PLANNING ANNUALISED HOURS WITH FULLY VARIABLE HOLIDAY WEEKS

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***Abstract**: Seasonal demand for staff in service industry can be met using a labour contract with annualised hours (AH). Under AH, annual contracted hours are irregularly distributed per year. This paper proposes a Mixed Integer Linear Programming (MILP) model to solve an annualised working hours planning problem in which workers are assumed to be cross-trained, and the weekly working hours must belong to a previously agreed finite set. Which weeks will be the holiday weeks is a decision variable in this model. That is, worker's holiday weeks are fully variable and the nature of demand has an impact in the determination of holiday weeks. The number of holiday weeks is same for all. Illustrative example shows that this model provides reduced relative capacity shortage compared to the individualised holiday weeks. In an AH problem with individualised holiday weeks, the holiday weeks for a worker is determined in consultation with the worker.*

Keywords: Manpower planning, Annualised hours, Seasonal demand, Mixed integer linear programming

Sub theme- Human Resource Flexibility

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1. Introduction

Manpower constitutes the most critical resource of any enterprise. One of the reasons for this is that it directly affects available production capacity. So, proper manpower planning is crucial for any type of organisation. Manpower planning is the process which includes forecasting, developing and controlling by which an industry ensures the right number of people and the right kind of people at the proper places, at the proper time, for doing work for which they are economically most useful. It helps in avoiding the sudden interruption of production of an enterprise since, it displays shortage of particular types of personnel well in advance thus enabling management to adopt suitable strategies to cope with the situation. By anticipating the need for various types of skill requirements and levels of personnel, a manpower plan will be able to provide appropriate action for recruitment, selection and training of such persons.

Some industries face seasonal demand pattern of manpower. In situation where the demand fluctuates, the manpower planning is, obviously, a hectic task. Employers may find difficulty to tackle this type of demand pattern when constant workforces with regular hours are fixed. The problem with this pattern of manpower requirement is that in slack times people are underutilized, costing money without adding value. Manning for peaks, on the other hand, attracts unwanted costs in terms of premium overtime rates or employing temporary staff.

But, there is a method to face seasonal demand. The concept is called annualised hours. It is a type of flexible working in which averaging working time across a year so that employees work a given number of hours over 12 months rather than a specified number of hours a week. The weekly working hours fluctuate with the demand pattern. During busy period they may have to work more and on the other hand in slack period they need to work less. The hours, which the employee has to execute, will be decided in advance and it can vary on a daily, weekly or monthly basis. Thus, annualised hours (AH) allows employer to vary workforce availability according to the demand level without incurring much overtime or without employing temporary workers.

The major advantage of annualising working hours is the reduced cost in comparison to other options. By using AH, costs due to a lack of capacity can be diminished and in some cases eliminated. A reduction in the use of temporary workers can also lead to an improvement in productivity and in the quality of the product or service. Furthermore, the service level can be improved, since demand can be covered on time and the competitiveness can be sustained with respect to the manpower.

A consensus between the relevant social partners may be required to amend the established norm for regulating working time and the introduction of AH scheme. It may be implemented in an individual enterprise/establishment/site level. The implementation is possible through agreements between management and labour unions. The management should not consider the implementation of such schemes as their prerogative. Irrespective of the way of implementation, this scheme could be considered as a potential means for achieving greater flexibility in manpower utilisation (Kouzis and Kretsos, 2003).

However, AH often may leads to some inconvenience to the worker (because of the irregular schedule), and this makes it necessary to solve the complex working time planning problem. To reduce the negative effects on the workers, the annualising of working time has to be negotiated and may be followed by some sort of compensation or incentive: additional holidays, financial compensation, etc. At the same time, legal constraints or conditions from a collective bargaining agreement must be taken into account (Kouzis and Kretsos, 2003).

In the annualised hours scenario, the annualised hours are determined as shown below. Consider a person who is working on an average of 35-hour per week with an annual leave of 7 weeks and it is assumed that a year consists of 52 weeks. Total number of working weeks (52-7) = 45weeks. Now, the annual hours for a worker = 45 weeks ×35 hours per week = 1,575 hours. Here, the average weekly working hours are fixed as per the rules prevailing in the respective countries. Holiday weeks are always associated with annualised hours. The number of holiday weeks for every worker will be same. Flexibility in capacity can further be achieved by properly distributing the holiday weeks in the planning horizon.

