Integrating workers’ differences into workforce planning

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Abstract

In today’s competitive market, manufacturers need to work hard towards improving their production system performance in order to satisfy customer demands. In such a situation, most companies develop production systems that can help in quality improvement, cost reduction and throughput time reduction. In this research, we consider a workforce planning (WP) model including some human aspects such as skills, training, and workers’ personalities and motivation. A multi-objective non-linear programming model is developed in order to minimize the hiring, firing, training and overtime costs and minimize the number of fired most productive workers. The purpose is to determine the number of workers for each worker type, the number of workers trained, and the number of overtime hours. Moreover, a decision support system (DSS) based on the proposed model is introduced using the Excel-LINGO software interfacing feature. The results indicate that the proposed model can provide a promising workforce planning approach to easily apply it in practice.

1. Introduction

Effective production planning processes are essential for success in manufacturing operations. Production plans are developed in order to produce the right amount of products at the right time so that the production time and costs are minimized or the contribution to profit is maximized. Production planning is the process of determining how much production will occur in the next planning horizon in order to satisfy demand. It determines expected inventory and workforce levels, and other resource requirements. Most manufacturing planning systems are becoming more complex in order to improve the productivity and the flexibility of the production operations. Managers in a production system can make different types of decisions that depend on the planning horizon. There are three types of planning horizons: long, medium, and short. A long-term planning horizon, or strategic planning, has a long-range impact on the direction of the production system. It covers a horizon of year to decades. The decisions made by top management might involve capacity, product, supplier needs and quality policy. A medium-term planning covers a period from week to one year. It gives more detailed decisions than the strategic decisions. Determining workforce levels, production rates, projected inventory levels, outsourcing and subcontracting and quality costs are examples of the tactical decision made by the middle management. Finally, a short-term planning horizon, or operational planning, covers any period from 1 h to 1 week and it involves the allocation of jobs to machines as well as parts movement on the shop floor (Hopp & Spearman, 2008). Most managers find that existing production planning models are not being implemented in real life (Byrne & Bakir, 1999). A major problem with existing models is the lack of information about the actual situation on the shop floor regarding the condition of the workers and the uncertainties inherent in the production system. As one of the main elements in production planning, human issues cannot be ignored without considerably reducing benefits of the production system. The advantages derived from integrating human factors with production systems have been discussed (Porter & Lawler, 1968; Udo & Ebiefung, 1999). In highly competitive companies, integration of human aspects with production planning helps to increase productivity, reduce throughput times, and improve product quality. These findings present a significant research opportunity.

Workforce planning determines what workforce is needed to support production. It ensures having the right people at the right place at the right time to meet the company’s employment needs. This includes planning for hiring new workers, firing extra workers, and training existing workers. In this paper, a new model for workforce planning to support production planning is developed to help make the implementation of the plan much easier in practice. Also, a decision support system (DSS) is developed to aid managers with the practical implementation of the model.

The paper is organized as follows: Section 2 presents a literature review of human factors and their relation to production planning. Section 3 discusses the proposed workforce planning model. Next, Section 4 presents the preliminary results generated from the proposed model. Finally, conclusions and future research directions are presented in Section 5.
2. Literature review

The International Ergonomics Association (IEA) has defined human factors as understanding of interactions among humans and other elements of a system in order to optimize human well-being and overall system performance (IEA Council, 2000). During the last decades, human factors are often considered too late in the production system development process, making most business decisions hard to change (Helander, 1999; Jensen, 2002; Neumann & Medbo, 2009). There are specific challenges in integrating human issues into production planning because people differ from one another. In reality, there is a tremendous variability in individual capabilities. Buzzacott (2002) studied the impact of worker differences on the production system since individual differences can result in substantial loss in throughput. Previous literature on workforce management has addressed various issues such as personality dimensions and worker differences and how much performance improvement can be gained (Barrick & Mount, 1991; Hunter, 1986; Hunter, Schmidt, & Judiesch, 1990; Kanfer & Ackerman, 2000; Ragotte, 1990; Wirojanagud, Gel, Fowler, & Cardy, 2007). Penney, David, and Witt (2011) presented a comprehensive review that study the relationships between personality and job performance and provided directions for future research. Human performance is the accomplishment of a task by a human operator. Jones (1993) presented a model that highlights the four components of job performance a manager controls. These components are selection such as skills, and personality, training, courses such as people, machines, policies and finally motivation. People with high personality levels will be more motivated to perform well because they are confident they have the ability to do their job (Bono & Judge, 2003). Personality is a major force behind individual differences in behavioral tendencies. It influences job performance by determining whether an individual has a natural inclination for job duties whether a physical or cognitive job. It can be used by human resource professionals to evaluate job applicants and predict job performance (Rothstein & Goffin, 2006). Motivation is generally the most accepted mediator of personality dimensions and job performance relationship (Erez & Judge, 2001). Hackman and Oldham (1976) proposed a model that studies the interaction among three variables which affect the job design: personal psychological state, jobs characteristics, and individual's attributes that determine his response for a challenging work. General cognitive ability (GCA), defined as the ability to process information, was used to model individual differences to predict job performance in all jobs (Hunt, 1986). Kroemer, Kroemer, and Kroemer-Elbert (2001) mentioned that many attributes, conditions, and reactions affect the person's performance. Examples of these factors are task type, task quantity, task environment, person’s capability and attitude.

