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College of Humanities and Sciences  
Virginia Commonwealth University

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**“Modeling the Homeschool timetabling problem using Integer programming”**  
has been approved by her committee as satisfactory completion of the thesis requirement  
for the degree of  
Master of Science in Mathematical Sciences with a concentration in Operations Research

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**“Modeling the Homeschool timetabling problem using Integer programming.”**

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Mathematical Sciences with a concentration in Operations research at Virginia Commonwealth University

by

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Abstract

## **MODELING THE HOMESCHOOL TIMETABLING PROBLEM USING INTEGER PROGRAMMING**

By SUBHASHINI SRINIVASAN B.E (Hons.)

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Mathematical sciences with a concentration in Operations research at Virginia Commonwealth University.

Virginia Commonwealth University, 2011.

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Home schooling has steadily been increasing in the past decade. According to a survey in 2007, about 2.5 million children were being home schooled in the US. Typically, parents provide education at the convenience of their home and in some cases an instructor is appointed for the same. The Home School Timetabling problem (HSTP) deals with assigning subjects, timeslots and rooms to every student. In doing so, there are certain hard and specialty constraints that are to be satisfied. Integer programming (IP) has been used in solving the HSTP as it has the advantage of being able to provide information about the relative significance of each constraint with respect to the objective. A prototype in the form of a GUI has been built such that the parent can enter each student's name, his/her subjects, duration, days and time for each subject, availability times of the parent etc. This data is then fed into the IP model so that it can generate a feasible timetable satisfying all of the constraints. When a solution is found it is formatted to provide the weekly timetable for each student, individually, as well as a complete timetable for all students each day.

## INTRODUCTION

### Home schooling

Home schooling is the education of children by parents or tutor at home, rather than by sending them to a private or public school [1]. It was not until the 18<sup>th</sup> century that traditional schools came into existence and before that many children were either home schooled (especially in their early childhood days) or received no education at all [2].

Home schooling is legal in many parts of the world including the United States, Canada, United Kingdom, Australia, New Zealand and South Africa to name a few [3]. Parents who home school their children teach a variety of subjects, involve them in various indoor and outdoor activities, monitor their progress and also provide religious instruction. They also make use of the technological resources that are available such as online courses, libraries, museums and internet-based learning techniques to supplement their teaching methods.

According to the National Household Education Survey program (NHES) conducted by the U.S. Department of Education's National Center for Education Statistics (NCES), about 850,000 children were being home schooled in the United States in 1999 and in 2007 the survey showed that about 2.5 million children were being home schooled - a 74% relative increase from 1999. This estimate includes children who were either home schooled exclusively or home schooled while being enrolled in a school for less than 25 hours per week [4]. During the survey, about 67% of the students' parents stated that the

three main reasons for home schooling were to provide religious, ethical and moral instruction; concerns about the school environment (drug use, peer pressure); and dissatisfaction with the quality of academic instruction (e.g. lack of one on one attention and discipline available at schools).

The most important reason for home schooling selected by parents during the 2007 survey is listed in Table 1. [4]

| <b><u>Percentage</u></b> | <b><u>Reason for home schooling</u></b>  |
|--------------------------|--|
| 36%                      | To provide religious or moral instruction.                                     |
| 21%                      | Concerns about the school environment.   |
| 17%                      | Dissatisfaction with the quality of academic instruction available at school.  |
| 2%                       | Child has a physical or mental health problem.                                 |
| 4%                       | Child has other special needs.   |
| 7%                       | Interest in non-traditional approach to education.                             |
| 14%                      | Other reasons such as family time, financial instability, travel and distance. |

**Table 1: Summary of reasons for home schooling**

One of the biggest challenges faced by parents in home schooling their children is the preparation of a daily work/study timetable. This gets even more tedious when multiple children are to be home schooled, as parents need to make sure that they allot enough

time for each child. In order for home schooling to be highly effective, it is important to design a daily or weekly work schedule. Designing a timetable ensures that the children cover all of the subjects that are to be taken on a daily basis, in addition to completing daily chores and spending time learning new extracurricular activities. It also helps parents spend enough time teaching each student thereby working within their own personal schedules.

### The Timetabling Problem

Every year at various educational institutions, faculty and administration spend a considerable amount of time trying to build a schedule for the school year. In this regard, the university timetabling problem (TTP) deals with scheduling of lectures for students during the week at designated time slots depending upon the availability of lecturers and class rooms, taking into account some hard and soft constraints [5]. A number of variations of the timetabling problem have been analyzed in the past. Each TTP varies with the type of institution (school or university) being considered, the constraints involved, and the approach used to analyze and solve the problem [6]. A schedule depends upon the availability of the professors and their preferences, number of classrooms available at a particular time, capacity of the rooms, number of students registered for the course, time length of the course and a number of other factors [7].

Some of the most common constraints are:

- Not more than one class is scheduled in a particular room at any given time.

- Not more than one lecture is assigned to a particular lecturer at any given time.
- A student group cannot be in more than one lecture at any given time.
- The capacity of the room should be equal to or more than the number of students registered for the lecture assigned to that room.
- A lecture cannot be assigned to two or more different rooms at the same time.
- Certain lectures may require specific resources and that should be available in the room where the lecture is assigned [8].

The goal of the university-timetabling problem is to obtain a feasible schedule that is complete; that is, all of the courses for all groups of students should be scheduled such that the requirements of the course and those of the students are satisfied. In addition, the schedule should not have any conflicts.

### Integer Programming

Math programming or optimization refers to choosing the best solution from a set of available alternatives associated with a given problem. Typically, in an optimization problem we try to maximize or minimize a function which is the objective of the problem. This is done by changing the values of the controllable parameter called the decision variables which determine the behavior of the system. These variables also have restrictions on what values they can take which is expressed in terms of constraints and the solution to an optimization problem must satisfy these conditions. Operation Research

Analysts use math programming to solve a wide variety of problems in various fields. For example,

- Health care systems and hospitals use math programming to schedule staff and operating rooms. It is also used by the emergency services to plan the deployment and routing of ambulances.
- It is used in Airline industry to devise flight and crew schedules, develop disaster recovery plans and pricing strategies.
- Disaster management systems use optimization to help route trucks with medical and food supplies to the affected areas in the quickest way possible.
- Manufacturing industries use math programming to help increase productivity with minimal resource usage.
- Banking and Investment firms use math programming to analyze risks and to manage investment security portfolios.
- Educational institutions such as schools and universities use math programming techniques to devise optimized schedules for the school year.

Linear programming (LP) is a branch of mathematical programming that uses mathematical processes for determining a way to achieve the best outcome (such as maximum profit or lowest cost) in a given mathematical model for some list of requirements (constraints) represented as linear relationships. It involves using linear functions and its equalities/inequalities to come up with a best possible solution that satisfy all of the given constraints. The parts of a general LP model are:

- Decision variables – A decision variable is a variable whose value is determined by the model that is built and influences the performance of the system.
- Objective function – In most models, the objective of the problem is written mathematically as a function of the decision variables which could be either maximized or minimized. This function is called the objective function.
- Constraints – Restrictions on the values of the decision variables
- Non-negativity constraints – Constraints which prevent the values of the decisions variables from being non-negative.

An integer LP model is an LP model where the values of the decision variables are restricted to integers. This is highly useful for problems where fractional quantities are not allowed. In IP when the values of variables are either 0 or 1 it is called binary integer programming (BIP). Mixed integer programming is a special case of IP in which only some of the integers are required to be 0 or 1. The approach we use for the solving the home school-timetabling problem is binary IP.

## LITERATURE REVIEW

The Time Tabling Problem (TTP) is being analyzed from as early as the 1960's starting with Gotlieb [9]. A variety of papers related to the educational timetabling problem have been published in the past. Some of the successful approaches have been employed in practice. Many research surveys have also been published and provide good introduction to the educational timetabling. [10, 11]

Researchers have taken up different approaches to study and solve some variation of the TTP. These TTPs can be classified into three main classes:

- School TTP: Scheduling of classes at schools for different grades by avoiding teachers meeting more than one class at the same time and vice versa.
- University Course TTP: Scheduling lectures of a set of university courses on a weekly basis by minimizing the overlap of lectures having common students.
- Examination TTP: Scheduling of examinations of the courses in a university by avoiding conflicts of exams having common students and also allowing enough time for students between exams.

Some of the common approaches and techniques to solve the TTP are discussed below.



## Graph coloring

The graph coloring problem is one of the classical NP-complete problems on graphs [12]. Given an undirected graph  $G = (V;E)$ , the problem consists of finding a partition of  $V$  into a minimum number of colors  $c_1, c_2 \dots c_n$ , where no two vertices can be in the same color class if there is an edge between them. A reduction to the general graph coloring problem was proposed by Neufeld and Tartar (1974) in which each lecture is associated with a vertex in a graph, and there is an edge between each pair of lectures that cannot be scheduled at the same time especially for lectures which share a common class or an instructor (or both) [13]. The paper concludes that the problem of the coloration of a graph with the given type of external constraints can be transformed into the colorability of a graph without any constraints.

Welsh and Powell (1967) proposed a variant of the graph coloring technique for school TTP in which the vertices are ordered in such a way that the vertices with highest degree are colored first [14]. The idea behind this technique is that the vertices with high degree are most difficult to be colored. There have been other methods proposed based on this idea. Notably, Leighton (1979) adds to the algorithm of Welsh and Powell the idea of re-computing the degree of the vertices at each step, eliminating the vertices already colored [15]. A number of methods based on ordering the vertices by degree is discussed in (Carter, 1986) [16]. The simplest graph coloring heuristics is called SEQ (Johnson et al., 1991) [17]. In this approach vertices  $v_1, v_2 \dots v_n$  and colors  $c_1, c_2 \dots c_n$  are arranged in order. Vertex  $v_1$  is initially assigned to color  $c_1$  and then vertex  $v_i$  in turn is assigned to

the smallest color that contains no vertices adjacent to  $v_i$ . In worst case scenarios, this method is found to perform poorly (Johnson et al., 1991) [17].

