

WORKER SELECTION WITH MULTIPLE SKILLS IN LABOR-INTENSIVE INDUSTRY

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Introduction

With the increasing of global competition, all manufacturing sectors have been forced to not only improve efficiency but also increase productivity gain along its supply chain. An efficient management on manufacturing resources is one key concern to be appropriately utilized and to reach the competitive advantage. In labor-intensive manufacturing environment, workforce plays an important role as a major resource that drives and control the entire system. By its nature, labor-intensive refers to an industry that requires a substantial involvement of worker especially in the operational level which directly impacts the overall production performance. Furthermore, the system mostly consists of small and inexpensive machines and equipment (Söer and Bera, 1998). Regarding to the importance of labor resource, worker's capabilities or skills have become an influencing factor since an individual worker will have different skills to perform a specific task. It is commonly agreed that workers with different skill levels will have different abilities in terms of operational understanding and response times, this highly effects the overall performance. To achieve a successful workforce management, the effective methods of evaluation and ranking for workers with different competencies are needed to select the most appropriate worker and place to the right task and it is the most challenging goal of all organizations (Güngör *et al.*, 2009). However, in the workforce management literature, much of the existing studies has been focused the final workforce management decision in allocating worker-to-task problem which strongly pushed by the mathematical models, without respect to the real manufacturing practice. On the other hand, workforce management decision in the first stage, namely worker selection, is an essential decision that should be made effectively. It is found from the previous studies that there is a little attention paid in this stage. In worker selection management, an effective evaluation of worker performance is required to individually indicate worker's performance.

In order to fill the gaps, this paper aims to present a methodology of workforce management in selection stage, with the different perspectives drawn from academia to real manufacturing. The important worker selection criteria with multiple skills from previous literature and real manufacturing practice are identified and prioritized using the Analytic Hierarchy Process (AHP) as a Multi-Criteria Decision Making (MCDM) tool. Furthermore, the worker selection practice is also investigated through a case study of a labor-intensive industry to represent as labor-intensive sector which reflects the real world problem. The rest of the paper is organized as follows: literature review, proposed methodology, computational results of AHP model, and conclusions.

Literature Review

This paper focuses on the labor-intensive manufacturing environment in the operational level, which is operated by "workers". In literature review section, it is organized as follows: (1) skill gaps, (2) worker selection, and (2) analytic hierarchy process (AHP).

Skill Gaps

The skilled workers are the most powerful assets in achieving the business goals (Güngör *et al.*, 2009). In labor-intensive environment, it is commonly agreed that worker skill has a strong impact on the manufacturing performance. Skill is defined as one's ability to apply knowledge and use the know-how to perform tasks well. Generally, skills may be cognitive (use of logical, intuitive and creative thinking) or practical (use of methods, materials and tools) (Chryssolouris *et al.*, 2015). In the context of a learning process, skills generally involve the following elements, observation and replication of actions, task reproduction from instruction or memory, reliable execution independent of help, adaptation / integration of expertise to meet requirements and automated (Bloom *et al.*, 1956). Smits (2007) classified worker skills into two types; (1) generic skills and, (2) industry-specific skills. It is important for worker to have not only skills in specific industry, but also generic skills that create a wide range of applicability. Heijke *et al.* (2003) explained that generic skills are defined from a combination of learning abilities, analytical abilities, and problem solving abilities. On the other hand, Hendaman and Tjakraatmadja (2012) categorized skills into two types, one is soft skills and the other is hard skills. Soft skills refer to personal attributes that enhance an individual's interactions with work performance, while hard skills are a person's skills set and ability to perform a certain task. The skill