Many theoretical frameworks relating human factors and performance have been developed (Bonney, Head, Ratchev, & Moualek, 2000; Dahn & Laughey, 1997; Lewin, 1935; Miller & Swain, 1987; Torizuka, 2001). Many existing frameworks are quite general in nature. Recently, a theoretical framework for modeling human performance has been developed by Baines et al. (2005). The framework identifies the 30 key human factors and performance measures for worker behavior based on four criteria: general relevance, specific relevance, robustness and measurability. These factors provide a comprehensive picture of the factors that are to influence a worker performing production planning activities. The key factors are divided into two categories: personal factors and environmental factors. The personal factors are divided into four major categories: cognition, personality, work attitude and biographic such as age, gender, and marital status, which can be easily obtained from personnel records. Schmidt and Hunter (1998) mentioned that cognitive ability and experience (or opportunity to learn) are the most valid predictors of job performance. They conducted empirical research about the validity of various individual measures for predicting future job performance. Similarly, they found that personality, biographic data and job knowledge has been used in theories of job development. However, personality traits (e.g. conscientiousness) can lead to higher job knowledge which causes higher levels of job performance (Barrick & Mount, 1991; Hurtz & Donovan, 2000; Salgado, 2002; Tett, Jackson, & Rothstein, 1991). Personality can be defined as the sum of physical, mental, emotional, and social characteristics possessed by a person that uniquely influences his cognitions, motivations, and performance in any environment. On the other hand, there are some limitations on the previous research. Firstly, individual factors' correlations have not been studied well. Also, some factors have been ignored, such as lifestyle and adaptability because they are difficult to measure or they do not affect manufacturing system performance. On the other hand, the environmental factors can be the organizational factors such as shift patterns, training, and job rotation and the physical characteristics of the workstation such as noise, ventilation and lighting levels. Research studies indicate that certain environmental factors beyond the employee's control play a stronger role in influencing his or her job performance (Porter & Lawler, 1968).

There is a small body of approaches that have been proposed for solving the workforce planning problem taking into account individual differences. Wirojanagud et al. (2007) developed a mixed integer programming model that considers worker differences in workforce planning. They used the general cognitive ability metric to model individual difference in efficacy of cross-training and worker productivity. Thompson and Goodale (2006) developed a non-linear workforce schedule that considers different productivity levels for each worker group. In their model, a new representation of the staffing problem that captures the non-linear nature is included. They found that incorporating workers productivity differences into workforce scheduling problem generates more realistic results. Aryannejad, Deljoo, and Mirzapour Al-e-hashem (2009) developed a mathematical model to deal with a simultaneous dynamic cell formation and worker assignment problem. They discussed the importance of incorporating the human issues into traditional dynamic cell formation. In their model, they considered some human issues such as hiring and firing workers, training, salary and workers’ skills. Norman, Tharmmapornphilas, Needy, Bidanda, and Warner (2002) proposed an MIP model for assigning workers to manufacturing cells in order to maximize the profit. The model considered both technical skills and human skills. Results indicate that the model provides better worker assignments than the one considering only technical skill. Azizi, Zolfaghari, and Liang (2010) presented a methodology for job rotation taking account of learning, forgetting and boredom. Billionnet (1999) formulated the problem of scheduling a workforce assignment with different levels of worker qualifications in order to minimize labor costs. As far as the authors are aware, incorporating human factors such as personality, skills, training and motivation together into workforce planning had not been previously discussed in the literature. The literature on production planning models that consider the human aspects was also surveyed. It was found that many quantitative models on aggregate planning, master scheduling and material planning including optimization, heuristics, and simulation have been developed (Campbell & Diaby, 2002; Chu, 1995; Jain & Palekar, 2005; Jamalnia & Soukhakian, 2009; Lee, 1990; Leung & Chan, 2009; Mazzola, Neebe, & Rump, 1998; Nam & Logendran, 1992; Pradenas, Penailli, & Ferland, 2004; Torabi, Ebadian, & Tanha, 2010; Wang & Liang, 2004, 2005). There have been many interesting developments on the technical side of planning and
control, but, all of these models ignored most, if not all, of the important human factors that can be critical for production planning performance. This provides the motivation to work towards developing a more comprehensive model that includes manufacturing and human parameters. This paper attempts to incorporate worker differences to workforce planning and assignment by modeling individual differences explicitly.