A slightly different idea is used for the course TTP in the algorithm proposed by Breaz (1979) [18]. In every step, the algorithm chooses the vertex to color next by picking the one that is adjacent to the largest number of distinctly colored vertices. In 1985, de Werra<sup>10</sup> showed how to reduce a course TTP to a graph coloring problem. Similar to the course TTP, examination problem can also be easily reduced to a graph coloring problem. Mehta (1981) shows this by associating each exam with a vertex and drawing an edge between each pair of conflicting exams [19]. The paper concludes that examination timetabling problems with second order constraints cannot be easily formulated as graph coloring problems. Coloring of weighted graphs may also be useful for timetabling applications. The problem of coloring of weighted graphs and its application to timetabling are discussed in [20].

#### Network flow technique:

The network flow problem is a LP problem in which the objective is to maximize the overall flow from an initial source to a final sink. The network consists of nodes connected by directed arcs, each arc having a given direction and a limited capacity. The timetabling problem can be reduced to a sequence of network flow problems [21]. Here, they create a network for each period so that the flow in the network identifies the lectures given in that period. DeWerra (1985) proposes a similar method of creating a network for each class [10].

A network model has been proposed to be used as the core of the timetabling algorithm by Dyer and Mulvey, Mulvey, Chahal and de Werra, Dinkel et al. (1976,1982, 1989, 1989) [22, 23, 24, 25]. The network employed by Dinkel et al. contains three levels, in addition to a source and a sink vertex [25]. The first level includes a vertex for each department in the university, such that all of the vertices are connected to the source. The second level includes a vertex for each possible combination of teacher and course taught by the teacher; these vertices are connected to the vertices representing the departments to which the teachers belong. The third level contains a vertex for each combination of room and time. Every vertex in this level is connected to a vertex of the second level only if the size of the room represented by the vertex is compatible with the number of students of the course represented by the other vertex. An edge between levels 2 and 3 indicates a possible lecture. Edges representing the lectures have a capacity of 0 and a lower bound of 1 and due to unimodularity, this ensures that the optimal solution to the problem will possess all integer values. The coefficients of the objective function are assigned based on availabilities of teachers and rooms, and preferences of the teachers. The network model can be solved in polynomial time; however it does not prevent the solution from assigning a single teacher to multiple lectures at the same time. The procedure therefore solves the problem and, if it finds a feasible solution, the process ends, otherwise some of the weights have to be manually changed so as to get rid of the reason of infeasibility. The procedure is executed several times until a feasible solution is obtained.

## Tabu Search

Tabu search is a local search technique designed to solve optimization problems. Given an optimization problem  $P$ , let  $S$  be the search space of  $P$ , and let  $f$  the objective function to minimize (maximize). A function  $N$ , which depends on the structure of the specific problem, assigns to each feasible solution  $s \in S$ , its neighborhood  $N(s) \subseteq S$ . Each solution  $\acute{s} \in N(s)$  is called a neighbor of  $s$ . In tabu search, the algorithm explores a subset  $V$  of the neighborhood  $N(s)$  of the current solution  $s$ . The member of  $V$  that gives the minimum value of the objective function becomes the new current solution. This is independent of the fact that its value is better or worse than the value in  $s$ . In order to prevent cycling, there is a tabu list, which is the list of solutions to which it is forbidden to move back. When a new solution is added, due to a move, the oldest one is discarded. (Glover, 1989; Glover and Laguna, 1993) [26,27].

Tabu search has been used to solve high school timetabling problem by Costa (1994) , Alvarez-Valdes et al. (1996) , and Schaerf (1996b) [28,29,30]. Combinations of tabu search with other local search techniques have been analyzed by Alvarez-Valdes et al. (1996) and Schaerf (1996b) [29,30]. The representation chosen by Schaerf (1996b) is the same as Colorni et al., 1992 [31]. A solution is represented as a matrix  $M_{m \times p}$  such that each entry  $m_{ik}$  contains the name of the class that the teacher is meeting at period  $k$ . A move consists in exchanging two lectures for a given teacher or moving a lecture to a different period. Costa (1994) instead employs a different type of move [28]. In this representation a single teacher can teach more than one lecture at the same time. A swap

of assignments for a single teacher can be done in two consecutive moves letting both assignments in the same period at the intermediate step.

The tabu search technique has been applied to university course timetabling in (Hertz, 1991; Hertz, 1992) [32, 33]. The work in (Hertz, 1991) considers the optimization problem with the grouping option, whereas (Hertz, 1992) extends the approach to a more complex case which takes into account also lectures of different length. In (Hertz, 1991) the tabu search is applied to both the timetabling problem and the grouping sub-problem [33]. Only the application of tabu search to the pure timetabling problem is described. In particular, Hertz considers a feasible solution also a timetable in which courses given at the same time share a common teacher or involve common students.

#### Integer Programming:

There are number of papers that have been published which help solve the problem of course timetabling using IP. Most papers discuss the implementation of a model to solve a particular course scheduling problem involving real data obtained from certain educational institutions. [34,7, 35]. For example, Ohio University's College of Business currently uses the model that was developed by Martin to schedule classes at their institution. [36]. The faculty timetabling problem which is closely related to the TTP is solved using IP models by Breslaw [37] . Similarly an LP formulation designed to solve the problem of classroom allocation, which is a part of the university/class TTP was provided by Gosselin et al [38]. The teacher assignment problem is formulated as a MIP

problem and is solved as a special case of the fixed charge transportation problem by Hultberg and Domingos [39]. In this project, we use binary IP to try to solve the home school timetabling problem.

#### Other techniques:

Genetic algorithms are a solution technique for optimization problems (Davis, 1991; Michalewicz, 1994) [40]. It is different from tabu search and simulated annealing as they are not based on local search. Genetic algorithms have been used for course timetabling in (Ling, 1992; Paechter et al., 1994) [41, 42]. Infeasible timetables are also included in the search space of the algorithms. In order to bias the search toward feasible timetables the infeasibilities are given a very high weight in the objective function w.r.t. other constraints. Genetic algorithms have been applied to solve examination timetabling by many researchers including Burke et al., 1995, Corne et al., 1994b, Paechter, 1994, Corne et al., 1993 and is considered as a good approach to solve the examination TTP [42, 43, 44, 45].

Abramson (1991) used simulated annealing to solve a school TTP. This paper considers the possibility that two different classes may have common students and hence can be used to solve a course TTP [46]. A solution is described by a list of sets of lectures, one list for each period. Given a solution, the choice of the neighbor solution is performed by selecting at random a period and a lecture in the selected period, and moving the lecture to a different period randomly chosen. Eglese and Rand (1987) and Johnson (1990),

among others, have used simulated annealing for examination timetabling [47, 48]. Eglese and Rand actually solve a problem slightly different from the examination timetabling, which is the timetabling of conference presentations (or seminars). In their formulation, a presentation can be repeated more than once if necessary. In addition the number of rooms is fixed and all rooms are used for all periods.

A logic programming approach has been used by Fahrion and Dollansky (1992) [49]. The paper proposes a prolog implementation of a heuristics based on a priority of the lectures to be scheduled. Logic programming techniques are also used in (Monfroglio, 1986) and (Ling, 1992) [41,50]. Kang and White (1992) propose the logic programming approach to the school timetable problem [51]. In particular, they use PROLOG as the implementation language for their timetabling program. The main advantage of this approach is the ability to express in a declarative way the constraints involved in the problem. Another approach based on constraint logic programming is presented by Deris et al. and this was tested on real-world data [52]. The model presented in this paper was inspired by the general assignment type IP approach used by Haase et al. (2004) [53].

## PROBLEM DESCRIPTION

There are four children: Kayla, Karissa, Micah and Leah. Kayla and Karissa are twins and are in grade 9; Micah is in grade 7 and Leah in grade 4. All four students are being home schooled currently and the aim of this project is to build a homeschool timetable for them. In addition, a prototype in the form of a GUI for the same is also to be built such that the parent can enter each students' name, his/her subjects, details about the duration, days and time for each subject and availability times of the parent. This data is then to be fed into the IP model built, so that it can generate a feasible timetable satisfying all of the hard and soft constraints. When a feasible timetable solution is found it is to be formatted in such a way that it is user-friendly and can provide the weekly timetable for each student individually as well as a complete timetable for all students each day.

Each student has a list of subjects that are to be taken either at home or at an outside institution with the help of an instructor. Certain subjects are to be taken at home under the guidance of a parent and some are self-study. Also there are some subjects which are to be taken in groups and others to be studied individually. Grading for all four students is done individually.

The subjects for each student are listed in two sets as fixed time subjects and non-fixed time subjects (listed in table 2). Fixed time subjects are to be taken outside at an



institution at a specific time on a given day while non-fixed time subjects are to be taken at home. Not all of the subjects given are to be taken by every student. More information can be found in Appendix 3.

The duration of each subject in the non-fixed time subject is classified into three groups of 15, 30 and 45 minutes and that of fixed time subjects varies depending on the time taken to travel back and forth in addition to the duration of the class itself. Most of the subjects are to be scheduled only on weekdays except for a few (e.g. 'Read-Aloud' and 'Bible study and Church') which are to be taken on Sundays as well.

There are six rooms/places where the students can study at home and they are Living room (LR), Kitchen (K), Bedroom (BR), Master bedroom (MBR), Computer room (CR) and Lawn (OUT). The piano is in the kitchen and hence when a student is learning/practicing the piano none of the other students can study in the living room or in the kitchen at the same time. The family currently has two computers and one of them is located in the master bedroom and the other in computer room. Subjects that require the use of the computer like Math, Science HS, Typing, Art 2, Physical Education 1, Physical Education 2, Phys. Ed Practice, Writing and Grading are to be studied or done in either of the two rooms.

For a certain list of subject the presence of at least one of the parents is mandatory. Hence these subjects are to be taken only when at least one of the parents is present and in addition there are also subjects when mother's presence is absolutely required for the student to study that subject. The list of students and subjects for which mother's

presence is required are listed in Appendix 3. In order for the LP model to process this, it is required that we also provide the availability times of the parents so that the subjects are scheduled only when the required parent is present.

