20 years. This teaching factory uses simple manual process for core making, reamer for for mold making, and lip pour ladle for imprecise timing for pouring. In general, a foundry needs 2 steps shake out equipment splitting binders. However, this teaching factory only uses one step shaking out equipment with single conveyor for sand recycling so that the quality of recycled sand is low.

In depth focus group discussion with some supervisor concerning the above problems was done. From the discussion, two alternative solutions were proposed, i.e. designing splitting machine, and time reduction of mold before used. Designing splitting machine to improve the sand’s quality was considered too expensive and also needs long time (it may interrupt teaching schedule), so that the first proposal was considered not feasible. The low quality of sand was considered as the main problem. With low sand’s quality, longer time of waiting before pouring may damage the mold. Accordingly, time variation to store the mold (between molding process and pouring process) should be reduced. A re-assessment of scheduling method between molding and pouring was proposed.

The existing teaching factory is characterized as a hybrid flow shop, minimizing flowtime between molding and pouring, resulting in lot streaming for each job, and flexible job schedule. Accordingly, a multi-job lot streaming to minimize the mean completion time in m-1 hybrid flow shops method was considered [6]. All parameters were estimated using past data. Optimum solution was found using Lingo V11.0 with computation time 94 hours. Compared to the existing scheduling method, the result of proposed scheduling method is shown in Figure 3.

| Kode | PC | SD | SP | 145 | 119 | K07A | LP |
|------|----|----|----|-----|-----|------|----|
| [1] | 4  | 2  | 2  | 10  | 14  | 4    | 12 |
| [2] | 8  | 2  | 5  | 8   | 8   | 3    | 20 |

Figure 3. Lot streaming of (a) existing and (b) proposed scheduling methods.

By applying the proposed scheduling method, some improvements were resulted as shown in Table 3.

| Criteria               | Existing scheduling method | Proposed scheduling method | % reduced |
|------------------------|----------------------------|----------------------------|-----------|
| Completion Time (hour) | 84.6                       | 76.6                       | 9%        |
| Mean Completion Time (hour) | 65.04285714               | 32.45                      | 50%       |
| Waiting time (hour)    | 245.5                      | 13                         | 95%       |
4. Conclusion

Politeknik Manufaktur Bandung (Bandung Manufacture Polytechnic) is a polytechnic education that is not only to educate their students, but also manufactures order from customers at its teaching factory. This institution confronts two objectives, i.e., performing a controlled education program, and producing product in accordance to standardized requirements. In this paper, recommending improvements proposal is not straightforward since it has to meet both objectives. A QFD approach was chosen to identify the root cause of problems in order to fulfill requirements of a standard from customer. A proposed method of scheduling had been done at the foundry in order to reduce the level of defect of pintle chain; a product that is used for learning program as well as for outside customer.

5. References

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