AH planning has been implemented and found successful in many organisations. Rhodia and Tesco (Workforce logistics, 2007; MacMeeking 1995) are examples for this. Rhodia Consumer Specialities introduced the annualised hours for staff scheduling and the benefits claimed are that the consumer complaints fell by 25% and the service standard improved substantially. The results of implementation at 'TESCO' showed that after the introduction of AH, the stock levels have been reduced to a large extent. Different ways of planning AH scheme are available in literature. For example, AH planning is done with a finite set of weekly working hours and Mixed Integer Linear Programming (MILP) method (Corominas et al., 2004, 2007; Lusa et al., 2008; Sureshkumar and Pillai, 2009) in which the weekly working hours are taken from the finite set. For instance, if the total number of working week is 46, it can be divided as: 15 weeks with 25 hours, 21 weeks with 35 hours, and 10 weeks with 50 hours. So, the total number of working week = 15+21+10 = 46 and the weekly working hours is from the set {25, 35, 50}. AH planning is always associated with

holiday weeks. The holiday weeks can be either individualised holiday weeks (Corominas et al., 2004, 2007; Lusa et al., 2008) in which all the holiday weeks are decided after discussion with workers or partially individualised holiday weeks (Sureshkumar and Pillai, 2009), in which part of the holiday weeks are decided after discussing with the workers and the remaining weeks are taken as variable. The annualised hours planning is also applied where the facility operates in shifts (Hung, 1999a, 1999b; Hert et al., 2010). The policy of annualised hours planning has got good response from the business community. For example, in France the introduction of 35-hour working week maintained on an average within weekly limits, usually over a 12-month reference period has increased the interest of the people to this technique (Grabot and Letouzey, 2000).

As explained earlier, certain number of weeks can be availed as holiday weeks for workers. The fixing of these holiday weeks can be done in different ways. One way of fixing is by prior consultation with the workers and the holiday weeks are decided according to that. This is known as individualised holiday weeks. In this method the general practice is that the holiday weeks are provided in two periods of the planning horizon. In one period the workers can avail two consecutive holiday weeks and in the other period the workers can take four consecutive holiday weeks (Corominas et al., 2007). This method of fixing holiday weeks is considered as employee friendly.

Another method of fixing the holiday weeks is purely based on the demand situation. In this type of holiday weeks the employee's preferences will not be considered. This type of assignment of holiday weeks is known as variable holiday weeks. If all the holiday weeks are assigned without considering the employee's preferences, it is termed as fully variable holiday weeks. These holiday weeks are the decision variables of a mathematical program and on solving the program the holiday weeks are identified. This paper considers the situation of fully variable holiday week for minimising the objective function which is the weighted sum of maximum relative capacity shortages and sum of weekly relative capacity shortage, where the relative capacity shortage is the capacity shortage with respect to the required capacity (explained in Section 2). Then, the result is compared with the situation of individualised holiday weeks. It can be found that the objective function value is less in the case of fully variable holiday weeks. That is, this method of assigning holiday week provides more flexibility in labour utilisation with respect to meeting the required capacity for management.

The layout of this paper is as follows: Section 2 describes the problem. The computational experiment is presented in Section 3. A discussion on the results is provided in

Section 4 and Section 5 gives conclusion. The mathematical model developed for fully variable holiday weeks and the model of individualised holiday weeks are given in Appendix 1 and 2, respectively.

2. Problem Description

Solving AH planning problem, where seasonal demand occurs, involves the determination of number of weekly working hours for each member of the workers for each non-holiday week in the planning horizon (a year, for instance). The objective of the model, in general, is to optimise the weighted sum of maximum relative capacity shortage and sum of weekly relative capacity shortages (Corominas et al., 2007). As the service level improves the customer satisfaction increases. The capacity of the organization is fixed as per the forecasted demand. If the required capacity is more than the actual capacity then the service level deteriorates and hence the customer satisfaction will be poor. If the relative capacity shortage, which is defined as the capacity shortage relative to the required capacity, is large then the demand cannot be met. On the other hand, if the capacity shortage is a small part of the required capacity then the workers can meet the demand with a small extra effort. That is, the demand will be met with slightly reduced service quality.