There are restrictions on days of the week a subject should be certainly taken and the number of times in a week that subject should be taken. For example, Micah and Leah must do their math on the computer in computer room only, while Kayla and Karissa can do their math on either computer depending upon the availability. Other basic timetable requirements (e.g. a subject cannot be taken more than once in a day, not more than one subject can be studied at any given time, a student cannot be in more than one room at any given time) are to be satisfied. Since students are allowed to study in groups for certain subjects, more than one student can study in the same room at any given time. Resources like computer and piano are only available in specific rooms and hence the subjects can only be taken in those specific rooms when they are available.

## HOMESCHOOL TIMETABLING MODEL

The Home school timetabling problem is attempted to solve using GLPK (GNU Linear Programming Kit), a math modeling software used to solve large scale LP and MIP problems.<sup>54</sup> Problems are usually modeled in the language, GNU MathProg which has a syntax similar to AMPL (A Modeling language for mathematical programming) and the model is solved with a standalone solver GLPSOL. GLPK uses the revised simplex method and the primal-dual interior point method for non-integer problems and the branch-and-bound algorithm together with Gomory's mixed integer cuts for MIPs. Due to its capacity to handle large number of variables, the Home School TTP model was programmed and solved using GLPK.

Sets (indices):

**Student** –  $i$

**Subject** –  $j$

**Day** –  $k$

**Room** –  $l$

**Time** –  $m$ , in 15minute slots

**CompSub** –  $j$ , Subjects that require the use of a computer.

**Group** –  $t$

**PianoRooms** –  $l$

**PianoSubjects** –  $j$ , Subjects that require the use of a piano.

**KandK** –  $i$

**KKandM** –  $i$

### Parameters

**NumStudents** – Total number of students for whom the timetable is to be prepared.

**D<sub>ijk</sub>** - 1 if Student  $i$ , must take Subject  $j$  on Day  $k$ , 0 otherwise.

**NumDays<sub>ij</sub>** - The total number of times a Student  $i$ , must take Subject  $j$  in a week.

**NumDaysG<sub>jt</sub>** – The total number of times a group  $t$  must take subject  $j$  in a week.

**R<sub>jl</sub>** - 1 if Subject,  $j$  could be studied in Room  $l$ , 0 otherwise.

**M<sub>km</sub>** – 1 if Mom is available on Day  $k$  at time  $m$ , 0 otherwise.

**T<sub>jt</sub>** – 1 if Mom is needed for Subject  $j$  and Group  $t$

**C<sub>j</sub>** – 1 if a subject  $j$  is to be assigned a single timeslot, otherwise the subject is to be assigned consecutive time slots of the number (#) specified.

**G<sub>ijt</sub>** – 1 if Student  $i$  is in Group  $t$  for Subject  $j$ , 0 otherwise.

**Numgroups<sub>j</sub>** – Total number of groups for subject  $j$

**alpha** – Balance coefficient

**beta** - Balance coefficient

### Decision variables

Binary variable:  $X_{i,j,k,l,m}$  – The variable is set to 1, when student  $i$ , begins subject  $j$ , on day  $k$ , in room  $l$  in time slot  $m$ .

Binary variable:  $Z_{i,j,k,l,m}$  – The variable is set to 1, when student  $i$ , is busy with subject  $j$ , on day  $k$ , in room  $l$  during time slot  $m$ . (This variable is used to set consecutive time slots for a subject).

Binary variable:  $Y_{j,t,k,l,m}$  – The variable is set to 1, when subject  $j$ , for group  $t$  is scheduled on day  $k$ , at time  $l$  in room  $m$ .

### Objective Function

#### **Minimize**

$$\alpha \sum_{i \in \text{Student}} \sum_{j \in \text{Subject}} \sum_{l \in \text{Room}} \sum_{m \in \text{Time}} X_{ij' \text{ Sunday } tm} + \beta \sum_{i \in \text{Student}} \sum_{j \in \text{Subject}} \sum_{k \in \text{Day}} \sum_{l \in \text{Room}} \sum_{m \in \text{Time}} X_{ijklm}$$

## Constraints

### 1) Subjects that are to be absolutely taken on certain days.

If  $D_{ijk} \rightarrow \{1 \text{ if Student } i, \text{ must take Subject } j \text{ on Day } k, 0 \text{ otherwise}\}$  is set to 1, then, binary variable  $X_{ijklm}$  should be set to 1.

If  $D_{ijk} \rightarrow \{1 \text{ if Student } i, \text{ must take Subject } j \text{ on Day } k, 0 \text{ otherwise}\}$  is set to 0, then, binary variable  $X_{ijklm}$  can be set to either 0 or 1.

$$\sum_{l \in Room} \sum_{m \in Time} X_{ijklm} \geq D_{ijk} \quad \begin{array}{l} \forall i \in Student \\ \forall j \in Subject \\ \forall k \in Day \end{array}$$

### 2) Number of days in a week a subject must be taken by each student.

$NumDays_{ij} \rightarrow \{ \text{the total number of times a Student } i, \text{ must take Subject } j \text{ in a week} \}$

$$\sum_{k \in Day} \sum_{l \in Room} \sum_{m \in Time} X_{ijklm} = NumDays_{ij} \quad \begin{array}{l} \forall i \in Student \\ \forall j \in Subject \end{array}$$

### 3) Number of days in a week a subject must be taken by each group.

$NumDaysG_{jt} \rightarrow \{ \text{the total number of times a Group } t, \text{ must take Subject } j \text{ in a week} \}$

$$\sum_{k \in Day} \sum_{l \in Room} \sum_{m \in Time} Y_{jtklm} = NumDaysG_{jt} \quad \begin{array}{l} \forall j \in Subject \\ \forall t \in Group \end{array}$$

4) A subject  $j$ , cannot be taken more than once on any given day  $k$ , by any student  $i$ .

$$\sum_{l \in \text{Room}} \sum_{m \in \text{Time}} X_{ijklm} \leq 1$$

$$\forall i \in \text{Student}$$

$$\forall j \in \text{Subject}$$

$$\forall k \in \text{Day}$$

5) Not more than one Subject,  $i$  can be taken in any Time slot,  $m$ ; &  
a Student,  $i$  cannot be in more than one Room,  $l$  at any Time,  $m$ .

$$\sum_{j \in \text{Subject}} \sum_{l \in \text{Room}} Z_{ijklm} \leq 1$$

$$\forall i \in \text{Student}$$

$$\forall k \in \text{Day}$$

$$\forall m \in \text{Time}$$

6) Computer Constraint: Not more than 2 students can study a subject that requires  
the use of a computer at the same time.

$$\sum_{i \in \text{Student}} \sum_{j \in \text{CompSub}} \sum_{l \in \text{Room}} Z_{ijklm} \leq 2$$

$$\forall k \in \text{Day}$$

$$\forall m \in \text{Time}$$

7) **Specific Room Constraint:** Certain Subjects can only be taken in any one of the rooms specified.

If  $R_{jl} \rightarrow \{1 \text{ if Subject, } j \text{ could be studied in Room } l, 0 \text{ otherwise}\}$  is set to 1, then binary variable  $X_{ijklm}$  could be set to either 0 or 1.

If  $R_{jl} \rightarrow \{1 \text{ if Subject, } j \text{ could be studied in Room, } l, 0 \text{ otherwise}\}$  is set to 0, then, binary variable  $X_{ijklm}$  should be set to 0.

$$\sum_{i \in Student} \sum_{m \in Time} X_{ijklm} \leq NumStudents * R_{jl} \quad \begin{array}{l} \forall j \in Subject \\ \forall k \in Day \\ \forall l \in Room \end{array}$$

8) **Group/ Individual Study:** Certain subjects are to be studied in groups and some individually.

$G_{ijt} = 1$  if Student  $i$  is in Group  $t$  for Subject  $j$ , 0 otherwise.

$$X_{ijklm} \geq (G_{ijt} * Y_{jtklm}) \quad \begin{array}{l} \forall i \in Student \\ \forall j \in Subject \\ \forall k \in Day \\ \forall l \in Room \\ \forall m \in Time \\ \forall t \in Group \end{array}$$

9) **Mom Constraint:** Students can take certain subjects only when Kara (mom) is present.

If  $M_{km} \rightarrow \{1 \text{ if Mom is available on Day } k \text{ at Time } m, 0 \text{ otherwise}\}$



$T_{jt} \rightarrow \{1 \text{ if Mom is needed for Subject } j \text{ group } t, 0 \text{ otherwise}\}$

$$\sum_{j \in \text{Subject}} \sum_{t \in \text{Group}} \sum_{l \in \text{Room}} (T_{jt} * Y_{jtklm}) \leq M_{km} \quad \forall k \in \text{Day}$$

$$\forall m \in \text{Time}$$

**10) Time Constraint: The subjects must be scheduled at different consecutive timeslots that each subject requires.**

If  $C_j \rightarrow \{1 \text{ if a subject requires one 15 minute time slot, 2 if a subject requires two fifteen minute time slots etc.}\}$

$$Z_{ijklm} \leq \sum_{s=\max(1, m+1-C_j)}^m X_{ijklms} \quad \forall i \in \text{Student}$$

$$\forall j \in \text{Subject}$$

$$\forall k \in \text{Day}$$

$$\forall l \in \text{Room}$$

$$\forall m \in \text{Time}$$

**11) If student  $i$ , begins subject  $j$  on day  $k$ , then that subject must be studied for exactly  $C_j$  timeslots on that day.**

$$\sum_{m \in \text{Time}} Z_{ijklm} = C_j * \sum_{m \in \text{Time}} X_{ijklm} \quad \forall i \in \text{Student}$$

$$\forall j \in \text{Subject}$$

$$\forall k \in \text{Day}$$

$$\forall l \in \text{Room}$$

12) **Piano Constraint 1**: When subject Piano is scheduled in the kitchen, no other subject  $j$  can be studied in the kitchen or in the living room at the same time.

$$\left( \sum_{i \in Student} \sum_{j \in Subject} \sum_{l \in PianoRooms} Z_{ijklm} - \sum_{j \in Subject} \sum_{l \in PianoRooms} Z_{jpklm} \right) \leq NumStudents * \left( 1 - \sum_{j \in PianoSubjects} \sum_{l \in PianoRooms} Z_{jpklm} \right)$$

$$\forall p \in Student$$

$$\forall k \in Day$$

$$\forall m \in Time$$

13) **Piano Constraint 2**: Not more than one student can study a subject that requires the use of a Piano at the same time.

$$\sum_{i \in Student} \sum_{j \in PianoSubjects} \sum_{l \in Room} Z_{ijklm} \leq 1 \quad \forall k \in Day$$

$$\forall m \in Time$$

14) **Specific timed subjects**: These are the constraints for subjects that must be taken at a specific time on a specific day outside at an institution.

$$\sum_{i \in Student} X_{i, 'BSandC', 'Sunday', 'OUT', '5'} = 4$$

$$\sum_{i \in Student} X_{i, 'FWB', 'Thursday', 'OUT', '19'} = 4$$

$$\sum_{i \in K \text{ and } K} X_i, 'Choir', 'Monday', 'OUT', '43' = 2$$

$$\sum_{i \in K \text{ and } K} X_i, 'HH', 'Thursday', 'OUT', '27' = 2$$

$$\sum_{i \in K \text{ and } M} X_i, 'Swimming', 'Thursday', 'OUT', '23' = 3$$

$$X 'Micah', 'Drums', 'Thursday', 'OUT', '33' = 1$$

## DISCUSSION

### Discussion of Model Constraints:

In building the optimal Homeschool timetable there are some hard constraints that are to be satisfied to ensure feasibility.

