Time Table Scheduling for Educational Sector on an E-Governance Platform: A Solution from an Analytics Company

Vimal Kumar

Department of Management Studies Maulana Azad National Institute of Technology (MANIT) Bhopal- 462003, India (vimaljss91@gmail.com)

Ankita Malviya

Indian Space Research Organization (ISRO), India (ankita03.iitk@gmail.com)

Pratima Verma

Department of Industrial & Management Engineering, Indian Institute of Technology Kanpur, Kanpur, India (way2pratima@gmail.com)

Vignaesh Muthukumaar

Consultant, EXL Services, Bengaluru, India (vignaeshmk@gmail.com)

Sunil Kumar Jauhar

Department of Mechanical Engineering Maulana Azad National Institute of Technology, MANIT-462003, Bhopal, India (suniljauhar.iitr@gmail.com)

Nagendra Kumar Sharma

Department of Management Studies Maulana Azad National Institute of Technology (MANIT) Bhopal- 462003, India (nagendrasharmag@gmail.com)

Abstract:

Course timetabling is a multi-dimensional assignment problem which is the assignment of courses to faculty members, and then the assignment of these courses to time slots. Class scheduling, from the perspective of a school or a department, is a difficult problem. Typically, each course must be assigned an instructor, time slot(s) during the week, and a classroom. At any given time slot, at most one course can be assigned to an instructor and a room. The requirements and preferences of the instructors, estimated enrollment of students, and characteristics of the course must also be taken into account. The timetabling problem has become much more complex. This problem is solved based on many restrictions such as the period time, the available number of classrooms, capacity of the classrooms or number of seats in each, amount of the registered student and other restrictions from faculty members. Because of the reasons mentioned, a scheduler, a human decision-maker, consumes time to solve the problem. Furthermore, the assignment of the students to classrooms requires concerning the suitable number of students for the classroom since it may increase cost and waste opportunity for another appropriate classroom.

I. Introduction and Literature Review:

About the Organization (XYZ Company):

It is an organization into developing high-quality analytical products and services. It looks into the needs and places of data to be analyzed for better performances in any organizations and educational institutes including schools and colleges. It is founded by a group of researchers and practitioners from top-notch institutes such as IIT Kanpur and IISc Bengaluru. Its new analytical product of this company is a stride towards its objective.

The company is a maiden stride towards its vision; it is an analytical web-based solution aimed at redefining the ways educational institutions are managed. The application facilitates automation, monitoring, and analysis of different facets of an institute's operation. The embedded analytical capabilities generate insights which help to address the bottlenecks in achieving good governance, quality education, cost-effective operations, efficient time utilization and Revenue generation. The contemporary products in education domain are predominantly automation solutions which fail to address the above-mentioned factors critical to an educational institution success.

The main goals of the Company:

AUTOMATE: Automation leads to integration & synchronization of different facets of institute operations. It further helps in reducing workload, saving money and saving time.

MONITOR: Monitoring helps to keep continuous track of different operations based on Key Performance Indicators. It also checks and warns by performing a systematic review to keep things under controllable limits.

ANALYZE: Analysis involves detail examination and interpretation of data generated through different administrative and academic processes. It facilitates good governance, imparting quality education and improving revenue growth.

With the blooming growth of educational institutions, it has become challenging to remain productive and competitive as well as provide quality education, good governance, and costeffective operation. Thus the role of data-driven decision making from the data generated out of daily operations can be a game changer to grapple with these contemporary challenges. The company is a stride towards it. Mere automation of the institution fails to fully address the contemporary challenges. This company generates real-time analytical insights with key metrics for academic and administrative operations. It takes governance to the next level.

The optimization problem is the problem involving one or more decisions with restrictions. A goal or an objective is considered. The objective is represented by an objective function which identifies the function of the decision variables. The decision maker may want to either maximize or minimize the objective e.g. minimizing cost and maximize profit. The constraint is represented in a mathematical model, e.g. $f(x_1,x_2,...,x_n) \leq b$, $f(x_1,x_2,...,x_n) \geq b$. Linear programming (LP) involves an optimization problem with linear objective of goal that is aimed to optimize. b. Constraints or restrictions that are needed to satisfy, for example, a limited amount of raw materials or labors and c. Decision variables or the solutions, the non-negativity restrictions accounting for this requirement. Integer linear programming (ILP) is linear programming in which some or all the variables are restricted to an integer value. The Hungarian method is used to solve the assignment problem and performance of each of n persons on each of n jobs (Kuhn, 1955; Chopra et al., 2017). The following algorithm applies the above theorem to a

given $n \times n$ cost matrix to find an optimal assignment. (a). Subtract the smallest entry in each row from all the entries of its row. (b). Subtract the smallest entry in each column from all the entries of its column. (c). Draw lines through appropriate rows and columns so that all the zero entries of the cost matrix are covered and the minimum number of such lines is used and (d). Test for Optimality: (i) If the minimum number of covering lines is n, an optimal assignment of zeros is possible and we are finished. (ii) If the minimum number of covering lines is less than n, an optimal assignment of zeros is not yet possible. In that case, proceed to (e). (e). Determine the smallest entry not covered by any line. Subtract this entry from each uncovered row, and then add it to each covered column then return to (c). Hence an assignment matrix is obtained.