On the other hand, Blumberg and Pringle (1982) proposed a model that can link between worker motivation and productive performance. In their paper, they suggested that expected work performance of individuals is determined by three factors:

1. **Capacity:** the ability to perform a mental or physical task based on skill, age, health, knowledge, energy level, strength and intelligence.
2. **Opportunity:** factor beyond a person’s control, such as tools and material availability, working conditions, policies and payment rules.
3. **Willingness:** the inclination to perform a task affected by attitude, personality, task characteristics, job status and feeling of equity.

However, the strength of motivation formula is not in its exactness but in its structure. Riggs (1987) suggested ways for quantifying the factors that model the motivation formula on a zero-to-one scale. Previous research supported the modeling approach of individual differences (Waldman & Spangler, 1989). In this paper, we will adapt their theoretical model for measuring the expected performance of the workers. The three factors are rated on a zero-to-one scale in order to apply their formula in our model. We used interval scale method to measure the three factors. The first step is to define the criterion. This is done by identifying the ideal state that can best satisfy the criterion. First, one of the objective metrics that can be used to measure the capacity is: endurance: low endurance level (0–33.3rd percentile), medium endurance level (33.4th–66.6th percentile), and high endurance level (66.7th–100th percentile). Second, one of the metrics that can be used to measure the willingness is: personality level zones: low personality level (0–33.3rd percentile), medium personality level (33.4th–66.6th percentile), and high personality level (66.7th –100th percentile). Third, one of the metrics that can be used to measure the opportunity is: working conditions such as noise level, and ventilation: low working environment level (0–33.3rd percentile), medium working environment level (33.4th–66.6th percentile), and high working environment level (66.7th–100th percentile). The test should be applied many times for the same worker and working environment to calculate the average values. The ideal state is defined by recognizing the superior personal abilities or working conditions that fits the machine level and set to be 1. Next, the least desirable state is identified and set to be 0. Any worker can be tested and compared by the best and worst situation. If the worker is very close to the perfect number, the rating may be 0.95. However, special structured questionnaires can be developed and validated for use in applied research settings to quantify the personality domains. Each worker has at least one skill or personal level and can be assigned to certain machine levels. In each period, workers can be trained in order to improve only their skill level. In many cases, training is better than hiring and firing new workers. It is assumed that the training period is zero, which means that the worker is productive as soon as he is trained. Layoffs are never easy and do incur a human cost. When the company has a high percentage of layoffs, the loyalty to the company will be decreased. Also, most companies use labor laws and contracts to control the firing of workers. However, hiring new workers affects the performance of the present workers because they need to be trained to the same level of the previous fired workers.