#### *Constraint 1*

$$\sum_{l \in Room} \sum_{m \in Time} X_{ijklm} \geq D_{ijk}$$

$$\forall i \in Student$$

$$\forall j \in Subject$$

$$\forall k \in Day$$

Some subjects are required to be taken absolutely on certain days of the week.

Constraint1 ensures that each student studies a list of subjects that is required to be taken on each day of the week. For this purpose, a binary parameter  $D_{ijk}$  is created which when set to 1 indicates that Student  $i$ , must study subject  $j$  on day  $k$  and 0 otherwise. Binary variable  $X_{ijklm}$  is set to 1 when the parameter  $D_{ijk}$  is set to 1 and when the parameter is set to 0,  $X_{ijklm}$  can be set to either 0 or 1.

### Constraint 2

$$\sum_{k \in Day} \sum_{l \in Room} \sum_{m \in Time} X_{ijklm} = NumDays_{ij} \quad \forall i \in Student$$
$$\forall j \in Subject$$

Students are required to take their subjects exactly a certain number of times in a week.

$NumDays_{ij}$  in constraint 2 is a parameter between students and subjects and indicates the number of times in a week a student  $i$  must take subject  $j$ . Hence constraint 2 makes sure that the  $X_{ijklm}$  binary variable is set to 1 exactly the number of times that each student must take a subject.

### Constraint 3

$$\sum_{k \in Day} \sum_{l \in Room} \sum_{m \in Time} Y_{jtklm} = NumDaysG_{jt} \quad \forall j \in Subject$$
$$\forall t \in Group$$

Constraint 3 works similar to constraint 2 except that this constraint is for when a group of students must take a subject. Parameter  $NumDaysG_{jt}$  indicates the number of times a group  $t$  must take subject  $j$ . And the group binary variable  $Y_{jtklm}$  is set to 1 exactly the number of times that  $NumDaysG_{jt}$  indicates.

#### Constraint 4

$$\sum_{l \in \text{Room}} \sum_{m \in \text{Time}} X_{ijklm} \leq 1$$

$$\forall i \in \text{Student}$$

$$\forall j \in \text{Subject}$$

$$\forall k \in \text{Day}$$

Constraint 4 is a hard constraint that is to be absolutely satisfied for feasibility. It makes sure that any subject  $j$  is studied not more than once in a day. Specifically, a student  $i$  cannot begin studying a subject  $j$  more than once on day  $k$ .

#### Constraint 5

$$\sum_{j \in \text{Subject}} \sum_{l \in \text{Room}} Z_{ijklm} \leq 1$$

$$\forall i \in \text{Student}$$

$$\forall k \in \text{Day}$$

$$\forall m \in \text{Time}$$

The work of constraint 5 is twofold here. Firstly, it makes sure that a student  $i$  is not busy with more than one subject  $j$  in a time slot  $m$ . Secondly, it also ensures that a student  $i$  is not present in more than one room  $l$  at the same time  $m$ . This constraint is also a hard constraint as it is required to be satisfied for feasibility.

#### Constraint 6

$$\sum_{i \in \text{Student}} \sum_{j \in \text{CompSub}} \sum_{l \in \text{Room}} Z_{ijklm} \leq 2$$

$$\forall k \in \text{Day}$$

$$\forall m \in \text{Time}$$

There are two computers available for students to study at home. This means that not more than two students can be busy with a subject that requires the use of a computer at the same time. Constraint 6 guarantees that more than two students are busy with a computer subject.

*Constraint 7*

$$\sum_{i \in Student} \sum_{m \in Time} X_{ijklm} \leq NumStudents * R_{jl} \quad \begin{array}{l} \forall j \in Subject \\ \forall k \in Day \\ \forall l \in Room \end{array}$$

Resources like computers and piano are only available in specific rooms and hence those subjects must be studied in rooms where they are available. This calls for a constraint that makes sure that subjects are allowed to be studied only in specific rooms. Binary parameter  $R_{jl}$ , between subject and room, when set to 1 indicates that subject  $j$  could be studied in room  $l$  and 0 otherwise. Since students will have to study certain subjects in groups, the constraint is designed to accommodate group study as well.

*Constraint 8*

$$X_{ijklm} \geq (G_{ijt} * Y_{jtklm})$$

$$\forall i \in \text{Student}$$

$$\forall j \in \text{Subject}$$

$$\forall k \in \text{Day}$$

$$\forall l \in \text{Room}$$

$$\forall m \in \text{Time}$$

$$\forall t \in \text{Group}$$

The binary parameter  $G_{ijt}$  when set to 1 indicates that student  $i$  is in group  $t$  for subject  $j$  and 0 otherwise. When students study subjects individually each of the four groups has one student and when students study in groups the number varies for each group. The binary variable  $Y_{jtklm}$  is set 1 when group  $t$  takes subject  $j$  on day  $k$  at time  $m$  and room  $l$ . Hence when the group variable for a student is set to 1 then this constraint makes sure that every student in that group takes the subject  $j$  on the same day  $k$  at time  $m$  and room  $l$  and their corresponding  $X_{ijklm}$  binary variable is set to 1.

*Constraint 9*

$$\sum_{j \in \text{Subject}} \sum_{t \in \text{Group}} \sum_{l \in \text{Room}} (T_{jt} * Y_{jtklm}) \leq M_{km}$$

$$\forall k \in \text{Day}$$

$$\forall m \in \text{Time}$$

In the list of subjects provided there are subject which requires the mother to be present when a particular student takes that subject. Hence the times when these subjects are taken should coincide with the availability times of the mother as the subject cannot be taken when the mother is not present. Here, the binary parameter  $M_{km}$  indicates the availability times of the mother. Parameter  $M_{km}$  when set to 1 indicates that the mother is



available and 0 otherwise. At any point of time at most only one student or group can be aided. Another binary parameter  $T_{jt}$  helps indicate if the mother is required to be present for subject  $j$  and group  $t$ . A value of 1 indicates that the mother should be present and 0 otherwise. With this the constraint 9 ensures that a subject that requires the mother to be present with the student can only be taken when she is available.

#### Constraint 10

$$Z_{ijklm} \leq \sum_{s=\max(1, m+1-C_j)}^m X_{ijklms}$$

$$\begin{aligned} \forall i \in Student \\ \forall j \in Subject \\ \forall k \in Day \\ \forall l \in Room \\ \forall m \in Time \end{aligned}$$

In this model, time is represented using various timeslots of 15 minutes each. If a subject is required to be studied for 45 minutes then it is assigned 3 consecutive time slots of 15 minutes each. This constraint makes sure that if a student  $i$  should study a subject  $j$  for 45 minutes then the variable  $Z_{ijklm}$  should be set to 1 for the student  $i$  and that subject  $j$  on day  $k$  at room  $m$  for three consecutive time slots.

#### Constraint 11

$$\sum_{m \in Time} Z_{ijklm} = C_j * \sum_{m \in Time} X_{ijklm}$$

$$\begin{aligned} \forall i \in Student \\ \forall j \in Subject \\ \forall k \in Day \\ \forall l \in Room \end{aligned}$$

The parameter  $C_j$  indicates the number of timeslots required for each subject  $j$ . That is, if a subject is to be studied for 30 minutes then it requires 2 time slots (15 minutes each). Hence  $C_j$  for that subject is set to 2. This constraint makes sure that the student  $i$  is busy with subject  $j$  for exactly  $C_j$  time slots corresponding to the subject  $j$  from when the student begins studying that subject. While constraint 10 ensures that the timeslots are consecutive, constraint 11 takes care of the assignments of the  $Z_{ijklm}$  variables to make sure that they add up to the same number as the number of timeslots required for each subject  $j$ .

*Constraint 12*

$$\left( \sum_{i \in Student} \sum_{j \in Subject} \sum_{l \in PianoRooms} Z_{ijklm} - \sum_{j \in Subject} \sum_{l \in PianoRooms} Z_{jplm} \right) \leq NumStudents * \left( 1 - \sum_{j \in PianoSubjects} \sum_{l \in PianoRooms} Z_{jplm} \right)$$

$$\forall p \in Student$$

$$\forall k \in Day$$

$$\forall m \in Time$$

The Piano is set up in the kitchen which opens into the living room. Hence when piano is being practiced or learned by a student in the kitchen, no other student can study any subject in the kitchen or in the living room at the same time when piano is being used.

Constraint 12 is designed to ensure that no other subject is scheduled to be studied in the kitchen or in the living room when piano is scheduled to be studied in the kitchen.