list of Consoli and Rentocchini (2015) were drawn from the manufacturing which machines are the major resource. In this paper, worker skill is classified into two types; (1) general skills and, (2) technical skills. In whilst, general skills mainly refer to any fundamental skills which can be applied in different industry sector (i.e. analytical thinking, communication, learning), unlike technical skills which mainly focus on any specific skills used in operations of a specific industry sector (i.e. production and processing, quality control). In production planning and designing systems, workers are commonly assumed to be equal in their abilities and perform tasks at a steady pace (Bentefouet and Nembhard, 2013) and most of the mathematical models consider worker resource with only one skill (Wongwai and Malaikrisanachalee, 2011). Generally, these assumptions totally conflict the real world problem. Ignoring the impact of workers with various skills would result the effectiveness of services provided which lead to the organization's outcomes (Lee, 2004). In workforce allocation and scheduling problems, Warner et al. (1997) assigned workers to machines based on their human and technology skills. Wongwai and Malaikrisanachalee (2011) proposed an algorithm for resource scheduling which multiple skills had been considered. Fowler et al. (2008) studied decisions in workforce management with respect to differences in individual workers measured by general cognitive ability (GCA). The workforce flexibility was focused as an effective way to deal with the various variabilities in manufacturing systems. A mixed integer programming (MIP) model is used to determine different staffing decisions (i.e. hire, cross-train and fire) to minimize workforce related costs. It is seen that all of the afore-mentioned literature has emphasized on dealing with the differences of worker skills by generating skill level and placing it as a constraint in mathematical models. On the other hand, Mori et al. (2015) presented a quantitative approach for design and formation of workforce skills using simulations to achieve the efficient assembly. The skill of workers is one major cause of uncertainties. Demand fluctuations also cause the difficulty in maintaining the efficient skilled workers in machine tool production. From the literature review, it is found that there are a few studies on workforce management with the consideration of worker's multiple skills with regard to labor-intensive manufacturing nature. Thus, this paper aims to intensely investigate the influencing workforce skill required in labor-intensive industry sector.

Worker Selection

A lot of existing literature has been focused on workforce management problem which is carried out into different stages; e.g. worker evaluation, selection, allocation and worker scheduling in Majazi and Zhu (2005). This classification corresponds to Şen and Çinar (2010) which focused on worker evaluation and pre-worker allocation phase. In brief, evaluation refers to the performance measurement of workers (e.g. competency, experience). Selection refers to the question of "who" will be selected? (Nembhard and Bentefouet, 2014), and grouping is concerned with clusters of selected workers who have similar competencies. Worker allocation is concerned with "who works where?", but worker scheduling is concerned with "who works when?" (Majazi and Zhu, 2005). Worker allocation and scheduling problems are considered as the final workforce management decisions. They have been widely published in today's research with strong focuses on mathematical models. Meanwhile, there are prior activities in worker selection stage that has been still neglected in those study areas. In managerial viewpoint, the workforce management stage derived from the relevant literature is presented in Figure 1, consisting of selection, grouping and allocation. Each stage is connected by supporting the effective decision-making to another. In this paper, worker selection stage is only focused to response the question of "how to effectively select" worker with respect to their capabilities in the operational level of labor-intensive manufacturing. The most challenging goal of all organizations is to select the effective methods of ranking a group of workers with the different competencies (Güngör et al., 2009). It is evident that worker selection management plays a key role in achieving success of an organization through worker performance. To select workers, a proper performance evaluation process is required to identify strengths and weaknesses of each worker (Rani et al., 2014). Worker performance evaluation is considered as a critical operation in labor-intensive manufacturing since it strongly impacts the productivity gain.



Figure 1: Workforce management stage

From the literature review, a few studies on worker selection in labor-intensive manufacturing are found. Most attention has been devoted to the capital-intensive industry which machine is a major resource in operations and worker skill is not seriously considered. Güngör et al. (2009) proposed a

worker selection system based on Fuzzy Analytic Hierarchy Process (FAHP) to achieve the best qualified worker dealing with both qualitative and quantitative selection criteria. The criteria are built-up into three main categories, general work factors, complimentary work factors, and individual factors. Majazi and Zhu (2005) presented a worker selection with a consideration of worker evaluation (grading) using an application of Fuzzy Set Theory (FST). The selection criteria are defined, expertise, skill, age, health, and availability. Similarly, Şen and Çınar (2010) used a combined fuzzy AHP and max-min approach to deal with worker selection based on worker's individual performance. The powerful criteria were determined by reaching consensus from manufacturing experts, it resulted in five main criteria, competency, experience, personal characteristics, assemble capability, and control capability. An actual application in an electronic industry is also studied. On the other hand, Rani *et al.* (2014) studied the performance evaluation based on six main criteria derived from previous literature, i.e. competency, experience and skill, teamwork and time punctuality, personal characteristics, capability, and outcome. The six different ranking methods were presented and applied in a food processing industry. It is found that output criterion is the most important factor in selecting worker. Furthermore, they revealed that AHP is the suitable method to evaluate worker performance from a case study of the real manufacturing environment. They presented worker performance evaluation and ranking method by comparing six different multi-criteria decision making methods include Analytical Hierarchy Process (AHP), fuzzy AHP (FAHP), ELECTRE, PROMETHEE II, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and ViseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR). From this point, AHP is selected as an effective multi-criteria decision-making (MCDM) tool. Consequently, AHP is used in weighting and prioritization of the important worker selection criteria in labor-intensive manufacturing in this paper.