On the other hand, performance measures quantitatively tell us something important about products and services that organizations produce them. They are a tool to help us understand, manage, and improve what companies do. They can be represented by single dimensional units like hours, dollars, number of errors, number of CPR-certified employees, etc. In this paper, two performance measures are used to evaluate the generated workforce plan. The first one is to minimize the total costs resulted from the hiring, firing and training, and over time in dollars unit. The second one is used to minimize of the number of top performance workers fired. Ultimately, the number of top performers fired should be close to zero. Costs and workforce layoffs can be critical in production planning efficiency. However, in order to satisfy the total demand of each period, we are interested in determining:

### 3. Model description

We consider a job shop environment consisting of different machines types, which are grouped into several machine levels depending on their complexity. We assume that we have three machine levels; machine level one is the less complicated one and machine level three is the more complicated level. Several products are produced on different machine types based on the products’ routing sheet. Worker flexibility has been considered in order to reduce the manufacturing system variability. It can be achieved by using overtime and training. Workers are grouped according to different human skills and personalities. Various personal traits can make up a human being. They are the endowments of human character (personality traits). They are grouped within the categories of an individual’s: miscellaneous attributes and skills. If, for example, a worker wants to improve his skills, training can be used. Worker skills include communication skills, leadership skills, listening skills, management skills, planning skills, problem-solving skills, teamwork skills, and technical work skills. However, personal attributes include worker calm, clear thoughts, constructive, creative, dynamic, educated, efficient, energetic, focused, healthy, intelligent, integrity, knowledgeable, organized, previous success in work, relationship with others, responsible, seek improvement, and strong. However, due to difficulty in measuring some of the subjective personal attributes, we divided the skill levels and the personal levels into three levels: level 1 indicates the lowest level, level 2 indicates the middle level, and level 3 indicates the highest level. In this paper, personality levels are measured based on percentile scores. Level 1 indicates the range from 0 to 33.3th percentile, level 2 indicates the range from 33.4th to 66.6th percentile, and level 3 indicates the range from 66.7 to 100th percentile. For example, people with high scores on conscientiousness tend to be responsible, organized and mindful of details, whereas people with low scores on openness tend to have less curiosity and more traditional interests. However, people with similar characteristics are grouped into personality levels, which reduce the variability of considering individual personality profiles. Special self-report questionnaires can be developed and validated for use in applied research settings to quantify the personality domains. Each worker has at least one skill or personal level and can be assigned to certain machine levels. In each period, workers can be trained in order to improve only their skill level. In many cases, training is better than hiring and firing new workers. It is assumed that the training period is zero, which means that the worker is productive as soon as he is trained. Layoffs are never easy and do incur a human cost. When the company has a high percentage of layoffs, the loyalty to the company will be decreased. Also, most companies use labor laws and contracts to control the firing of workers. However, hiring new workers affects the performance of the present workers because they need to be trained to the same level of the previous fired workers.

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3.2. Mathematical modeling

3.1. Assumptions

1. The values of all parameters are certain over the planning horizon.
2. The cost of hiring, firing and training workers is known and deterministic for each skill level and personal capabilities.
3. The availability of all workers is assumed to be equal to 80% by considering daily breaks.
4. The number of worker skill levels is equal to the number of machine levels.
5. Capacity and willingness of the workers are increased as their skills and personalities levels increased.
6. The top performance workers have skill and personality levels greater than or equal to 2.

3.2. Mathematical modeling

The model developed is a multi-objectives non-linear programming model that allows a number of different staffing decisions (e.g., hire, train, fire and overtime) in order to minimize the sum of hiring, firing, training and overtime costs and minimize the top performance workers fired over all periods. In presenting the model, the following notations are used.

Indices:

- \( t \) Index of planning periods (weeks), \( t = 1, 2, \ldots, T \)
- \( j, k \) Indices of human skill levels, \( j, k = 1, 2, \ldots, S \)
- \( x, y \) Indices of machine levels, \( X, Y = 1, 2, \ldots, M_L \)
- \( p \) Index of personality attributes, \( p = 1, 2, \ldots, P \)

Parameters:

- \( h_{ipt} \) Cost of hiring a \( p \)-level worker with skill level \( j \) in period \( t \) ($/worker-week)
- \( f_{ipt} \) Cost of lay-off of a \( p \)-level worker with skill level \( j \) in period \( t \) ($/worker-week)
- \( tr_{kpt} \) Cost of training a \( p \)-level worker from skill level \( k \) to skill level \( j \) in period \( t \) ($/worker-week)
- \( so_{ipt} \) Hourly rate of a \( p \)-level worker with skill level \( j \) at overtime in period \( t \) ($/worker-hour)
- \( A_yt \) Average regular working hours of a worker with skill level \( j \) for each person in each period \( t \) (worker-hours/worker-week)
- \( AOT_yt \) Overtime working hours of a worker with skill level \( j \) for each person in each period \( t \) (worker-hours/worker-week)
- \( C_{ipt} \) Capacity of a \( p \)-level worker with skill level \( j \) for each person in each period \( t \) (worker-hours/worker-week)
- \( O_{cx} \) Opportunity to work on machine level \( x \) in each period \( t \)
- \( R_{iptx} \) Readiness (willingness) of \( p \)-level workers with skill level \( j \) to work on machine level \( x \) in period \( t \)
- \( D_M \) Demand for skill \( j \) in period \( t \) (worker-weeks)
- \( SSky \) \( \begin{cases} 1 & \text{if training from skill level } k \text{ to skill level } j \text{ is possible;} \\ 0 & \text{otherwise.} \end{cases} \)
- \( WSky \) \( \begin{cases} 1 & \text{if working on machine level } x \text{ with skill level } j \text{ is possible;} \\ 0 & \text{otherwise.} \end{cases} \)

Goal 1: minimize:

\[
Z_1 = \sum_{t=1}^{T} \sum_{p=1}^{P} \sum_{j=1}^{S} \sum_{k=1}^{M_L} \left( h_{ipt} \times H_{iptx} + f_{ipt} \times L_{iptx} + so_{ipt} \times OT_{iptx} \right) + \sum_{p=1}^{P} \sum_{j=1}^{S} \sum_{k=1}^{M_L} \sum_{l=1}^{S} \left( tr_{kptx} \times Y_{kptyx} \right)
\]

Goal 2: minimize:

\[
Z_2 = \sum_{t=1}^{T} \sum_{p=2}^{P} \sum_{j=1}^{S} \sum_{x=1}^{M_L} L_{iptx}
\]

Subject to:

\[
0.8 \times A_yt \times \left( \sum_{p=1}^{P} \sum_{j=1}^{S} \sum_{x=1}^{M_L} C_{iptx} \times O_{cx} \times R_{iptx} \times W_{iptx} \right) + \sum_{p=1}^{P} \sum_{j=1}^{S} \sum_{k=1}^{M_L} \sum_{l=1}^{S} \left( tr_{kptx} \times Y_{kptyx} \right) \leq AO_{iptx} \times W_{iptx} \quad \forall j, p, t, x
\]

\[
L_{iptx} \leq M \times W_{iptx} \quad \forall j, p, t, x
\]

\[
H_{iptx} \leq M \times W_{iptx} \quad \forall j, p, t, x
\]

\[
Y_{kptyx} \leq M \times SS_{ky} \quad \forall j, k, p, t, x, y
\]

\[
Y_{kptyx} \leq M \times WS_{ky} \quad \forall j, k, p, t, x, y
\]

\[
\sum_{k=1}^{S} Y_{kptyx} \times L_{iptx} = 0 \quad \forall j, p, t, x, y
\]

\[
H_{iptx} \times L_{iptx} = 0 \quad \forall j, p, t, x
\]

\[
W_{iptx}, H_{iptx}, L_{iptx}, Y_{kptyx} \geq 0 \quad \forall j, k, p, t, x, y
\]
The objective function aims to minimize all costs incurred workers hiring and firing, training costs and overtime costs and minimize the top performers laid-offs. Constraint (1) shows the total available worker hours is equal to the number of hours required for each skill in each period. Constraint (2) guarantees that the available workforce in any period equals workforce in the previous period plus the change of workforce in the current period. Constraint (3) ensures that the overtime workforce available should be less than the maximum overtime workforce available in each period. Constraint (4) ensures that the total number of workers who are assigned to machine level \( x \) in period \( t - 1 \) and now fired or trained for upper skill levels should not be greater than the number of workers required in previous period. Constraint (5) ensures that workers can be fired if and only if the assignment is possible. Constraint (6) denotes that workers can be hired if and only if the previous assignment is possible. Constraint (7) training for better skills is possible if and only if the previous assignment is possible. Constraint (8) ensures that training for better skills is possible if and only if the latter assignment is possible. Constraint (9) ensures that training for better skills is possible if and only if training to that skill is possible. Constraint (10) guarantees the workers who are trained for skill level \( j \) should not be fired in the same period. This constraint contains a non-linear formula that can be transformed to a linear term with the help of a binary variable as follows:

\[
\sum_{k=1}^{S} Y_{gpxj} \leq M \times Z_{gpx} \quad \forall j, p, t, x, y
\]  
(13)

\[
L_{gpx} \leq M(1 - Z_{gpx}) \quad \forall j, p, t, x
\]  
(14)

\[
Z_{gpx} \in \{0, 1\} \quad \forall j, p, t, x
\]  
(15)