II. Problem Description:

The problem involves scheduling of timetable of classes in a school where common faculty members are assigned to these classes. There is more than one faculty for each subject and timetable is scheduled for classes with same subjects to be allotted. The first aim is to allocate these faculties (linked to a subject) to each class as to who teaches which class. And then timetable scheduling accordingly. There are a number of constraints to be followed while scheduling. Develop an algorithm for the same. The following requirements must be satisfied:

(a) A teacher cannot teach more than one class at the same time, i.e, a timetable cannot have an overlapping of teachers;

(b) A class cannot have a lesson with more than one teacher at the same period, i.e, a timetable cannot have an overlapping of classes;

(c) Each teacher must fulfill his/her weekly number of lessons; (d) a teacher cannot be scheduled for a period in which he/she is not available;

(e) A class cannot have more than two lessons a day with the same teacher.

A. Challenges:

In a general educational timetabling problem, a set of events (e.g. courses and exams, etc) are assigned into a certain number of timeslots (time periods) subject to a set of constraints, which often makes the problem very difficult to solve in real-world circumstances. In fact, large-scale timetables such as university timetables may need many hours of work spent by qualified people or team in order to produce high-quality timetables with optimal constraint satisfaction and optimization of timetable's objectives at the same time. These constraints are of two types Hard and Soft Constraints. Hard constraints include those constraints that cannot be violated while a timetable is being computed. For example, for a teacher to be scheduled for a timeslot, the teacher must be available for that time slot. A solution is acceptable only when no hard constraint is violated. On the other hand, soft constraints are those that are desired to be addressed in the solution as much as possible. For example, though importance is given to a teacher's scheduling, the focus is on setting a valid timetable and this can lead to a teacher going free for a time slot. Thus, while addressing the timetable and this can lead to a teacher going free for a time slot. Thus, while addressing the timetable problem, hard constraints have to be adhered, at the same time effort is made to satisfy as many soft constraints as possible.

Scheduling problems are challenging as there is no agreed technique for representing the problem or a solution as individuals. Scheduling problems belong to the class of combinatorial optimization problems. A combinatorial optimization problem is either a minimization or maximization problem and consists of a set of instances, a finite set of candidate solutions for each instance, and a function that assigns to each instance. These combinatorial optimization problems are solved by finding the optimal solution for each instance of the optimization

problem. These problems are NP-hard (Non-deterministic polynomial-time hardness) and hence neither there are polynomial time-complexity algorithms to solve them most efficiently (Knuth, 1974; Van Leeuwen, 1991; Akbalik et al., 2017). This implies, there must exist an element of approximation. There are different scheduling problems such as Job-Shop Scheduling Problem, Processor Scheduling Problem, and Timetable Scheduling Problem. Here in this paper, we have discussed the class timetable scheduling problem, which is the planning of allocating a number of subjects into a set of timeslots while respecting some other constraints.

III. Problem Approach & Solution:

Consider there are "t" teachers, total "s" subjects, "c" classes to be scheduled together, "n" number of periods in a day, "d" working days for a week, each teacher can teach maximum "mt" periods in a week and maximum "ms" classes of a subject to be held in a week. Firstly to solve this we allot which teacher teaches in which class first as we have multiple teachers for a single subject so we first go for Hungarian method for such an allotment. For better understanding, we take up a case and solve that further: Making a timetable for allotting 6 teachers, 3 subjects among 5 classes namely c1, c2, c3, c4, c5. Maximum no. of periods a teacher can teach is 30 and each subject should have 8 classes in a week.

- A- Mathematics teacher
- B- Mathematics teacher
- C- Science teacher
- D- Science teacher
- E- English teacher
- F- English teacher

The number of classes a teacher can be allotted is found by (mt/ms) here it turns out to be 3. For allotment a matrix is developed similar to a cost matrix in which rows and columns are as follows: Since A& B are mathematics teachers so in the slot for mathematics slot for each class we assign a small number say 0,1,2 depending on the choice of faculty for each class otherwise a large number here 5000. And so on.