Analytical Hierarchy Process (AHP)

It is developed by Saaty (Saaty, 1980) which has found wide range of applications in today's studies and industry area. AHP is a simple tool to deal with complex, unstructured and multi-attributed problems using a hierarchical structure and utilizes pairwise comparisons. A core issue to influence the final decision choice in AHP is prioritization of the reciprocal matrix (Yuen, 2010). Furthermore, modeling the problem and identifying the decision hierarchy is the key factor in using AHP. In multi-criteria analysis, AHP is suggested as a tool for implementing a multiple criteria performance scheme (Güngör *et al.*, 2009). In AHP, verbal judgments are provided by decision makers, to be used in pairwise comparison, the reciprocal matrices are transformed from linguistic labels to numerical values (Yuen, 2010). The primary steps of AHP are provided as follows (Rani *et al.*, 2014; Bhushan and Rai, 2004):

Step 1: Form a hierarchy consisting of the overall objective at the top, criteria, sub-criteria, and the alternatives at subsequent level of the hierarchy.

Step 2: Construct the pairwise comparison matrix based on Saaty's intensity importance table (as shown in Table1). The table is used by decision maker to prioritize the criteria, sub-criteria and decision alternatives within each sub-criterion.

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favour one activity over another
5	Strong importance	Experience and judgement strongly favour one activity over another
7	Very strong or demonstrated importance	An activity is favoured very strongly over another. Its dominance demonstrated in practice.
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between adjacent scale values	

Table 1: Intensity of importance (Saaty, 2008)

Step 3: The principal eigenvalue and the corresponding normalised right eigenvector of the comparison matrix give the relative importance of the various criteria being compared. The elements of the normalised eigenvector are termed weights with respect to the criteria or sub-criteria and ratings with respect to the alternatives.

Step 4: The consistency of the matrix of order n is evaluated. Comparisons made by this method are subjective and the AHP tolerates inconsistency through the amount of redundancy in the approach. If this consistency index fails to reach a required level then answers to comparisons may be re-examined. The consistency index, CI, is calculated as $CI = (\lambda_{max} - n)/(n - 1)$ where λ_{max} is the maximum eigenvalue of the judgement matrix. This CI can be compared with that of a random matrix,

RI. The ratio derived, CURI, is termed the consistency ratio, CR. Saaty (1980) suggested the value of CR should be less than 0.1.

Step 5: The rating of each alternative is multiplied by the weights of the sub-criteria and aggregated to get local ratings with respect to each criterion. The local ratings are then multiplied by the weights of the criteria and aggregated to get global ratings.

The AHP produces weight values for each alternative based on the judged importance of one alternative over another with respect to a common criterion. The prioritized criterion relies on the content of a pairwise comparison matrix which is used in worker performance evaluation regarding to its importance weight.

Proposed Methodology

The methodology in this paper is primarily carried out into three parts, (1) input/tools, (2) methodology and, (3) output which is illustrated in Figure 2. The study is introduced with the identification of worker selection criteria derived from previous literature and industry viewpoint. The important criteria are validated in the context of labor-intensive environment that considers workforce as a major resource of the entire system. After all selection criteria are validated, it is weighted and prioritized using AHP as a multi-criteria decision-making (MCDM) tool. Each criteria is individually weighted from the intensity of importance shown in Table 1 (Saaty, 2008), with the scale of 1 to 9 judged by an expert from labor-intensive manufacturing. This step contributes the important weights of each selection criteria which is used in worker performance evaluation. This paper examines worker performance evaluation with respect to the important weights of each criteria determined by AHP, the individual performance score of worker on all dimensions is assumed, given n equals 10 workers. Next, worker selection rules are then built-up using experiences to generate the worker selection model which can be effectively used.