Constraint (11) ensures that either hiring or firing workers occurs but not both. Also, this constraint has a non-linear formula that can be transformed into linear one in the same way as the previous constraint, as follows:

\[
H_{gpx} \leq M \times U_{fjtx} \quad \forall j, p, t, x
\]  
(16)

\[
L_{gpx} \leq M(1 - U_{fjtx}) \quad \forall j, p, t, x
\]  
(17)

\[
U_{fjtx} \in \{0, 1\} \quad \forall j, p, t, x
\]  
(18)

Finally, Constraint (12) is the non-negativity constraint.

Goal programming can be used to solve the multi-objective functions. In this paper, the non-preemptive method (weighted method) is used to solve the problem. The decision maker must determine penalty weights that reflect his preferences regarding the relative importance of each goal. For example, penalty weights equal to 1 signify that all goals carry equal weights. The solution procedure considers one goal at a time, starting with the costs minimization goal, and terminating with the number of top performers fired minimization goal. The process is carried out such that the solution obtained from the first goal never degrades the second goal solutions. Weighted goal programming considers all goals simultaneously within a composite objective function comprising the sum of all deviational variables of the goals from their targets (Hillier & Lieberman, 2010). The following steps can be used to handle multi-objective functions:

1. Define the LP1 as the first linear programming model with objective function \( Z_1 \) and LP2 is the second linear programming model with objective function \( Z_2 \).
2. Identify the goals of the model and rank them in order of priority: priority 1: minimize total costs (\( Z_1 \)), priority 2: minimize the number of top performers fired (\( Z_2 \)).
4. Computational results

To illustrate the model proposed in this paper and assess the effect of workers' differences on total costs and workforce plan, a simple example is presented in this section. Insights on the effect of workers' differences on total costs and workforce plan, a numerical example.


4.1. Numerical example

A company produces its products to fulfill known demand along an 8-week planning horizon. The hiring, firing and training costs are assumed to be higher for higher skill and personal levels. Also, it is assumed that the worker is available for 40 h (160 h per month) at regular time and he is available for 10 h a week (40 h per month) at overtime. However, it is assumed that a worker is not productive during daily breaks that are assumed to last for a minute of program running.

Results from the proposed model are shown in Table 8. In this paper, many human factors such as workers' training, skills, abilities and 3634 constraints and the optimal solution for the problem can be easily obtained using LINGO 10 software in less than a minute of program running. Results from the proposed model are shown in Table 8. In this paper, many human factors such as workers' training, skills, abilities and 3634 constraints and the optimal solution for the problem can be easily obtained using LINGO 10 software in less than a minute of program running.

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overtime, workers’ availabilities, workers’ capacities, workers’ personalities and workers’ motivation are considered to show the importance of including these factors at the early planning stages. However, the results from the model offer staffing decisions on what, how and when to hire, fire and train. Also, the number of worker-hours during regular time and overtime is determined. The results show that hiring, firing and training of workers are varied between all personality levels depending on hiring, firing or training costs and performance levels. It is generally assumed that workers are identical. This research shows that workers performance can be used to model workers’ differences and to predict hiring, firing and training workers. Table 8 shows the number of workers hired, fired and trained in each period for different personality level. From the table, it can be seen that most of the workers hired and trained have high personality level. Also, the number of fired workers is increased as the performance decreased. Thus, performance is a critical factor in hiring, layoff and training decisions. However, if the prioritization of the goals and initial settings are modified, the results are likely to be different. For example, when the company first goal is to reduce the number of top performers fired, we can see that the workers who are motivated are increased by 2.7%, which represents the normal scenario in practice.

Table 8
Resulting workforce plan.

<table>
<thead>
<tr>
<th>Demand (workers)</th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W4</th>
<th>W5</th>
<th>W6</th>
<th>W7</th>
<th>W8</th>
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<td>100</td>
<td>65</td>
<td>100</td>
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Worker skill 1

<table>
<thead>
<tr>
<th>P1</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Workers used on level 1</td>
<td>32.7</td>
<td>14</td>
<td>14</td>
<td>4.7</td>
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4.2. Insights on worker differences effects

In the previous section, a simple numerical example is given to illustrate the performance of the model. In this section, the same example is used to study the effects of human factors and other important model parameters on workforce decisions. These factors are personality levels, worker capacity, motivation, initial number of workers, and training and hiring cost.