	C1-	C2-	C3-	C4-	C5-	C1-	C2-	C3-	C4-	C5-	C1-	C2-	C3-	C4-	C5-	DUM	DUM	DUM
	MATHS	MATHS	MATHS	MATHS	MATHS	SCI	SCI	SCI	SCI	SCI	ENG	ENG	ENG	ENG	ENG	MY	MY	MY
Α	0	0	0	0	0	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Α	0	0	0	0	0	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Α	0	0	0	0	0	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
В	1	1	0	0	1	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
В	1	1	0	0	1	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
В	1	1	0	0	1	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
С	5000	5000	5000	5000	5000	0	1	1	0	0	5000	5000	5000	5000	5000	5000	5000	5000
С	5000	5000	5000	5000	5000	0	1	1	0	0	5000	5000	5000	5000	5000	5000	5000	5000
С	5000	5000	5000	5000	5000	0	1	1	0	0	5000	5000	5000	5000	5000	5000	5000	5000
D	5000	5000	5000	5000	5000	0	0	0	1	1	5000	5000	5000	5000	5000	5000	5000	5000
D	5000	5000	5000	5000	5000	0	0	0	1	1	5000	5000	5000	5000	5000	5000	5000	5000
D	5000	5000	5000	5000	5000	0	0	0	1	1	5000	5000	5000	5000	5000	5000	5000	5000
E	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	0	2	0	0	0	5000	5000	5000
Е	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	0	2	0	0	0	5000	5000	5000
E	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	0	2	0	0	0	5000	5000	5000
F	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	1	1	1	1	0	5000	5000	5000
F	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	1	1	1	1	0	5000	5000	5000
F	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	1	1	1	1	0	5000	5000	5000

The above matrix is solved using a Hungarian solving package "clue" in R programming software. The result of this turns out to be:

5 classes have been allotted one teacher each subject

- c-1- A(maths), C (science), E (eng)
- c-2- A(maths), D(sci), F (eng)
- c-3- B(maths), D(sci), E (eng)
- c-4- B(maths), C(sci), E(eng)
- c-5- A (maths), C(sci), F(eng)

There are 4 periods in a day. The next step is scheduling of the allotted subject-teacher to classes in a timetable. Mostly constraints are

- One teacher is allotted 1 class in a time slot on the same day.
- Total no. of classes of a particular subject should be 8 in a week
- Maximum 2 classes of the same subject can be held on a day.
- Total no of classes in a day should be 4
- Avoid multiple classes in a single time slot for a class
- All decision variables can take either value 1 or 0

The rows are such:

- A- Period 1
 - Period 2
 - Period 3
 - Period 4
- B- Period 1
 - Period 2

Period 3..... so on

The columns are:

- C1- Monday
- C1- Tuesday
- C1- Wednesday
- C1- Thursday
- C1- Friday
- C1- Saturday
- C2- Monday
- C2- Tuesday..... so on

It is developed as a maximization problem so at the cells where an allocation is to be done is filled with a large number say 5000, otherwise -1. The decision variables coefficient in the objective function is this matrix itself read column-wise. The optimization is done by R programming using integer programming method. The matrix is developed so that in programming the constraints and objective function it becomes easier and logical to implement in R. The numbers in the cells are nothing but objective function coefficient. The table shows that how the variables are numbered.

-																														
	C1 MON	C1 TUE	C1 WED	C1 TID	C1 FDI	C1 SAT	C2	C2	C2	C2	C2	C2	C3	C3	C3	C3	C3 EDI	C3	C4 MON	C4	C4	C4	C4	C4	C5 MON	C5	C5	C5	C5	C5
4.1	MON	IUL	WED		T KI	SAT	MON	IUE	WED		F KI	SAT	MON	IUL	WED		F KI	SAI	MON	IUL	WED		F KI	SAI	MON	IUE	WED		F KI	SAI
AI		0		0				0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	1		0	0		1
AZ	0	0	0	0	U	0	0	0	0	0	0	0	U	0	U	0	U	U	0	U	0	0	0	0	1	0	0	0	U	U
A3	0	1	0	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
A4	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
B1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	1	0	0	1	1	0	0	0	0	0	0
B2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
B3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
B4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
C1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
C2	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1
C3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0
C4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
D1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D2	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
D3	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D4	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
E2	1	0	Ô	Õ	Ő	ů	Ő	Ő	0	Ő	Ô	Ő	ů	1	1	ů	ů	Ő	ů	1	1	ů	ů.	Ô	ů	Ő	Ô	Ô	Ő	Ő
E3	1	Ő	Ő	Ő	1	1	Ő	Ő	Ő	Ő	Ő	Ő	Ő	0	0	Ő	Ť	1 1	Ő	0	0	Ő	Ť	Ť	Ő	Ő	Ő	Ő	Ő	Ő
E4	0	Ő	Ô	1	1	1	Ő	Ő	0	Ő	Ô	Ő	ů	Ő	Ő	1	1	1	ů O	Ő	ů	1	1	1		Ő	Ô	Ô	Ő	Ő
F1	0	0	Ő	0	0	0	ů 0	1	1	0	ů	Ô	0	0	ů N	0	0	0	Ő	ů 0	ů 0	0	0	0	0	0	1	ů	0	ů N
F2	0	Ő	Ő	Ő	Ő	Ő	1	0	1	Ő	Ő	Ő	0	Ő	Ő	Ő	Ő	Ő	Ő	Ő	0	Ő	Ő	Ő	Ő	1	1	Ő	0	Ő
F3	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	- J - 1
F3	0	0	0	0	0	0	0	0	0	1	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
r4	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1