Figure 2: Steps of proposed methodology

Data Collection

To propose workforce management decision models in worker selection stage drawn from the academic standpoint to the real manufacturing standpoint, data collection is organized into two sections:

(1) *Primary data* refers to the data that highly relies on the real manufacturing practice. An expert who was frequently involved in worker-related activities in labor-intensive industry, is investigated, using an in-depth interview as a research tool to intensely draw worker selection practice from the real industry setting, which includes the following elements:

- Manufacturing nature
- Worker selection criteria
- Worker ranking method
- Impacts of worker skills
- Worker selection rules

(2) *Secondary data* refers to the data from previous studies on workforce management which consists of worker skills, worker performance evaluation, and worker selection model, in the context of labor-intensive manufacturing nature.

The summary of worker selection criteria derived from previous studies and industry viewpoint, is presented in Figure 3. The criteria are hierarchically structured. Main criteria are at the first level and sub-criteria are at subsequent level.

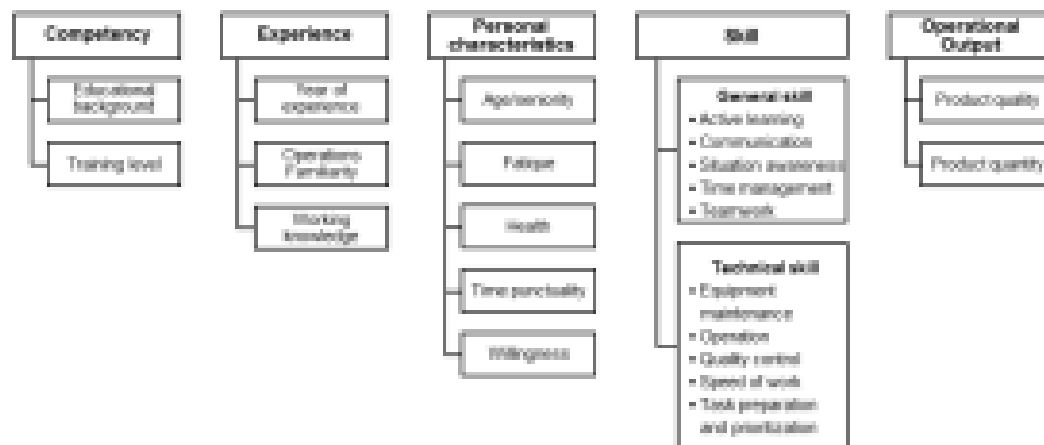


Figure 3: Worker selection criteria structure

Figure 3 illustrates the structure of worker selection criteria in the context of labor-intensive manufacturing. Both qualitative and quantitative criteria are defined to be individually considered in worker performance evaluation process. The hierarchical structure of selection criteria consists of five main criteria; namely competency, experience, personal characteristics, skill, and operational output formed as the first level of hierarchy. The main criteria are branched into sub-criteria which are in level 2 and 3. Descriptions of each criteria are provided in the following.

- **Competency** – It pertains to work mainly on the basis of educational background and previous job training achievements. There are two sub-criteria related to competency; namely educational background and training level.

- **Experience** – with the level of experience, the working performance can be predicted. As working basis, the operational performance of workers with high experience level can be quickly enhanced and compared to the lower ones. Three related criteria is taken into account; namely year of experience, operations familiarity, and working knowledge.

- **Personal characteristics** – They primarily introduce the individual qualifications in attitude, mind-set, and personal goal setting. Five criteria is associated with personal characteristics; namely age/seniority, fatigue, health, time punctuality, and willingness.

- **Skill** – Worker skills play a great role in the environment of labor-intensive manufacturing. It directly creates the enhancement on operational performance to achieve a sustainable manufacturing. In this paper, skill is categorized into two types, general skill and technical skill, where general skill is divided into five sub-criteria (level 3); namely active learning, communication, situation awareness, time management, and teamwork/cooperation. Similarly, the technical skill consists of five sub-criteria (level 3); namely equipment maintenance/repairing, operation and control, quality control, speed of work, and task preparation and prioritization.