Constraint 13

$$\sum_{i \in \text{Student}} \sum_{j \in \text{PianoSubjets}} \sum_{l \in \text{Room}} Z_{ijklm} \leq 1 \quad \forall k \in \text{Day} \\ \forall m \in \text{Time}$$

This constraint makes sure that not more than student studies a subject that requires the use of a piano at the same time. Since there is only one piano available, at most one student  $i$  can use it at any time  $m$ .

Constraint 14

$$\sum_{i \in \text{Student}} X_{i, 'BSandC', 'Sunday', 'OUT', '5'} = 4$$

$$\sum_{i \in \text{Student}} X_{i, 'FWB', 'Thursday', 'OUT', '19'} = 4$$

$$\sum_{i \in \text{KandK}} X_{i, 'Choir', 'Monday', 'OUT', '43'} = 2$$

$$\sum_{i \in \text{KandK}} X_{i, 'HH', 'Thursday', 'OUT', '27'} = 2$$

$$\sum_{i \in \text{KKandM}} X_{i, 'Swimming', 'Thursday', 'OUT', '23'} = 3$$

$$X_{i, 'Micah', 'DrumsL', 'Thursday', 'OUT', '33'} = 1$$

There are certain subjects that must be taken only at specific times and days of the week.

These subjects are to be taken outside at an institution and hence do not allow any room for flexibility. The table below provides more information about these subjects.

| <b>Students</b>                | <b>Subject</b>                  | <b>Days</b> | <b>Timings</b> | <b>Venue</b> |
|--------------------------------|---------------------------------|-------------|----------------|--------------|
| Kayla, Karissa, Micah and Leah | Bible Study and Church (BSandC) | Sunday      | 9:00-12:30 am  | Outside      |
| Kayla, Karissa, Micah and Leah | Fitness with Brittany(FWB)      | Thursday    | 12:30–1:30 pm  | Outside      |
| Micah                          | Drums lesson (DrumsL)           | Thursday    | 4:00-4:30 pm   | Outside      |
| Kayla and Karissa              | Choir                           | Monday      | 6:30-8:15 pm   | Outside      |
| Kayla and Karissa              | Heavenly Hoofs (HH)             | Thursday    | 2:30 -6:00 pm  | Outside      |
| Kayla, Karissa and Micah       | Swimming                        | Thursday    | 1:30-2:00 pm   | Outside      |

**Table 2: Specific timed subjects**

### Discussion of Objective Choice:

#### **Minimize**

$$\alpha \sum_{i \in \text{Student}} \sum_{j \in \text{Subject}} \sum_{l \in \text{Room}} \sum_{m \in \text{Time}} X_{ij' \text{ Sunday}lm} + \beta \sum_{i \in \text{Student}} \sum_{j \in \text{Subject}} \sum_{k \in \text{Day}} \sum_{l \in \text{Room}} \sum_{m \in \text{Time}} X_{ijklm}$$

Initially, the working hours for each day had to be extended from the original working hours actually allotted for the sake of feasibility. Hence the objective function of this model is built with two choices either to study until late in the weekdays thereby avoiding to study on Sundays or to study on Sundays and hence avoiding working late on weekdays. This choice can be made by the user depending upon their priority. If the user chooses to study late on weekdays then the balance coefficient  $\alpha$  is set to a high value and the  $\beta$  balance coefficient is made very small indicating their preference. If the user wishes to study on Sundays rather than working late on weekdays,  $\alpha$  value is made very small and  $\beta$  is set to a very high value.

## MODELING CHALLENGES

The Homeschool TTP is very dynamic in nature, meaning that the subjects, requirements and the resources are bound to change within each year for every student. Due to this the model built for the purpose of generating a timetable every semester should be kept as flexible as possible. In keeping the model flexible there is a need to foresee some of the possible changes that the model should be able to accommodate in the future. Since this TTP is closely associated with a particular audience, there are also some constraints that were very specific to this problem which are to be satisfied not for feasibility but for user preference. Some of the modeling challenges faced are discussed below:

- It is required that some subjects be absolutely taken on certain days and some have the flexibility on which days it could to be taken. But all the subjects are to be taken exactly a specific number of times in a week. Hence constraints were built in order to satisfy both these requirements when students study either individually or in groups. (refer to constraints 1, 2 and 3)
- Students have to take subjects that require the use of resources such as the piano and computers. Currently there is one piano which is available in the kitchen and there are two computers one available in the computer room and other is located in the bedroom. Due to the fact that these resources are available only at specific

rooms of the house, at any instant of time only a limited number of students can use these resources at the same time. For example, since there is only one piano available in the kitchen, not more than one student can study a subject that requires the use of a piano at the same time. Moreover, since the piano is located in the kitchen which opens into the living room, when piano is scheduled in the kitchen no other student can study any subject in the living room or in the kitchen at the same time. This condition is true when students study either individually or in groups. (refer to constraints 6, 7, 12 & 13)

- It is a requirement that students must study some subjects individually and some only in groups. Among the subjects that are to be studied in groups it is again required that some subjects be studied in groups of 4 (Kayla, Karissa, Micah and Leah) at the same time  $m$  and in the same room  $l$ . A few subjects require Kayla and Karissa to study together in one group whereas Micah and Leah must study individually. Whenever students are required to study in groups it is also to be made sure that all students in the group study together at the same time  $m$  and in the same room  $l$ . (refer to constraint 8) A detailed list of group and individual study subjects is provided in Appendix 3.
- Mother's guidance is essential when students study certain subjects. This means that students can take those subjects only when Mother is present. Hence availability times of Mother are required in order to schedule these subjects. At any instant of time Mother can guide at most one student or group. (Refer to

constraint 9). When Mother is not available no student is allowed to take a subject that requires her assistance.

- Every subject is to be studied for varied durations. This model is set to handle durations in terms of time slots of 15 minutes each. Now, if a subject is to be studied for 45 minutes then that subject should be allotted 3 timeslots. Apart from this it is also required that these slots be continuous. For example, if Kayla has to study subject “Readers” for 45 minutes on Monday in the living room. Then Kayla is required to study the subject for three consecutive time slots. Hence if she starts studying “Readers” on Monday in the living room at time slot 4, she should continue studying the subject on the same day in the same room at time slots 5 and 6. Hence the constraints should make sure that she starts studying that subject in a time slot and the number of time slots for which she studies that subject is continuous.



## TESTING PROCESS

The testing process for the model involved designing various data sets which are smaller in size. These data sets put together were used to test the model exhaustively as they covered different scenarios possible. The information in each data set includes the subjects, the students who take each subject, information about the days each subject should be taken, the duration for the same and resources required for each subject. It also includes information about the availability times of the mother and if she is required to be present when a student takes a particular subject.

Dataset 1 (See Appendix 2) is a simple one, involving just one subject “Piano1” taken by Kayla and Karissa only. To keep things simple, this data set included just Monday and has 4 time slots of 15 minutes each. In order to test the correctness of the time constraints “Piano1” is set to be taken for two consecutive time slots. Subject “Piano1” is to be taken only in the kitchen where the piano is available. Since it is a non-group subject, the group constraints are not tested using this dataset. Mother’s assistance is not required for this subject hence “Mom constraint” is also not tested here. In the next dataset, Dataset 2 (See Appendix 2), subject “Piano 2” is added to the previous dataset for Micah and Leah only. All other parameters remain the same for this dataset except the number of time slots which is 8 here. The timetable schedule for these subjects is given below and the model generated about 1102 constraints and 576 variables:

| Name/Venue              | Kayla     | Karissa   | Micah     | Leah      |
|-------------------------|-----------|-----------|-----------|-----------|
| <b>Monday/Timeslots</b> |           |           |           |           |
| 1                       |           | Piano1(K) |           |           |
| 2                       |           | Piano1(K) |           |           |
| 3                       | Piano1(K) |           |           |           |
| 4                       | Piano1(K) |           |           |           |
| 5                       |           |           | Piano2(K) |           |
| 6                       |           |           | Piano2(K) |           |
| 7                       |           |           |           | Piano2(K) |
| 8                       |           |           |           | Piano2(K) |

**Table 3: Timetable schedule for dataset 2**

The primary aim of dataset 3 (See Appendix 2) is to test the correctness of computer constraint. Here the only subject in the dataset is “Math” which requires the use of a computer for all four students. There are only 2 computers available and hence not more than two students can study this subject at the same time. This subject is tested only for Monday and is to be taken only for 15 minutes. It does not require mother’s assistance for the children and is to be studied individually. Dataset 4 is simply the combination of the previous three data sets. It also tests the constraint, “When piano is scheduled in the kitchen, no other subject could be studied either in the kitchen or in the living room.” The model for this dataset generated about 1621 constraints and 864 variables. The solution for dataset 4 is given below.

| Name/Venue              | Kayla     | Karissa   | Micah     | Leah      |
|-------------------------|-----------|-----------|-----------|-----------|
| <b>Monday/Timeslots</b> |           |           |           |           |
| 1                       | Piano1(K) | Math(CR)  | Math(CR)  |           |
| 2                       | Piano1(K) |           |           |           |
| 3                       |           |           |           | Piano2(K) |
| 4                       | Math(CR)  |           |           | Piano2(K) |
| 5                       |           |           | Piano2(K) |           |
| 6                       |           |           | Piano2(K) | Math(CR)  |
| 7                       |           | Piano1(K) |           |           |
| 8                       |           | Piano1(K) |           |           |

**Table 4: Timetable schedule for dataset 4**

Unlike the previous datasets this dataset included Tuesday in addition to Monday.