The maximum relative capacity shortage, which is to be minimised, can be considered as the objective function, thus optimising the service level. This function avoids large capacity shortages and tends to distribute capacity over the course of the year in a regular way. It minimises the maximum capacity shortage, however, it is not giving consideration to periods where capacity shortage is less than the maximum relative capacity shortage.

For obtaining a small capacity shortage in every week, a secondary objective function, which is the sum of relative capacity shortages, is considered. Now the objective function is defined as the weighted sum of these two functions. That is, the objective function minimises the weighted sum of two terms: (i) the maximum relative capacity shortage and (ii) the sum of weekly relative capacity shortages.

A scenario with constant workforce level is considered for AH planning. Usually, the planning horizon is a year (52 weeks). The planning horizon consists of working week and holiday weeks. The total holiday weeks for each worker in the organisation is usually constant and it is assumed as 7 weeks and the remaining 45 weeks will be the working weeks. But, the holiday weeks which will be distributed to the workers will be, purely, on the basis of demand. The workers are assumed to be cross trained and hence they are able to carry out different types of job (task) but, their efficiency for various types of job is not same.

Generally, a worker is known for a particular skill and a job where this skill required is carried out with 100% efficiency. Hence, his/her relative efficiency is considered as 1. For the other types of task his/her relative efficiency will be less than 1. A relative efficiency 0.9 means a worker can complete the task in 1/0.9 hours compared to a worker, with relative efficiency one, who requires one hour to do the job. It is assumed that the workers are recruited for different types of task, say, three types of task. Workers with relative efficiency one is recruited for each type of task. However, workers can be cross trained and hence can be used for other types of task also. The relative efficiency of this situation is given in Table 1. The other characteristics of the problem are given below:

1) The weekly working hours is taken from a finite set (e.g. 25, 35, 50 hours).
2) The average weekly working hours for a group of 12 consecutive weeks cannot be larger than 44 hours per week.
3) Total capacity in hours is same as the demand requirements. The number of workers is equal to the ratio of total forecasted demand hours to the annual working hour of a worker.
4) Hiring of temporary workers is not possible. Similarly, overtime is not permitted.
5) The demand is seasonal and the demand pattern is as shown in Figure 1.
6) According to the assumptions of the problem (that overtime and temporary workers are not permitted), the cost of the staff is the same for any feasible solution. Thus, capacity has to be distributed in order to optimise the service level.

Annualisation of this scenario is achieved through a Mixed Integer Linear Program (MILP) which is described in Appendix 1. Instead of annualised hours the requirement can be met with regular hours and overtime also, but it may be very expensive and in some cases not feasible due to legal constraints.

Table 1 Relative efficiency

	Task 1	Task 2	Task 3
Category 1	1	0.9	0
Category 2	0	1	0.9
Category 3	0	0	1

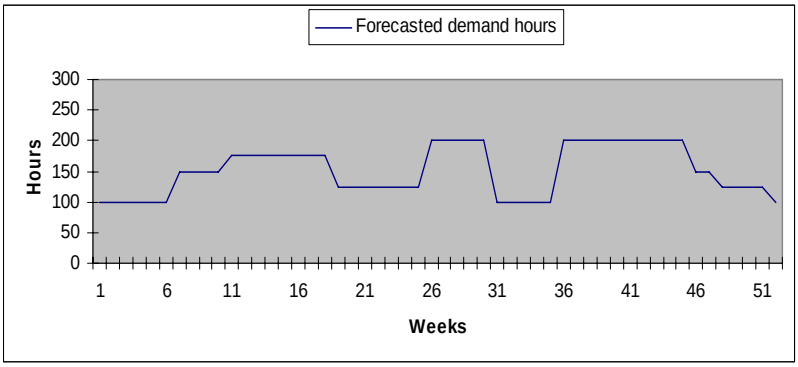

Fig. 1 General demand pattern for the problem described

3. Computational demonstration

A computational exercise is performed in order to evaluate the MILP model developed and to compare the results with the existing model which uses individualised holiday weeks. The problem is solved using LINGO 11 package and the results show that the model gives a better capacity shortage than the individualised holiday-weeks model. A few more data related to the problem which are not given in Section 2 are given below.