The objective function matrix:

	C1	Cl	Cl	Cl	C1	C1	C2	C2	C2	C2	C2	C2	C3	C3	C3	C3	C3	C3	C4	C4	C4	C4	C4	C4	C5	C5	C5	C5	C5	C5
	MON	TUE	WED	THR	FRI	SAT	MON	TUE	WED	THR	FRI	SAT	MON	TUE	WED	THR	FRI	SAT	MON	TUE	WED	THR	FRI	SAT	MON	TUE	WED	THR	FRI	SAT
AI	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	5000	5000	5000	5000	5000	5000
A2	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	5000	5000	5000	5000	5000	5000
A3	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	5000	5000	5000	5000	5000	5000
A4	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	5000	5000	5000	5000	5000	5000
BI	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-l	-1	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	-1	-1	-1	-1	-1	-1
B2 D2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-l	-1	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	-1	-1	-1	-1	-1	-1
B3	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	-1	-1	-1	-1	-1	-1
B4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	-1	-1	-1	-1	-1	-1
CI	5000	5000	5000	5000	5000	5000	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
C2	5000	5000	5000	5000	5000	5000	-1	-1	-1	-1	-l	-1	-l	-1	-1	-1	-1	-1	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
<u>C3</u>	5000	5000	5000	5000	5000	5000	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
	<i></i>																		E 11111	5000	<i>E</i> 11111	<i>E</i> / M M M								
C4	5000	5000	5000	5000	5000	5000	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	5000	3000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
D1	-1	-1	-1	-1	-1	-1	-1 5000	-1 5000	-1 5000	-1 5000	-1 5000	-1 5000	-1 5000	-1 5000	-1 5000	-1 5000	-1 5000	-1 5000	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
D1 D2	-1 -1	-1 -1	-1 -1	-1 -1	-1 -1	-1 -1	-1 5000 5000	-1 5000 5000	-1 5000 5000	-1 5000 5000	-1 5000 5000	-1 5000 5000	-1 5000 5000	-1 5000 5000	-1 5000 5000	-1 5000 5000	-1 5000 5000	-1 5000 5000	-1 -1	-1 -1	-1 -1	-1 -1	-1 -1	-1	5000 -1 -1	-1 -1	5000 -1 -1	-1 -1	-1 -1	-1 -1
D1 D2 D3	-1 -1 -1	-1 -1 -1	-1 -1 -1	-1 -1 -1	-1 -1 -1	-1 -1 -1	-1 5000 5000 5000	-1 5000 5000 5000	-1 5000 5000 5000	-1 5000 5000 5000	-1 5000 5000 5000	-1 5000 5000 5000	-1 5000 5000 5000	-1 5000 5000 5000	-1 5000 5000 5000	-1 5000 5000 5000	-1 5000 5000 5000	-1 5000 5000 5000	-1 -1 -1	-1 -1 -1	-1 -1 -1	-1 -1 -1	-1 -1 -1	-1 -1 -1	5000 -1 -1 -1	-1 -1 -1	5000 -1 -1 -1	-1 -1 -1	5000 -1 -1 -1	-1 -1 -1
D1 D2 D3 D4	-1 -1 -1 -1 -1	-1 -1 -1 -1	-1 -1 -1 -1	5000 -1 -1 -1 -1	5000 -1 -1 -1 -1	5000 -1 -1 -1 -1	-1 5000 5000 5000 5000	-1 5000 5000 5000 5000	-1 5000 5000 5000 5000	-1 5000 5000 5000 5000	-1 5000 5000 5000 5000	-1 5000 5000 5000 5000	-1 5000 5000 5000 5000	-1 5000 5000 5000 5000	-1 5000 5000 5000 5000	-1 5000 5000 5000 5000	-1 5000 5000 5000 5000	-1 5000 5000 5000 5000	-1 -1 -1 -1	-1 -1 -1 -1	-1 -1 -1 -1 -1	-1 -1 -1 -1 -1	-1 -1 -1 -1	5000 -1 -1 -1 -1	5000 -1 -1 -1 -1	5000 -1 -1 -1 -1	5000 -1 -1 -1 -1	5000 -1 -1 -1 -1	5000 -1 -1 -1 -1	-1 -1 -1 -1
D1 D2 D3 D4 E1	-1 -1 -1 -1 -1 5000	-1 -1 -1 -1 5000	-1 -1 -1 -1 5000	-1 -1 -1 -1 5000	-1 -1 -1 -1 5000	-1 -1 -1 -1 5000	-1 5000 5000 5000 -1	-1 5000 5000 5000 -1	-1 5000 5000 5000 5000 -1	-1 5000 5000 5000 5000 -1	-1 5000 5000 5000 5000 -1	-1 5000 5000 5000 5000 -1	-1 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000	-1 -1 -1 -1 5000	-1 -1 -1 -1 5000	-1 -1 -1 -1 -1 5000	-1 -1 -1 -1 -1 5000	-1 -1 -1 -1 -1 5000	-1 -1 -1 -1 -1 5000	5000 -1 -1 -1 -1 -1 -1	-1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1	-1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1	-1 -1 -1 -1 -1 -1