Dataset 5 has the same set of subjects as dataset4 with the addition of Tuesday to dataset

4. The schedule produced by the model for this data set looks like below and about 4208 constraints and 2304 variables were generated.

| Name/Venue              | Kayla | Karissa   | Micah    | Leah      |
|-------------------------|-------|-----------|----------|-----------|
| <b>Monday/Timeslots</b> |       |           |          |           |
| 1                       |       | Piano1(K) |          | Math(CR)  |
| 2                       |       | Piano1(K) |          |           |
| 3                       |       |           | Math(BR) | Piano2(K) |
| 4                       |       | Math(BR)  |          | Piano2(K) |

|   |           |  |           |  |
|---|-----------|--|-----------|--|
| 5 | Piano1(K) |  |           |  |
| 6 | Piano1(K) |  |           |  |
| 7 |           |  | Piano2(K) |  |
| 8 | Math(CR)  |  | Piano2(K) |  |

**Table 5: Timetable schedule for dataset 5 (Monday)**

| Name/Venue               | Kayla     | Karissa   | Micah     | Leah      |
|--------------------------|-----------|-----------|-----------|-----------|
| <b>Tuesday/Timeslots</b> |           |           |           |           |
| 1                        | Piano1(K) |           |           |           |
| 2                        | Piano1(K) | Math(BR)  |           | Math(BR)  |
| 3                        | Math(CR)  | Piano1(K) |           |           |
| 4                        |           | Piano1(K) |           |           |
| 5                        |           |           | Piano2(K) |           |
| 6                        |           |           | Piano2(K) |           |
| 7                        |           |           |           | Piano2(K) |
| 8                        |           |           | Math(CR)  | Piano2(K) |

**Table 6 : Timetable schedule for dataset 5 (Tuesday)**

Dataset 6 (See Appendix 2) tests the correctness of the “Mom constraint”. Here the subject “PianoL” which requires Mother’s assistance is added in addition to the previously mentioned subjects. Tuesday is not included in this data set and “PianoL” is to be taken for just one time slot. The number of time slots available is increased to 12 to be able to accommodate all of the subjects. All of the subjects here are to be taken

individually. Dataset 7 (See Appendix 2) is similar to dataset 6 with addition of Tuesday.

The solution for dataset 7 looks like below and the model generated about 8200

constraints and 4608 variables.

| <b>Name/Venue</b>       | <b>Kayla</b> | <b>Karissa</b> | <b>Micah</b> | <b>Leah</b> |
|-------------------------|--------------|----------------|--------------|-------------|
| <b>Monday/Timeslots</b> |              |                |              |             |
| 1                       | Math(CR)     |                |              | Piano2(K)   |
| 2                       |              |                |              | Piano2(K)   |
| 3                       |              |                | Piano2(K)    |             |
| 4                       |              |                | Piano2(K)    |             |
| 5                       |              | Piano1(K)      |              |             |
| 6                       |              | Piano1(K)      |              |             |
| 7                       |              |                | PianoL(K)    |             |
| 8                       |              | PianoL(K)      |              |             |
| 9                       | PianoL(K)    |                |              |             |
| 10                      |              |                |              | PianoL(K)   |
| 11                      | Piano1(K)    | Math(BR)       |              |             |
| 12                      | Piano1(K)    |                | Math(BR)     | Math(BR)    |

**Table 7: Timetable schedule for dataset 7 (Monday)**

| Name/Venue               | Kayla     | Karissa   | Micah     | Leah      |
|--------------------------|-----------|-----------|-----------|-----------|
| <b>Tuesday/Timeslots</b> |           |           |           |           |
| 1                        |           | PianoL(K) | Math(BR)  | Math(BR)  |
| 2                        | Math(CR)  | Math(BR)  |           | PianoL(K) |
| 3                        |           | Piano1(K) |           |           |
| 4                        |           | Piano1(K) |           |           |
| 5                        | Piano1(K) |           |           |           |
| 6                        | Piano1(K) |           |           |           |
| 7                        |           |           | PianoL(K) |           |
| 8                        |           |           |           | Piano2(K) |
| 9                        |           |           |           | Piano2(K) |
| 10                       | PianoL(K) |           |           |           |
| 11                       |           |           | Piano2(K) |           |
| 12                       |           |           | Piano2(K) |           |

**Table 8: Timetable schedule for dataset 7 (Tuesday)**

The next data set is designed to test all the constraints in the model. Dataset 8 (See Appendix 2) has 5 subjects in total and tests the correct working of the group constraint in addition to others. It is tested only for Monday, has 13 timeslots and “Devotions” is the additional subject here. “Devotions” is to be taken in groups of 4 and mother’s guidance is required for this subject. Dataset 9 has Tuesday in addition to other parameters in

dataset 8. About 11006 constraints and 6240 variables were generated by the model for this dataset. The optimal schedule for this dataset is given below.

| Name/Venue              | Kayla         | Karissa       | Micah         | Leah          |
|-------------------------|---------------|---------------|---------------|---------------|
| <b>Monday/Timeslots</b> |               |               |               |               |
| 1                       | Math(BR)      |               |               | Piano2(K)     |
| 2                       |               |               |               | Piano2(K)     |
| 3                       |               |               | PianoL(K)     |               |
| 4                       | PianoL(K)     | Math(BR)      |               |               |
| 5                       |               |               |               |               |
| 6                       |               |               | Piano2(K)     |               |
| 7                       |               |               | Piano2(K)     |               |
| 8                       |               | Piano1(K)     |               |               |
| 9                       |               | Piano1(K)     |               |               |
| 10                      | Piano1(K)     |               |               |               |
| 11                      | Piano1(K)     |               |               |               |
| 12                      | Devotions(LR) | Devotions(LR) | Devotions(LR) | Devotions(LR) |
| 13                      |               | PianoL(K)     | Math(BR)      | Math(BR)      |

**Table 9: Timetable schedule for dataset 9 (Monday)**

| Name/Venue               | Kayla     | Karissa   | Micah     | Leah      |
|--------------------------|-----------|-----------|-----------|-----------|
| <b>Tuesday/Timeslots</b> |           |           |           |           |
| 1                        |           |           | Math(BR)  | PianoL(K) |
| 2                        | Piano1(K) | Math(BR)  |           | Math(CR)  |
| 3                        | Piano1(K) |           |           |           |
| 4                        | PianoL(K) |           |           |           |
| 5                        |           |           | Piano2(K) | PianoL(K) |
| 6                        |           |           | Piano2(K) |           |
| 7                        |           |           | PianoL(K) |           |
| 8                        |           |           |           |           |
| 9                        |           |           |           | Piano2(K) |
| 10                       |           |           |           | Piano2(K) |
| 11                       |           | Piano1(K) |           |           |
| 12                       |           | Piano1(K) |           |           |
| 13                       | Math(BR)  | PianoL(K) |           |           |

**Table 10: Timetable schedule for dataset 9 (Tuesday)**

Dataset 10 (See Appendix 2) has about 19 subjects and is larger than the previous datasets. The total number of timeslots available here is 52 and the days used include Monday through Friday and Sunday. The dataset has three subjects that use the Piano and one subject that uses the computer. Mother's assistance is required for 7 subjects for different sets of students. Some subjects require the students to study individually and



others in groups. The dataset was run with model and a feasible timetable schedule was obtained.

#### Limitations:

The model designed was able to find a feasible solution for dataset 10. When more subjects were added to this dataset the model was unable to find an integer feasible solution due to size limitations of the virtual memory. The model was run on a personal computer with 4 GB RAM with a processor speed of 2.0 GHz. When a dataset with 15 subjects was run, the model compiled without any errors. The total run time for this dataset was about 26 hours after which it ran out of virtual memory space (RAM). This is thought to be because of the numerous variables (generally in millions) generated by the model.

## SOLUTION PROCESS

As mentioned earlier a GUI is built to facilitate the user in entering the required information for building a timetable. The forms were designed using Visual Basic in Visual Studio Express 2010. The various forms that are required to obtain the information are listed below with a brief idea of the functionality.

### Startup Form



Figure 1: Startup Form.

Figure 1 gives a view of how the welcome page is set up. There are five buttons in the startup form and when each button is clicked a popup form appears. These five buttons are used to obtain all the information that is required to generate the data required for the model. The “Help” button on the welcome page guides the user in filling the forms.

### Student details Form

The image shows a screenshot of a software application window titled 'frmSecond'. The window has a background illustration of a library with bookshelves and a girl sitting on the floor reading. A yellow dialog box, labeled 'GroupBox1', is centered on the screen. Inside this dialog box, there is a text input field with the label 'Enter Student's Name'. Below the input field is an 'OK' button. Underneath the 'OK' button is a label 'Students entered are:' followed by a large, empty text area with a vertical scrollbar. At the bottom of the main application window, there are two buttons: 'Help' on the left and 'DONE' on the right.

Figure 2: Student Details Form

Through this form the user can enter the names of the students for whom the timetable is to be generated. When the user enters the first students name and hits the “OK” button it

automatically appears in the “Students entered are” textbox. Finally, when all the names have been entered, the user hits the “DONE” button confirming the list of students.

### Room details Form

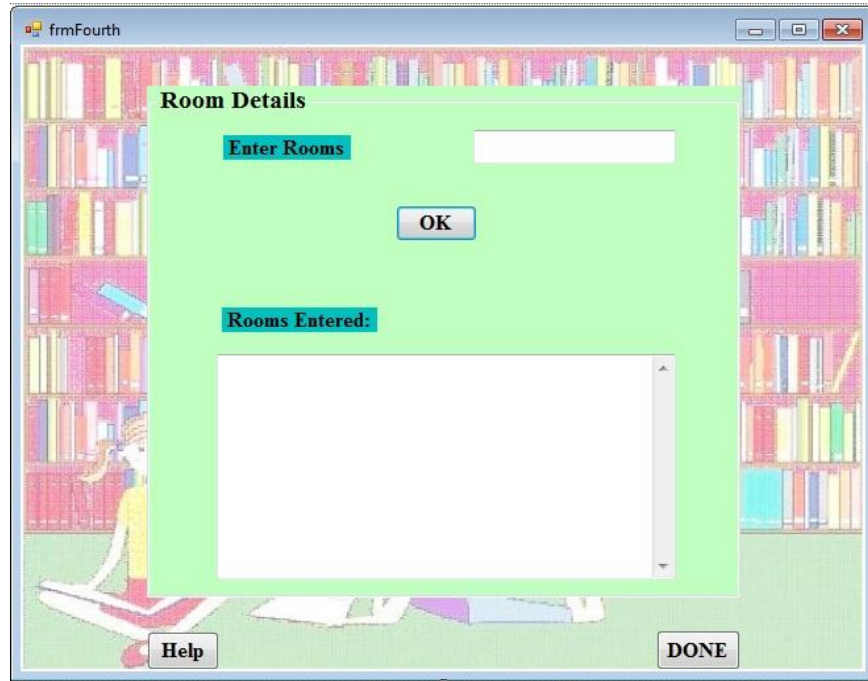


Figure 3: Room Details Form 1

Similar to the student details form in this form the user enters the names of all the rooms available for the students to study. The “Help” button guides the user in entering the details.