- The annual average of weekly working hours for the working weeks is taken as 35 hours.
- The demand follows a seasonal pattern as shown in Figure 1 and the total forecasted demand for this pattern is 7875 hours. The total number of staff required to meet this demand is 5.
- There are three types of working week for each worker. The number of hours in each type of working week and the number of weeks for each type of working week are as follows:
  - Type 1 – number of hours (H_1) = 25 hours and number of weeks (n_{i1}) = 15weeks
  - Type 2 – number of hours(H_2) = 35 hours and number of weeks (n_{i2}) = 20weeks
  - Type 3 – number of hours (H_3) = 50 hours and number of weeks (n_{i3}) = 10weeks

Results of the MILP model for a fully variable holiday weeks consist of type of working week assigned to each worker for each working week in the planning horizon and the holiday weeks. The same problem is solved using MILP model for individualised holiday weeks and the result consists of type of working week assigned to each worker for each working week in the planning horizon. In this case an additional data required as input is individualised holiday weeks which is given in Table 2.

Table 2 Individualised holiday weeks

Staff	Holiday Weeks
1	1, 2, 14, 15, 16, 17, 18.
2	3, 4, 19, 20, 21, 22, 23.
3	5, 6, 24, 25, 26, 27, 28.
4	7, 8, 14, 15, 16, 17, 18.
5	9, 10, 19, 20, 21, 22, 23.

Evaluation and comparison of both models are shown here. In this respect the results required are objective function value and total capacity shortage of both models. In addition the holiday weeks assigned by the MILP model with fully variable holiday week is also required for comparison. These details are provided in Tables 3 and 4. The difference in modelling for individualised holiday weeks compared to variable holiday weeks is given in Appendix 2.

Table 3 Capacity shortage and objective function value

Model Type	Objective function value	Total capacity shortage (hours)
Fully variable holiday weeks	0.0992	259
Individualised Holiday weeks	0.198	510

Table 4 Variable holiday weeks

Staff	Holiday weeks
1	20, 24, 35, 37, 46, 50, 51
2	3, 4, 14, 32, 36, 38, 41
3	2, 10, 22, 25, 33, 48, 49
4	4, 6, 23, 31, 32, 34,35
5	1, 2, 3, 5, 19, 33, 52

4. Results and Discussion

The results required for evaluation and comparison of different models are available in Tables 3 and 4. Table 4 shows the holiday weeks which is coming under variable holiday weeks. These holiday weeks are part of the solution of the problem. From this table it can be seen that total holiday weeks for each worker is same and it is equal to seven but the holiday weeks are spread out in the planning horizon. In this model the number of holiday weeks is set as equal to the number of holiday weeks of the individualised holiday-weeks model. Table 2 shows the individualised holiday weeks which is decided after consulting with workers. It is distributed in two periods; two consecutive holiday weeks in one period from week 1 to 10 and four consecutive holiday weeks in other period from 14 to 28. The input for the both

models are same except the difference that the individualised holiday weeks are input for one model but for the other the holiday weeks are decision variables. Table 3 shows that the fully variable holiday-weeks model is able to perform well with respect to the objective, and the total capacity shortage is less compared to the individualised holiday-weeks model. The total capacity shortage for individualised holiday-weeks model is 510 hours which is 96% higher than that of fully variable holiday weeks. That is, the fully variable holiday-weeks model is able to adjust with demand variation and hence the total capacity shortage is less. So, we can say that this model is giving better flexibility in utilising the manpower.