- **Operational output** – According to the natures of labor-intensive manufacturing, the operational output which transforms from raw material to final products is the most important goal to be achieved for all organizations. The operational output represents how well the manufacturing is managed on cost reduction and service level improvements. Two sub-criteria is considered; namely product quality and product quantity.

In worker selection practice, the selection rules are needed to be determined. The selection rules here refer to the rules that were published by the organization, to determine the acceptance level of worker performance. A worker will be selected only if his/her performance complies with all selection rules. This paper investigates worker selection rules from a manufacturing expert in labor-intensive area, given in the following;

Rule 1: Competency performance of a selected worker must be equal or greater than 70%

Rule 2: Experience performance of a selected worker must be equal or greater than 80%

Rule 3: Personal characteristics performance of a selected worker must be equal or greater than 70%

Rule 4: Skill performance of a selected worker must be equal or greater than 80%

Rule 5: Operational output performance of a selected worker must be equal or greater than 80%

Rule 6: Overall performance of a selected worker must be equal or greater than 80%

AHP Model of Worker Selection Criteria

According to the proposed methodology, AHP is presented as MCDM to weight and set priorities for each worker selection criteria. The preliminary steps are organized as follows: (1) all selection criteria used for worker performance evaluation process are identified, (2) worker selection criteria is structured into AHP hierarchy, (3) each criterion is weighted by using the intensity of importance from Table 1 which includes the numerical values from 1 to 9. In this step, the pairwise comparison matrix is used, and (4) the importance weights computed from the eigenvector of the comparison matrix that is determined with respect to the consistency ratio. Traditionally, there are many ways to process data, including by hand, spreadsheet program, or the specialized AHP software. Regarding to worker selection problem from many criteria, this paper uses the specialized AHP software called Super Decisions to process the data. Super Decisions developed by Thomas Saaty is a decision making software based on AHP. Priorities are derived through pairwise comparisons on the criteria of the problem. The structure of AHP is illustrated in Figure 4.

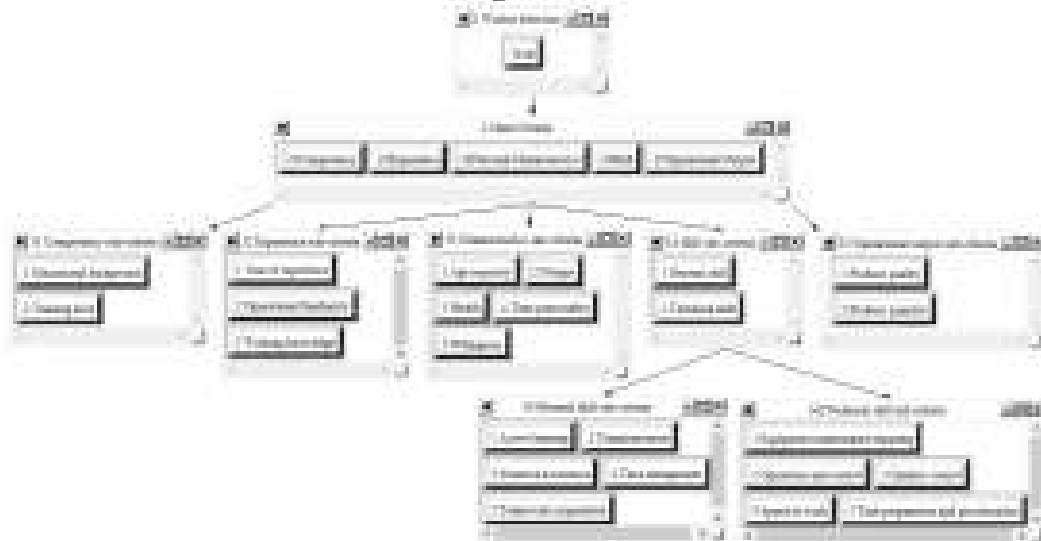


Figure 4: AHP model of worker selection criteria

The AHP model shown in Figure 4 is structured into hierarchy with four levels, worker selection is set as goal in the first level, followed by five main criteria in the second level, sub-criteria of each main criterion are constructed in the third level, and sub-criteria of general skill and technical skill are in the fourth level.

Computational Results of AHP Model

After the hierarchy structure of AHP model is constructed, the importance weight of each criterion is then calculated following the AHP steps explained in the previous section. The computational result of AHP model is shown in Table 2.