## Subject details Forms



Figure 4: Subject details Form 1

This form is used to enter the entire list of subjects that all students are required to take. After the list is entered, the “Next” button takes the user to the next forms, where specific details about each subject could be entered. The list subjects entered in this form automatically appears in the next form when the “Next” button is clicked.

Figure 5: Subject details Form 2

This form is used to enter specific details about each subject. The subject list entered in the previous form automatically appears under “Subject List” (Figure ). Now across each subject there are various check boxes present. These checkboxes help in providing information about which student takes that subject on what days. So the user has to simply click on the checkboxes for each subject. Under the “Properties” group box there are three groups of checkboxes. For every subject that requires the use of computer, the corresponding “Comp” checkbox is marked. The “Group” and the “Individual” checkboxes are used to specify if a subject is to be studied individually or in groups. When the “Group” checkbox is checked another form pops up requesting information about the number of groups and the students in each group. The “Freq” listbox is used to specify the number of time a subject must be studied in a week.



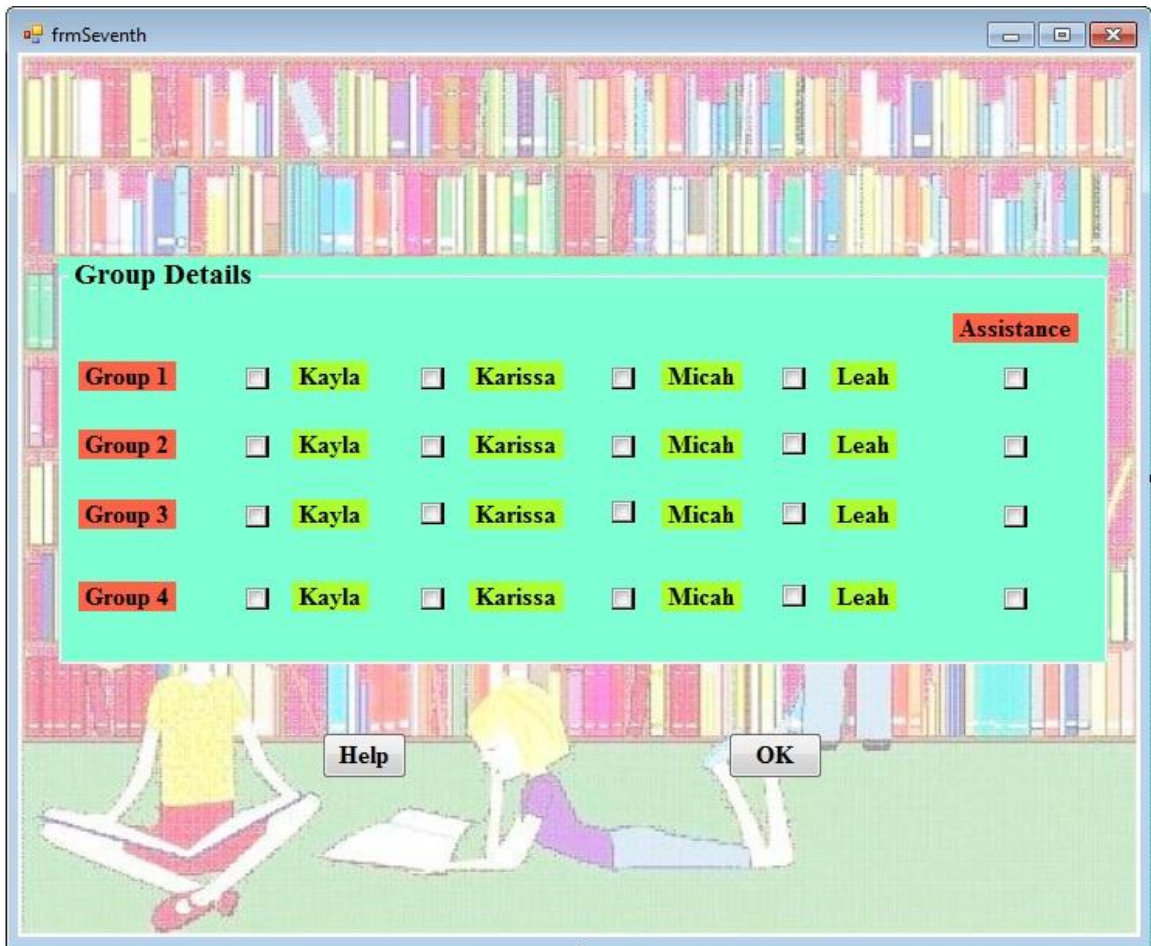


Figure 6: Group assistance form

Through this form details about the group can be specified. There is also a set of checkboxes under “Assistance”. These checkboxes are marked if a parent/tutor is required to be present with student while studying that subject.

The screenshot shows a software window titled "frmEighth" with a decorative border. The main content area is split into two panes. The left pane, titled "Subject List", is empty. The right pane, titled "Rooms", contains a table of checkboxes. The columns are labeled "Living Room", "Bed Room1", "Kitchen", "Computer Room", "Bed Room2", and "Outside". Each column has 15 checkboxes, all of which are currently unchecked. At the bottom left of the window is a "Help" button, and at the bottom right is an "OK" button.

Figure 7: Room Details Form 2

Once the lists of subjects and rooms have been entered, this form is used to enter details about which rooms could be used to study a particular subject. For example: Subject that requires the use of a computer could be studied either in the bed room (BR) or in the computer room (CR).



## Tutor details form

| Time Slots           | Monday                   | Tuesday                  | Wednesday                | Thursday                 | Friday                   |
|----------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 01 (08:00 - 08:15am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 02 (08:15 - 08:30am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 03 (08:30 - 08:45am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 04 (08:45 - 09:00am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 05 (09:00 - 09:15am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 06 (09:15 - 09:30am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 07 (09:30 - 09:45am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 08 (09:45 - 10:00am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 09 (10:00 - 10:15am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 10 (10:15 - 10:30am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 11 (10:30 - 10:45am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 12 (10:45 - 11:00am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 13 (11:00 - 11:15am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 14 (11:15 - 11:30am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 15 (11:30 - 11:45am) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 16 (11:45 - 12:00pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 17 (01:00 - 01:15pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 18 (01:15 - 01:30pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 19 (01:30 - 01:45pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 20 (01:45 - 02:00pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 21 (02:00 - 02:15pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 22 (02:15 - 02:30pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 23 (02:30 - 02:45pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 24 (02:45 - 03:00pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 25 (03:00 - 03:15pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 26 (03:15 - 03:30pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 27 (03:30 - 03:45pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 28 (03:45 - 04:00pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 29 (04:00 - 04:15pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 30 (04:15 - 04:30pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 31 (04:30 - 04:45pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 32 (04:45 - 05:00pm) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Figure 8: Tutor availability form

When the “Tutor” button on the startup page is clicked, this form appears. The availability times of the tutor or the parent over the week could be specified through this form. When the checkbox is marked it indicates that the tutor is available and busy otherwise.

## Preferences form

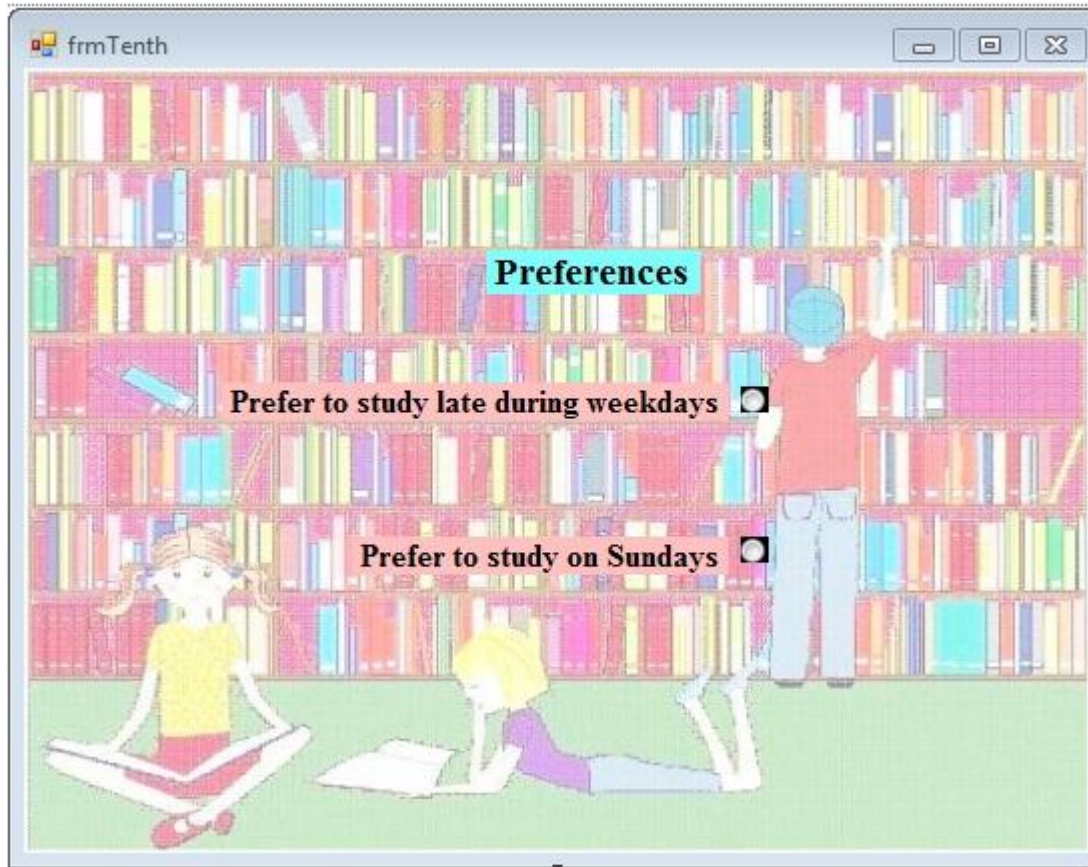


Figure 9: Preferences form

This form appears when user clicks the “Preferences” button on the Startup form. It is used to indicate the user’s preference for the children to study late during the weekdays or study on Sundays.