C4 D1 D2 D3 D4 E1 E2	-1 -1 -1 -1 5000 5000	-1 -1 -1 -1 5000 5000	-1 -1 -1 -1 5000 5000	-1 -1 -1 -1 5000 5000	5000 -1 -1 -1 -1 5000 5000	-1 -1 -1 -1 5000 5000	-1 5000 5000 5000 5000 -1 -1	-1 5000 5000 5000 -1 -1	-1 5000 5000 5000 -1 -1	-1 5000 5000 5000 -1 -1	-1 5000 5000 5000 5000 -1 -1	-1 5000 5000 5000 -1 -1	-1 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000	-1 -1 -1 -1 5000 5000	-1 -1 -1 -1 5000 5000	-1 -1 -1 -1 5000 5000	-1 -1 -1 -1 5000 5000	-1 -1 -1 -1 5000 5000	5000 -1 -1 -1 -1 5000 5000 5000	5000 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1	-1 -1 -1 -1 -1 -1 -1 -1
C4 D1 D2 D3 D4 E1 E2 E3	-1 -1 -1 -1 5000 5000 5000	5000 -1 -1 -1 5000 5000 5000 5000	-1 -1 -1 -1 5000 5000 5000	5000 -1 -1 -1 5000 5000 5000 5000	5000 -1 -1 -1 5000 5000 5000 5000	5000 -1 -1 -1 5000 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1	-1 5000 5000 5000 -1 -1 -1	-1 5000 5000 5000 -1 -1 -1	-1 5000 5000 5000 -1 -1 -1 -1	-1 5000 5000 5000 -1 -1 -1 -1	-1 5000 5000 5000 -1 -1 -1 -1	-1 5000 5000 5000 5000 5000 5000 5000 50	-1 5000 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000 5000 50	-1 5000 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000 5000	-1 -1 -1 -1 5000 5000 5000	-1 -1 -1 -1 5000 5000 5000	-1 -1 -1 -1 5000 5000 5000	-1 -1 -1 -1 -1 5000 5000 5000	-1 -1 -1 -1 5000 5000	5000 -1 -1 -1 -1 5000 5000 5000	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	-1 -1 -1 -1 -1 -1 -1 -1 -1 -1
C4 D1 D2 D3 D4 E1 E2 E3 E4	-1 -1 -1 -1 5000 5000 5000	5000 -1 -1 -1 5000 5000 5000 5000	-1 -1 -1 5000 5000 5000 5000	5000 -1 -1 -1 5000 5000 5000 5000 5000	5000 -1 -1 -1 5000 5000 5000 5000 5000	5000 -1 -1 -1 5000 5000 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 -1 -1	-1 5000 5000 5000 -1 -1 -1 -1 -1 -1	-1 5000 5000 5000 -1 -1 -1 -1 -1 -1	-1 5000 5000 5000 -1 -1 -1 -1 -1 -200	-1 5000 5000 5000 -1 -1 -1 -1 -1 -1	-1 5000 5000 5000 -1 -1 -1 -1 -1 -1	-1 5000 5000 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000 5000 50	-1 -1 -1 5000 5000 5000 5000	-1 -1 -1 5000 5000 5000 5000	-1 -1 -1 -1 5000 5000 5000 5000	-1 -1 -1 -1 5000 5000 5000 5000	-1 -1 -1 -1 5000 5000 5000	5000 -1 -1 -1 5000 5000 5000 5000 5000	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	5000 -1	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
C4 D1 D2 D3 D4 E1 E2 E3 E4 F1	-1 -1 -1 -1 5000 5000 5000 -1	-1 -1 -1 -1 5000 5000 5000 5000 5000 5000 5000	-1 -1 -1 5000 5000 5000 -1	5000 -1 -1 -1 5000 5000 5000 5000 5000 5000 5000	5000 -1 -1 -1 5000 5000 5000 5000 5000 5000 5000	5000 -1 -1 -1 5000 5000 5000 5000 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 -1 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 -1 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 -1 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 -1 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 -1 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 -1 5000 5000	-1 5000 5000 5000 5000 5000 5000 5000 -1	-1 5000 5000 5000 5000 5000 5000 5000 5000 -1	-1 5000 5000 5000 5000 5000 5000 5000 -1	-1 5000 5000 5000 5000 5000 5000 5000 -1	-1 5000 5000 5000 5000 5000 5000 5000 -1	-1 5000 5000 5000 5000 5000 5000 5000 -1	-1 -1 -1 5000 5000 5000 -1	-1 -1 -1 5000 5000 5000 -1	-1 -1 -1 5000 5000 5000 -1	-1 -1 -1 -1 5000 5000 5000 -1	5000 -1 -1 -1 5000 5000 5000 5000 5000 -1	5000 -1 -1 -1 5000 5000 5000 5000 5000 5000 5000 -1	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1 -1 5000 5000	5000 -1 -1 -1 -1 -1 -1 -1 -1 5000 5000	5000 -10 5000	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1 -1 5000 5000