Figure 2 shows the profiles of the forecasted demand hours (required capacity), and assigned hours (actual capacity) considering the relative efficiency of the workers for different tasks for the fully variable holiday-weeks model. These details of individualised holiday-weeks model are shown in Figure 3. The capacity shortage is visible from these profiles. Figure 2 shows a better match of capacity with required capacity.

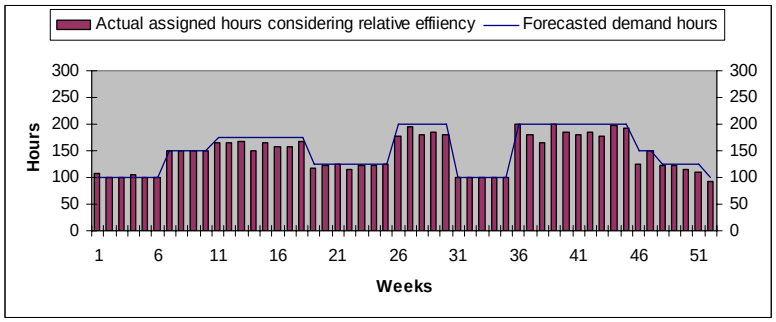

Fig. 2 The required capacity, actual capacity, and shortage profiles for variable holiday weeks

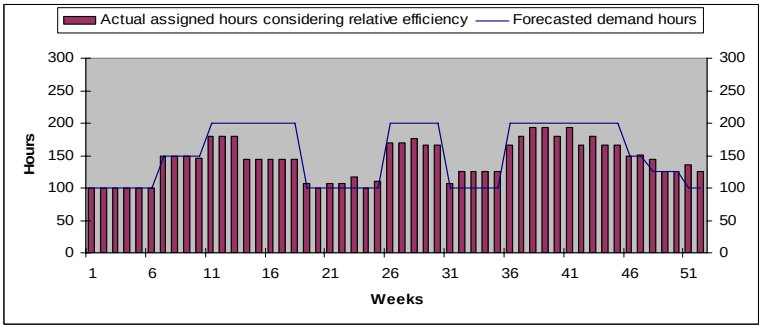

Fig. 3 The required capacity, actual capacity, and shortage profiles for individualised holiday weeks

5. Conclusion

The implementation of annualised hours scheme is a better option compared to other alternatives available for managing a seasonal demand pattern. This approach for manpower planning reduces the cost related to overtime, inventory, training, labour turnover, etc. An approach for AH implementation involve finite set of weekly working hours with a predetermined number of holiday weeks. Generally, the workers can decide the holiday weeks at the time of signing the contract agreement. However, the holiday weeks determined based on the demand requirement, instead of deciding it by the worker, will provide better response to demand variation. This is demonstrated in this paper with the help of a MILP model.

The annualised hours scheme with variable holiday weeks provides more flexibility for the management in manpower assignment and as a result the given capacity could be matched well with the seasonal demand. Hence capacity shortage is less. In an unpredictable demand situation the estimation of the demand is very uncertain. The modelling of AH scheme under such an environment is an area to be explored.

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Appendix 1: The MILP with variable holiday-weeks for AH planning

The mathematical formulation of the problem described in Section 2 is given below. The formulation is a Mixed Integer Linear Program (MILP). The problem parameters and the notations used are as follows:

W - Set of staff members
P - Number of weeks in the planning horizon
G - Set of categories of worker
T - Set of types of task
C_i - Category of worker i
τ_{gt} - Relative efficiency associated with category g workers in the accomplishment of a task of type t, $(\forall g \in G, \forall t \in T)$; $0 \le \tau_{gt} \le 1$. Efficiency $\tau_{gt} = 0$ indicates that category g workers are not able to perform type t task.
HP - Set of types of working week expressed working hours.
HP_K - The number of hours corresponding to working week type k, $k = 1,\ldots|HP|$
h_{ip} - Types of working week expressed in working hours, that worker i can perform during week p, $(\forall i \in W, \forall p \in P)$
n_{ik} - The total number of working hours over the year due to working week type k for the worker i, $(\forall i \in W, \forall k)$
L, h_L - The average number of working hours in a group of L consecutive weeks, which cannot be larger than h_L, (with L = 12 and h_L = 44 hours).
f_{tp} - Working hours required for type t task during week $p\,(\forall t \in T, p = 1 \cdots P)$ considering the time that a worker (with relative efficiency of 1) would need to complete the task, and it is fixed according to forecasted demand and the expected service level.