Most (if not all) previous models do not consider human differences in workforce planning. However, considering human differences those exist between workers results in more effective and accurate workforce decisions. In this experiment, it is assumed that there is no information about human differences, and costs of hiring, firing, and training the workers are set to be the average costs used in the previous example. Two different scenarios are considered: the first one represents the case where the workers’ performance is the same, and the second one represents the case where their performance is different. Fig. 1 shows the comparisons between the two scenarios regarding workforce decisions. The total cost when workers’ differences are not considered at all is $6,508,165 while in scenario 2, in which we consider workers’ differences, the total cost is $6,076,735. These differences in total costs between the two scenarios are due to the differences in labor, hiring, firing, and training costs and performance. The results show that by considering worker differences in the model and by comparing the scenario 1 with scenario 2, there is a cost reduction of 7.1%. However, if the manager decides to change the costs the results will be changed. Moreover, if the initial number of workers is changed, the number of hired, fired or trained workers is changed which will change the total costs.

On the other hand, Fig. 1a shows the resulting workforce plan generated by scenario 1. It can be seen from the plan in scenario 1 most of the hired workers has low level of personality and less motivated. Also, some top performers are fired in period 4. However, this plan is generated based on the input data that is estimated by the researcher without considering human differences which may give inaccurate results. Moreover, Fig. 1b shows the resulting workforce plan generated by scenario 2. In this scenario, there are more training options from lower skills to the upper skills, and most trained workers have high personal and skill levels. Therefore, most of the new workers who are hired have personal levels greater than 2. Also, the majority of the fired workers have low levels of personality.

This experiment shows that if the workforce planning model considers human factors such as personality and worker capacity, and worker motivation, we may be able to make better decisions regarding production and employees. For instance, by using a plan that considers the worker’s skills and personality, the decision of assigning the right worker to a right machine level will be made without need to modify the scheduling process every period so that the total cost and time will be reduced. Thus, the workforce plan highly depends on several parameters such as initial number of workers, worker personality and salary and training costs, which affect decision making.

4.3. Decision support system

We now present a decision support system to solve this problem based on the Linear Programming solver LINGO 10. First, a system user has to enter the historical demand in each period e.g. eight periods. Then, hiring, firing, training costs, regular and overtime salaries, and the estimated human attributes, as shown in Fig. 2. This effect of these switches is that we change the constraints in the actual LINGO model. Also, it is important that the user starts to solve the problem with a first priority goal and then solve the other problem to identify the values of the objective functions that the company wants to achieve. Then, he can solve the combined problem by assigning weights to the coefficients of the deviations based on the company concern.

However, it can be cumbersome and impractical to try to maintain workforce data in a LINGO model file. For this reason, LINGO program is linked to Excel through real-time Object Linking and Embedding (OLE) feature. OLE automation links can be used to drive LINGO from Excel macros, and embedded OLE links that allow you to import the functionality of LINGO into Excel. However, the computerized DSS presented herein makes the model an extremely useful problem solving tool for managers. The system has been designed to have an efficient interface with Excel, so the user can import input data directly from the organization’s database and export the output of the model to other database in the organization.

In order to solve any given problem, the user has to go through three phases. During the first phase, the user enters the necessary input data for solving model, such as hiring, firing, training costs, regular and overtime salaries, and the estimated human attributes, as shown in Fig. 2. This can be done through a user form designed for a user convenience. The entered data is stored directly in an Excel worksheet to be used as an input section for the LINGO program. In the second stage, the user can add or remove some options such as training and overtime from the original model by assigning 0 or 1 to each one, as shown in Fig. 3. The switches options provide the manager the advantage of conducting the what-if type of analyses to determine if the solutions are sensitive to different parameter values of a given problem. In the third stage, he needs to assign different weights to each goal based on the company policies and rules and then solve the model to generate the results that show how many workers hired, fired or trained for...
each personal level in each period. The results help the user to evaluate and compare various alternatives and decisions by considering different human aspects in a workforce planning problem. Finally, interfacing the LINGO model with Excel provides an efficient methodology to store a huge number of input data so that the proposed DSS can solve very large problems.