C4 D1 D2 D3 D4 E1 E2 E3 E4 F1 F2	-1 -1 -1 -1 5000 5000 5000 5000 -1 -1	5000 -1 -1 -1 5000 5000 5000 5000 5000 5000 -1 -1 -1	-1 -1 -1 5000 5000 5000 5000 -1 -1	5000 -1 -1 -1 5000 5000 5000 5000 5000 5000 5000 5000 -1 -1	5000 -1 -1 -1 5000 5000 5000 5000 5000 -1 -1	5000 -1 -1 -1 5000 5000 5000 5000 5000 -1 -1	-1 5000 5000 5000 -1 -1 -1 -1 5000 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 -1 5000 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000 5000 -1 -1 -1	-1 5000 5000 5000 5000 5000 5000 5000 5000 -1 -1	-1 5000 5000 5000 5000 5000 5000 5000 5000 -1 -1	-1 5000 5000 5000 5000 5000 5000 5000 5000 -1 -1	-1 5000 5000 5000 5000 5000 5000 -1 -1	-1 5000 5000 5000 5000 5000 5000 -1 -1	-1 -1 -1 -1 5000 5000 5000 5000 -1 -1	-1 -1 -1 5000 5000 5000 -1 -1	-1 -1 -1 -1 5000 5000 5000 5000 -1 -1	-1 -1 -1 -1 5000 5000 5000 5000 -1 -1	5000 -1 -1 -1 5000 5000 5000 5000 -1 -1 -1 5000 5000 -1 -1 -1 -1	5000 -1 -1 -1 5000 5000 5000 5000 5000 -1 -1 -1 -1 5000 5000 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 5000 5000	5000 -1 -1 -1 -1 -1 -1 -1 5000 5000	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 5000 5000 5000	5000 -1 -1 -1 -1 -1 -1 -1 -1 5000 5000	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 5000 5000	5000 -1 -1 -1 -1 -1 -1 -1 -1 5000 5000
C4 D1 D2 D3 D4 E1 E2 E3 E4 F1 F2 F3	-1 -1 -1 -1 5000 5000 5000 5000 -1 -1 -1	-1 -1 -1 -1 5000 5000 5000 5000 5000 5000 5000 -1 -1 -1	-1 -1 -1 -1 5000 5000 5000 5000 -1 -1 -1	5000 -1 -1 -1 5000 5000 5000 5000 5000 5000 5000 -1 -1 -1	5000 -1 -1 -1 5000 5000 5000 5000 5000 5000 5000 5000 -1 -1 -1	5000 -1 -1 -1 -1 5000 5000 5000 5000 5000 5000 5000 -1 -1 -1	-1 5000 5000 5000 -1 -1 -1 -1 -1 5000 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 -1 5000 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 5000 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 5000 5000 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 5000 5000 5000 5000	-1 5000 5000 5000 -1 -1 -1 -1 -1 5000 5000 5000 5000	-1 5000 5000 5000 5000 5000 5000 5000 -1 -1 -1 -1	-1 5000 5000 5000 5000 5000 5000 5000 5000 -1 -1 -1	-1 5000 5000 5000 5000 5000 5000 5000 5000 -1 -1 -1	-1 5000 5000 5000 5000 5000 5000 5000 5000 -1 -1 -1	-1 5000 5000 5000 5000 5000 5000 5000 5000 -1 -1 -1	-1 5000 5000 5000 5000 5000 5000 5000 -1 -1 -1	-1 -1 -1 -1 5000 5000 5000 5000 -1 -1 -1	-1 -1 -1 5000 5000 5000 5000 -1 -1 -1	-1 -1 -1 -1 5000 5000 5000 5000 -1 -1 -1 -1	-1 -1 -1 -1 5000 5000 5000 5000 -1 -1 -1 -1	5000 -1 -1 -1 5000 5000 5000 5000 5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	5000 -1 -1 -1 5000 5000 5000 5000 5000 5000 5000 -1 -1 -1	5000 -1 -1 -1 -1 -1 -1 -1 -1 -1 5000 5000 5000 5000	5000 -1 -1 -1 -1 -1 -1 -1 -1 5000 5000 5000	5000 -1 -1 -1 -1 -1 -1 -1 5000 5000 5000	5000 -1 -1 -1 -1 -1 -1 -1 5000 5000 5000	5000 -1 -1 -1 -1 -1 -1 5000 5000 5000 5000	-1 -1 -1 -1 -1 -1 -1 -1 5000 5000 5000