Worker selection criteria	Importance weight	Worker selection criteria	Importance weight
Competency	0.060	Skill	0.210
Educational background	0.143	General skill	0.167
Training level	0.857	Active learning	0.204
Experience	0.474	Communication	0.190
Year of experience	0.140	Situation awareness	0.206
Operational familiarity	0.526	Time management	0.179
Working knowledge	0.333	Teamwork/cooperation	0.221
Personal Characteristics	0.636	Technical skill	0.633
Appetibility	0.031	Equipment maintenance/repairing	0.033
Fatigue	0.631	Operation and control	0.309
Health	0.207	Quality control	0.236
Time punctuality	0.071	Speed of work	0.305
Willingness	0.061	Task preparation and prioritization	0.067
		Operational Output	0.201
		Product quality	0.667
		Product quantity	0.333

Table 2: The importance weight of each criterion from AHP model

The results reveal that experience is the most important criteria in worker selection with the importance weight of 47.14%, in the context of labor-intensive manufacturing industry. The second rank is drawn by skill at 20.98% which is quite close to the operational output at 20.06%. The third and fourth ranks are competency at 8.03%, and personal characteristics at 3.79%, respectively. However, in the skill aspect, *technical skill* at 83.33% is considered to be more important than *general skill* at 16.67%.

Next, the performance of each worker is evaluated with respect to the determined importance weights. Figure 5 illustrates the worker selection rules model. Lines in the radar chart represent worker performances ($n = 10$). For example, the competency performance of worker 1 is calculated using the equation below:

$$P_{W1, \text{competency}} = [(0.143 \times S_{c1}) + (0.857 \times S_{c2})]$$

Where $W1$ stands for worker 1, S_{c1} is score of criteria 1, and S_{c2} is score of criteria 2. The performance of each worker is computed by multiplying raw score of each criterion with its importance weights show in Table 2. After all worker performance is individually evaluated, the worker is ranked and selected with respect to the determined selection rules of the organization, as afore-mentioned. From Figure 5, the lines within the selection rules line represent workers with unsatisfied performance. In this example, worker 1, worker 3, worker 4, worker 5, worker 7, and worker 9 are only selected, but the rest of them are rejected.

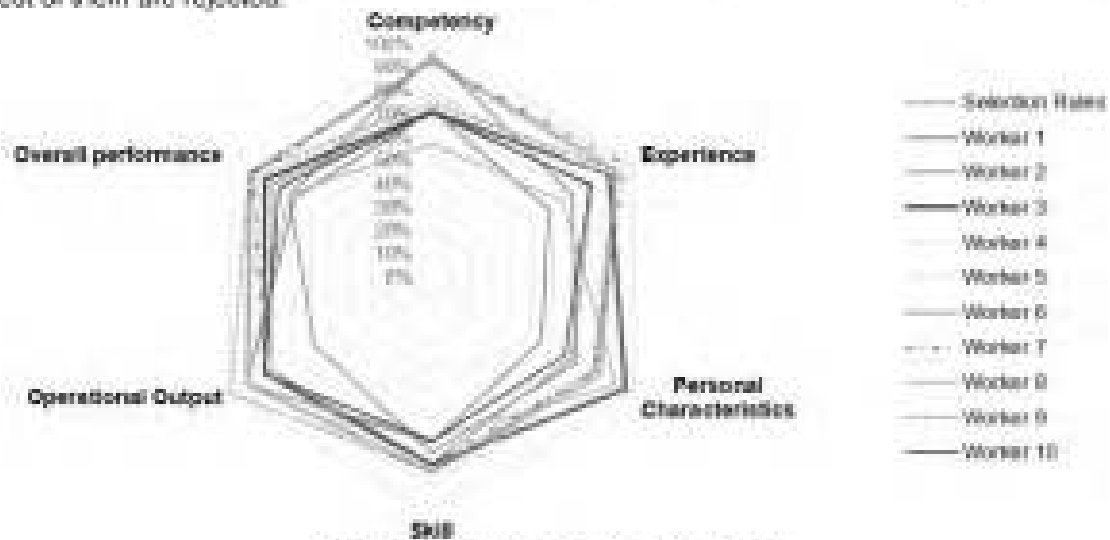


Figure 5: Worker selection rules model

This paper aims to contribute this worker selection practice to be applied in a wide range of the industry sector, especially in labor-intensive environment. Hence, the Overall Worker Performance (OWP) equation of a worker is originated as an effective worker selection tool for general use.