The decision variables are as follows:

y_{ikp} - Binary variable with value equal to 1 indicates whether worker i performs a working week of type k during week $p\,(\forall i \in W, p = 1 \cdots P)$.
a_{gtp} - Non-negative real variable that indicates the number of working hours that category g employees dedicate to task t during week $p\left(\forall g \in G, \quad \forall t \in T, p = 1 \ldots P \middle| \tau_{gt} > 0\right)$.
s_{tp} - Non-negative real variable that indicates the capacity shortage, that is to say, the forecasted need for task t that cannot be met by the staff during week $p\,(\forall t \in T, p = 1 \ldots P)$.
S - Non-negative real variable that indicates the maximum shortage, as related to the demand.

The weight parameter of the two terms of the objective function is α and β whose values are as follows:

$$\alpha = 0.99, \quad \beta = \frac{0.01}{P\ |T|}$$

Minimise

$$Z = \alpha\ S + \beta \sum_{\forall t \in T} \sum_{p=1}^{P} \frac{s_{tp}}{f_{tp}} \qquad \ldots \qquad (1)$$

Subjected to

$$S \geq \frac{s_{tp}}{f_{tp}} \qquad \forall t \in T, p = 1 \ldots\ldots P \qquad \ldots \qquad (2)$$

$$\sum_{\forall p} y_{ikp} = n_{ik}, \qquad \forall i \in W, \forall k \qquad \ldots \qquad (3)$$

$$\sum_{\forall k} y_{ikp} \leq 1 \quad \forall i \in W; \quad p = 1 \cdots P \qquad \ldots \qquad (4)$$

$$\sum_{(\forall g \in G)\,|\,(\tau_{gt} > 0)} \tau_{gt} a_{gtp} + s_{tp} \geq f_{tp} \qquad \forall t \in T,\ p = 1 \ldots P \qquad \ldots \qquad (5)$$

$$\sum_{\forall t \in T\,|\,(\tau_{gt} > 0)} a_{gtp} = \sum_{\forall i \in W\,|\,C_i = g} \sum_{\forall k} H_k \times y_{ikp}, \quad \forall g \in G, \quad p = 1 \ldots P \qquad \ldots \qquad (6)$$

$$\sum_{p=j-L+1}^{j} \sum_{\forall k} H_k\ y_{ikp} \leq h_L \times L \qquad \forall i \in W, \quad j = L \ldots P \qquad \ldots \qquad (7)$$

$$y_{ikp} = \{0,1\} \qquad \ldots \qquad (8)$$

$$a_{gtp}, s_{tp}, S \geq 0 \qquad \ldots \qquad (9)$$

The objective function (1) minimises the weighted sum of: (i) the maximum relative capacity shortage and (ii) the sum of weekly relative capacity shortages, with $\alpha, \beta > 0$;

The model is formulated based on the following constraints: (2) ensures effect of maximum relative capacity shortage; (3) assigns the required number of hours for each worker as stipulated in the contract; (4) allows to avail the total number of holiday weeks as stipulated in the contract; (5) demand requirements; (6) equalise the time allotted for all type of task in a week with the time assigned for a category of worker for the week; (7) ensures the contractual condition that the average time assigned over a consecutive L weeks is less than or equal to h_L, (8) and (9) are binary and nonnegative constraints respectively.

Appendix 2: The MILP with individualised holiday weeks for AH planning

The MILP model for AH planning under individualised holiday weeks differs from the model given in Appendix 1 with respect to the constraint (4) only and this constraint is modelled as given below.

$$\sum_{\forall k} y_{ikp} = v_{ip} \quad \forall i \in W; \quad p = 1 \cdots P \qquad \ldots \qquad (10)$$

Where

v_{ip} - Binary variable which has value zero for period p for the worker i, means the week p is a holiday week for worker i. $v_{ip} = \{0,1\};$