Objective function:

 $5000X_1 + 5000X_2 + 5000X_3 + 5000X_4 - X_5 - X_6 - X_7 - X_8 + \dots + 5000X_{720}$ (1) Constraints: • One teacher can be allotted 1 class in a time slot on the same day:

- $X_1 + X_{145} + X_{289} + X_{433} + X_{577} \le 1$ so on... for all teachers all days all time slots. (2)
- Total no. of classes of a particular subject should be 8 in a week X₁+X₂+X₃+X₄+X₂₅+X₂₆+X₂₇+X₂₈+X₄₉+....X₁₂₄ <=8 so on for all subject/class (3)
- Maximum 2 classes of the same subject can be held on a day X₁+X₂+X₃+X₄ <=2 so on for all subject/day/class (4)
- Total no of classes in a day should be 4 X₁+X₂+X₃+X₄+....X₂₄ <=4 so on for all days (5)
- Avoid multiple classes in a single time slot for a class X₁+X₅+X₉+...X₂₁ <=1 so on.

The constraints and the objective function are coded in R are solved using package LP solve as it is a linear programming problem with binary decision variables. The variables are equal to n^{t*c*d} .

Thus allotments are obtained for timetable scheduling through this for school classes.

The allotments obtained have scheduled the timetable according to the constraints we used. This case clearly shows how well and easily can be scheduled a timetable in a time saving and effortless way reducing manpower. The algorithm so developed here will be used as the background for the timetable scheduling in the company tool for schools and colleges. The interface is under construction by the organization. A number of other constraints according to the complexity of case can be added to the program and can be modified, one has to design a matrix appropriately is the first important task at hand. The intention of the algorithm to generate a time-table schedule automatically is satisfied. The algorithm incorporates a number of techniques, aimed at improving the efficiency of the search operation. It also addresses the important hard constraint of clashes between the availability of teachers. The non-rigid soft constraints i.e. optimization objectives for the search operation are also effectively handled. Given the generality of the algorithm operation, it can further be adapted to more specific scenarios, e.g. University, examination scheduling and further be enhanced to create railway timetables. Thus, through the process of automation of the time-table problem, many an-hours of creating an effective timetable have been reduced eventually. A similar approach is used for college scheduling problem where a single faculty can teach more than one subjects thus another constraint along with the above for avoiding a single faculty being allotted different subject/class in a time slot is introduced. A college timetable scheduling algorithm is also developed on similar lines in R.

IV. Conclusion and Future Scope:

A timetable scheduling algorithm is developed using Hungarian method and LPP in R software. The constraints can be varied according to using simple programming logic. Various packages of R come handy while developing an optimal solution. The algorithm developed will be used in the company analytical tool for schools and colleges and will be inbuilt into the software adding more utility and ease for the user (management, faculty, and students). Another dimension of

allotting classrooms in case of college timetable can be introduced and coded making it a more informative solution.

The work can be further extended to be used a college scheduling problem where which faculty is to teach which subject/subjects is already fixed. The allotment part in the school scheduling problem solved by Hungarian method can be skipped in this case and direct allotment matrix can be made and objective function realized and optimized. The only thing to keep in mind would be to add a constraint that would restrict the same faculty teaching different subjects to be allotted the same time slot. Also, the course preferences for classes can be incorporated by taking a different combination of large positive numbers in place of 5000 here. The dimension of classroom allocation is an important aspect that needs to be taken care of hence. This can be done by first obtaining the results of allotment and then optimizing it further on similar lines.

Heuristic optimization methods are explicitly aimed at good feasible solutions that may not be optimal where the complexity of the problem or limited time available does not allow an exact solution. Generally, two questions arise related to how fast the solution is computed and how close the solution is to the optimal one? The tradeoff is often required between time and quality which is taken care of by running simpler algorithms more than once, comparing results obtained with more complicated ones and effectiveness in comparing different heuristics. The empirical evaluation of heuristic method is based on the analytical difficulty involved in the problem's worst case result.

Solving Timetable Scheduling Problem by Using Genetic Algorithms: Genetic algorithms are adaptive systems inspired by natural evolution. They can be used as techniques for solving complex problems and for searching of large problem spaces. Genetic algorithms are belonging to guided random search techniques, which try to find the global optimum. Genetic algorithms are working with the set of potential solutions, which is called population. Each solution item (individual) is measured by the fitness function. The fitness value represents the quality measure of an individual, so the algorithm can select individuals with better genetic material for producing new individuals and further generations.