For practicing managers without the necessary mathematical knowledge on workforce planning models, finding an analytical solution to the proposed model can be quite challenging. However, the computerized DSS presented herein makes the model a useful problem-solving tool for such managers. The purpose of the DSS is to help managers, the intended users, obtain “the best solution” for a given problem without having to familiarize themselves with the mathematical complexities associated with the model. These findings provide motivation towards making the proposed model represent the current production systems in industrial companies.

4.4. Discussion

The results of this study are significant in a number of respects. Foremost among these was the use of theoretical frameworks proposed by Baines et al. (2005), Blumberg and Pringle (1982) and
Jones (1993) to identify the most important human factors that affect the workforce planning process. In contrast to prior research that has relied exclusively on ignoring workers' differences, this approach allowed us to address incorporating personality factor to decide what is the best scenario for hiring, firing and training workers to satisfy a company's goals and without changing their rules. Second, the results indicate that worker differences should be considered in workforce planning to generate realistic plans with minimum costs. Thus, we have shown that incorporating worker differences in the planning process reduces the total costs.

Third, unlike most prior studies of workforce planning, the current study suggests ways to quantify the intangible human factors that are difficult to measure. Finally, this paper investigates the effects of human performance and motivation on the workforce scheduling process. Human performance is a critical factor in hiring, layoff and training decisions. This model helps to find ways for keeping the workers based on their motivation and performance. Despite these strengths, a number of features of the current work also limit the conclusions that can be drawn from these results. First, although the model seems to provide reasonable results, the input data are assumed and generated based on the authors' experience and opinions. A second limitation of the current study is all the human factors parameters and total demand are assumed to be certain and known, which may generate unrealistic results. A third limitation is that this model ignores many human factors that can affect the planning process. Some of these factors are communication, experience, learning and forgetting process. Although we did not study the relationships between human factors, we provided them as an aggregate number representing a group of workers having similar characteristics. Until further research clarifies the direction of these relationships and effects, causal statements can only be made with caution.

It is clear that research on workforce planning has not come to an end, and the path is still open to make the proposed model more comprehensive and more realistic. It may consider other human factors such as learning curves and experience which can be a promising area of work for future research. However, learning curve effects should be considered in formulating the model. In assembly activities that require more manual work, it has been observed that production time decreases as workers learn more about their work and how to perform it, and their experience increases. Also, refining the proposed model to consider worker experience would be another approach to integrate human related aspects into production planning. For example, labor wages can be a function of time and experience which reflects the current system that management uses in different companies. Finally, future research might consider the development of an interactive DSS that will help managers to solve the model in the context of uncertainty of demand and costs parameters.

5. Conclusions

In this paper, a new approach for integrating workers' differences with workforce planning is proposed. A model is used to test configurations and evaluate their effects on the organizations' goals. This model can take into account the human aspects to plan the workforce of any company so that the customers' satisfaction will be achieved with minimum cost. Also, two examples are given to test the influence of worker's differences on the planning process. The importance of this research is its contribution to the production planning problem by incorporating the human aspects as being an integral part of the production system to represent the real situation inside the organizations. Furthermore, this research will provide the company's management with a clear understanding of how to integrate the human factors into production planning for better performance of production systems.

A workforce planning model has been developed in order to concentrate on human issues in production planning. The model allows a number of different staffing decisions (e.g. hire, train, fire, and overtime) in order to minimize the sum of hiring, firing, training and overtime costs and minimize the top performers fired over all periods. Human issues such as worker skill, training, breaks, vacations, availability, capacity, motivation, and personality are considered.

Specific contributions of this paper include: developing a workforce planning model that considers workers' differences, workers' training, workers' skills, workers' availabilities, workers' capacities, workers' motivation and workers' personalities. Also, the working levels and possibility of workers training and upgrading are considered. The results show that costs and workers' personalities have a significant effect on the selection of the workers with different skill ability. In addition, a decision support system is presented to bridge the gap between the theory and practice of workforce planning models.

In conclusion, the research has demonstrated the importance of considering human factors early in the planning process of manufacturing systems. It is one of the attempts to bridge the gap between the theory and practice of production planning models. By considering the technical and human factors, the proposed model can be used as a tool to support real world decision-making processes in a manufacturing system.

References