$$\begin{aligned} \text{Overall Worker Performance (OWP)} &= (W_{\text{competency}} \times S_c) + (W_{\text{experience}} \times S_e) + (W_{\text{personal characteristics}} \times S_p) + \\ &\quad (W_{\text{skill}} \times S_s) + (W_{\text{operational output}} \times S_o) \\ &= (0.080 \times S_c) + (0.471 \times S_e) + (0.038 \times S_p) + (0.210 \times S_s) + \\ &\quad (0.201 \times S_o) \end{aligned}$$

Where W stands for the importance weight; S_c is score of competency, S_e is score of experience, S_p is score of personal characteristics, S_s is score of skill, and S_o is score of operational output.

Conclusions

In worker selection management, it is evident from the computational results of AHP model which reveals that experience is the most important criterion in worker selection practice. In labor-intensive manufacturing, it can be concluded that worker experience in terms of year of experience, operational familiarity, and working knowledge plays an important role in all worker-related operations. The skill and operational output criteria are followed as the subsequent important criteria which should be also taken into account in worker selection practice. For competency and personal characteristics criteria, it is not considered as the powerful factor in labor-intensive environment. However, the performance index is developed and named the overall worker performance (OWP) by previous equation. It is able

to be applied in a wide range of industry sector with respect to the determined importance weights that represent different priorities of each factor and satisfy the organization natures. As extension of the current study, comparing the proposed method with other well-known multi-criteria decision making methods is suggested. Furthermore, in the context of manufacturing viewpoint, there is a significant relevance within experience, skill, and operational output. The crossed relationship of the proposed criteria could be considered in the future research.

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Admission Criteria

Admission to the program will be based on the following admission criteria established by the university's guidelines:

Master's degree requirement

Applicants must hold a Master's degree in business.

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Applicants must attend an interview. During the interview, students will discuss the requirements of the program.

Research Proposal

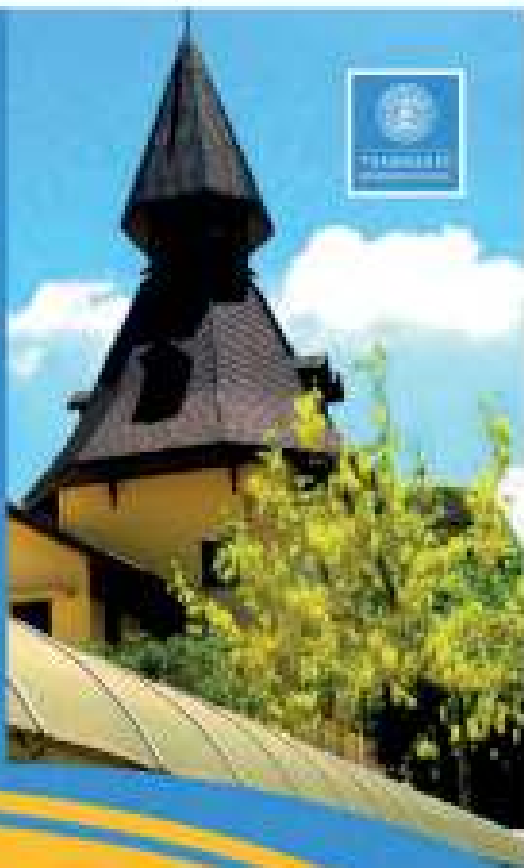
Along with the research proposal, the student has to submit a research proposal in word or pdf format with the MSJ committee members. The committee will evaluate the submission and will accept the student into the program.

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1. A 4-year college or university degree of 120 credit hours (120 semester hours) or degree holder of 120 credit of the local area or 1 year on the equivalent one.
2. A 2-year college or university degree or degree holder of 60 credit hours or 60 credit of the local area or 1 year on the equivalent one.
3. Two letters of recommendation.
4. A statement of intent to pursue a Ph.D. degree.
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Tuition Fees and Expenses

Costs vary greatly and are approximately \$1000 per semester.



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