TABU Search Algorithm to Solve Class Time Table Scheduling Problem: Tabu search uses memorized ability to prevent from searching previously visited the area; therefore it is easier to obtain an optimal solution in a short time. Here we introducing modified approaches which do not allow violations of any hard constraints, and it produces only feasible solutions.

References

Akbalik, A., Hadj-Alouane, A. B., Sauer, N., & Ghribi, H. NP-hard and polynomial cases for the singleitem lot sizing problem with batch ordering under capacity reservation contract. European Journal of Operational Research, Vol. 257, Issue 2, pp. 483-493, 2017.

Chopra, S., Notarstefano, G., Rice, M., & Egerstedt, M. Distributed Version of the Hungarian Method for a Multirobot Assignment. IEEE Transactions on Robotics, Vol. 33, Issue 4, pp. 932-947, 2017.

Knuth, D. E. Postscript about NP-hard problems. ACM SIGACT News, Vol. 6, Issue 2, pp. 15-16, 1974.

Kuhn, H. W. The Hungarian method for the assignment problem. Naval Research Logistics (NRL), Vol. 2, Issue 1-2, pp. 83-97, 1955.

Van Leeuwen, J. Handbook of theoretical computer science (vol. A): algorithms and complexity. MIT Press, 1991.

BIOGRAPHY

Vimal Kumar is an Assistant Professor at MANIT, Bhopal. He has done his Doctoral degree from the Department of Industrial & Management Engineering, IIT Kanpur, India in the year 2017. He completed his Masters in Supply Chain Management from the Department of Industrial & Management Engineering, IIT Kanpur in the year 2012. He completed his graduation (B.Tech) in Manufacturing Technology in the year 2010 from JSS Academy of Technical Education, Noida. Currently, he is pursuing research in the domain of TQM and Manufacturing Strategy. He has published fourteen articles in reputable international journals and presented nine papers at international conferences. He was invited to serve as session chair for Quality Control & Management at the International Conference on Industrial Engineering & Operations Management (IEOM-2016) at Kuala Lumpur, Malaysia. He is a contributing author in journals including *IJPPM*, *IJQRM*, *IJPMB*, *IJPQM*, *IJBIS*, *AJOR*, *The TQM Journal*, and Benchmarking: An International Journal, etc. and also a guest reviewer of a reputable journal like *TQM* & Business Excellence, Benchmarking: An International Journal, and JSIT. He is the corresponding author and he can be contacted at <u>vimaljss@gmail.com</u>.

Ankita Malviya received her Masters (MTech) from the Department of Industrial and Management Engineering, IIT Kanpur, India in 2016. She completed her graduation (BE) in Electronics and Telecommunication Engineering in 2013 from Jabalpur Engineering College (JEC), Jabalpur. Her research interest includes operations research and operations management etc. She has worked as a post-graduate engineer trainee in Tata Motors, Lucknow. Currently, she is working as a scientist/engineer in ISRO, India.

Pratima Verma is Doctoral Candidate in Industrial & Management Engineering at IIT Kanpur, India. She received her MBA in Finance and Human Resource Management from BBDNITM, Uttar Pradesh Technical University Lucknow, India in the year 2011. She completed her graduation (B.Tech) in Information Technology in the year 2009 from BBNITM, Lucknow. She has one year of experience in teaching. She is currently working in the field of horizontal strategy. She also awarded JRF/SRF in the area of human resource management. She has published eight articles in reputable international journals and presented nine papers at international conferences. She was invited to serve as session chair for Human Factors and Ergonomics Track at the International Conference on Industrial Engineering & Operations Management at Kuala Lumpur, Malaysia. She is a contributing author in journals including *IJPMB, IJISE, IJBIS, and Benchmarking: An International Journal*, etc. She can be contacted at way2pratima@gmail.com or pratima@iitk.ac.in.

Vignaesh Muthukumaar is currently working as a Consultant in Decision Analytics at EXL Services, Bengaluru, India. He graduated this year 2017 from the Indian Institute of Technology, Kanpur, India, with a B.Tech in Material Science and Engineering and a Minor in Industrial and Management Engineering. He has international publications to his credit. He can be contacted at vignaeshmk@gmail.com.

Sunil Kumar Jauhar is an Assistant Professor at MANIT, Bhopal. He did his Ph.D. from Indian Institute of Technology Roorkee, India. He received his M. Tech in Industrial Engineering from VNIT, Nagpur (MH) India and BE from SGSITS, Indore, India in Industrial and Production Engineering. He has over 2 years of teaching experience at his parent institute SGSITS, Indore and CDGI Indore. His research interests include Supply chain management, soft computing, Operations management, Artificial intelligence, and Industrial engineering.

Nagendra Kumar Sharma is Ph.D. Scholar of the department of Management Studies at MANIT Bhopal.