Once all the necessary information is provided through the forms, it is then saved in Microsoft Excel® directly. The Excel file is then stored as a comma delimited .csv file before feeding it to the GLPK model as the data file. The model is then run along with the data to find a feasible timetable. If an optimal solution is found, it is then converted into a readable format by feeding it back to the software.

## SUMMARY AND FUTURE DIRECTIONS

Many researchers in the past have analyzed and formulated different techniques such as tabu search, simulated annealing, genetic algorithms, graph coloring techniques etc. to solve a variant of the timetabling problem (TTP). Each TTP varies with the type of institution (school or university) being considered, the constraints involved, and the approach used to analyze and solve the problem. In this project, integer programming has been used to solve a homeschool timetabling problem (HSTTP). The HSTTP is very similar to the school TTP, university-course scheduling problem and the examination TTP. Here, an automated timetable is being built for the purpose of homeschooling four children.

A math model was built in order to schedule about 30 subjects for all four children over the week. The model was designed to satisfy certain constraints involving the number of resources required, parent availability, specific room allotments, etc. Having checked the model for errors this math model was programmed using GLPK. Alongside a prototype in the form of a GUI was built in Visual Basic. The basic idea behind the GUI is to create user friendly forms so that parents can enter the necessary information such as students' name, his/her subjects, details about the duration, days and time for each subject, availability times of the parent etc. The data entered is dumped in to Microsoft Excel® and this is then fed in to the model built as a .CSV file. The model along with the data is then run to check if an optimal timetable schedule exists. When a feasible timetable

solution is found it is formatted in such a way that it can provide the weekly timetable for each student individually as well as a complete timetable for all students each day.

During the testing process, the model was run with various smaller sets of data in order to check for feasibility and correctness. The model was able to produce an optimal timetable schedule for these smaller datasets successfully. However, a serious limitation of computational space occurred when larger datasets were fed in to the model. Specifically, for datasets containing more than 14 subjects the model was found to run out of memory while trying to get a feasible solution. Although the model schedules subjects by satisfying all of the constraints, due to the limitations of virtual memory available in any home PC, we were unable to find an optimal schedule for this model.

As an extension of this applied project, a possible direction would be to concentrate on model reduction. The model designed for the actual data requires a lot of computational space and time in order to arrive at a feasible schedule. This may not be practical with the average household computer specifications. In such a case, the user could be consulted for possible constraint relaxations that could be done. Another possible direction would be in improving the current GUI. The GUI could be further enhanced to directly feed the user data into GLPK in order to obtain a feasible timetable. Once a solution is found, this again could be fed back directly to the GUI so that the solution is presented in a readable format without the need of Microsoft Excel®.

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## APPENDIX 1 COMPLETE MODEL AND DATA FILE

Complete Model File:

```
set STUDENT;
set SUBJECT;
set DAY;
set ROOM;
set TIME;
set COMPSUB;
set GROUP;
set PianoRooms;
set PianoSubjects;
set KandK;
set KKandM;

param NumStudents >=0;
param D{j in SUBJECT, i in STUDENT, k in DAY} >= 0;
param NumDays{j in SUBJECT, i in STUDENT} >= 0;
param NumDaysG{j in SUBJECT, t in GROUP} >=0;
param R {j in SUBJECT, l in ROOM} >= 0;
param M{m in TIME, k in DAY} >= 0;
param C{j in SUBJECT} >= 0;
param T{j in SUBJECT, t in GROUP} >= 0;
param G{i in STUDENT, t in GROUP, j in SUBJECT} >= 0;
param Numgroups{j in SUBJECT} >= 0;
param alpha >= 0;
param beta >= 0;

var X {j in SUBJECT, i in STUDENT, k in DAY, l in ROOM, m in
TIME}, binary;

var Z {j in SUBJECT, i in STUDENT, k in DAY, l in ROOM, m in
TIME}, binary;

var Y {j in SUBJECT, t in GROUP, k in DAY, l in ROOM, m in TIME},
binary;

minimize obj: sum{j in SUBJECT, i in STUDENT, l in ROOM, m in
TIME}(alpha * X[j, i, 'Sunday', l, m]) + sum{j in SUBJECT, i in
STUDENT, k in DAY, l in ROOM, m in TIME} (beta * X[j, i, k, l,
m]);

/*Subjects that are to be absolutely taken on certain days of the
week.*/
subject to constraint1{j in SUBJECT, i in STUDENT, k in DAY}:
```

```

sum{l in ROOM, m in TIME} X[j, i, k, l, m] >= D[j, i, k];

/* Number of days in a week a subject must be taken */
subject to constraint2{j in SUBJECT, i in STUDENT}:
    sum{k in DAY, l in ROOM, m in TIME} X[j, i, k, l, m] =
NumDays[j, i];

/* Number of days in a week a subject must be taken by a group */
subject to constraint3{j in SUBJECT, t in GROUP}:
    sum{k in DAY, l in ROOM, m in TIME} Y[j, t, k, l, m] =
NumDaysG[j, t];

/* Not more than one Subject, j can be taken by any Student, i on
any Day k. */
subject to constraint4{i in STUDENT, j in SUBJECT, k in DAY}:
    sum{l in ROOM, m in TIME} X[j, i, k, l, m] <= 1;

/* Not more than one Subject i can be taken in any Time,m and a
Student, i cannot be in more than one Room, l at any time m.*/
subject to constraint5{i in STUDENT, k in DAY, m in TIME}:
    sum{j in SUBJECT, l in ROOM} Z[j, i, k, l, m] <= 1;

/* Not more than 2 students can study a subject that requires the
use of a computer at the same time.*/
subject to constraint6{k in DAY, m in TIME}:
    sum{i in STUDENT, j in COMPSUB, l in ROOM} Z[j, i, k, l, m]
<=2;

/* Certain subjects can only be taken in any one of the rooms
specified.*/
subject to constraint7{j in SUBJECT, k in DAY, l in ROOM}:
    sum{i in STUDENT, m in TIME} X[j, i, k, l, m] <=
(NumStudents * R[j, l]);

/*Certain subjects are to be studied in groups and some
individually.*/
subject to constraint8{i in STUDENT, j in SUBJECT, k in DAY, l in
ROOM, m in TIME, t in GROUP}:
    X[j, i, k, l, m] >= (G[i, t, j] * Y[j, t, k, l, m]);

/*Students can take certain subject only when mom is present.*/
subject to constraint9{k in DAY, m in TIME}:
    sum{j in SUBJECT, t in GROUP, l in ROOM} ((T[j, t]) * Y[j,
t, k, l, m]) <= M[m, k];

/* Consecutive time constraint: The subjects are to be allotted
the required number of consecutive time constraints depending on
the availability.*/
subject to constraint10{i in STUDENT, j in SUBJECT, k in DAY, l
in ROOM, m in TIME}:
    Z[j, i, k, l, m] <= (sum{s in max(1,m+1-C[j])..m} X[j, i,
k, l, s]);

```

```

/* If student i, begins subject j on day k, that subject should
be studied for exactly Cj time slots that day */
subject to constraint11{i in STUDENT, j in SUBJECT, k in DAY, l
in ROOM}:
    sum{m in TIME} Z[j, i, k, l, m] = (C[j] * (sum{m in TIME}
X[j, i, k, l, m]));

/* Piano Constraint1: No other subject j can be taken either in
the living room or in the kitchen when piano is scheduled in the
kitchen.*/
subject to constraint12{p in STUDENT, k in DAY, m in TIME}:
    sum{i in STUDENT, j in SUBJECT, l in PianoRooms} Z[j, i, k,
l, m] - sum{j in SUBJECT, l in PianoRooms} Z[j, p, k, l, m] <=
NumStudents*(1 - (sum{j in PianoSubjects, l in PianoRooms} Z[j,
p, k, l, m]));

/* Piano Constraint2: Not more than one student can study a
subject that requires the use of a piano at the same time.*/
subject to constraint13{k in DAY, m in TIME}:
    sum{i in STUDENT, j in PianoSubjects, l in ROOM} Z[j, i, k,
l, m] <= 1;

/* Specific timed subjects: These are the constraints for
subjects that must be taken at a specific time on a specific day
outside at an institution*/
subject to constraint14a:
    sum{i in STUDENT} X['BSandC', i, 'Sunday', 'OUT', 5] = 4;

subject to constraint14b:
    sum{i in STUDENT} X['FWB', i, 'Thursday', 'OUT', 19] = 4;

subject to constraint14c:
    X['DrumsL', 'Micah', 'Thursday', 'OUT', 33] = 1;

subject to constraint14d:
    sum{i in KandK} X['Choir', i, 'Monday', 'OUT', 43] = 2;

subject to constraint14e:
    sum{i in KandK} X['HH', i, 'Thursday', 'OUT', 27] = 2;

subject to constraint14f:
    sum{i in KKandM} X['Swimming', i, 'Thursday', 'OUT', 23] =
3;

```

Complete data File:

```
set STUDENT := Kayla, Karissa, Micah, Leah;

set SUBJECT := Readers, ReadAloud, ReadCompre, History,
HistoryCompre, Math, ScienceHS, Science, SciGradComp, Piano1,
Piano2, Grading, Writing, Devotions, BSandC, Choir, DrumsL,
PianoL, FWB, Swimming, HH, Drums, Bible, Memorywork,
MemoryRecite, Typing, Art1, Art2, PED1, PED2, PEDPrac;

set DAY := Monday, Tuesday, Wednesday, Thursday, Friday, Sunday;

set ROOM := LR, BR, KT, MBR, OUT, CR;

set TIME := 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31,
32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47,
48, 49, 50, 51, 52;

set COMPSUB := Math, ScienceHS, Writing, Grading, Typing, Art2,
PED1, PED2, PEDPrac;

set GROUP := 1, 2, 3, 4;

set PianoRooms := KT, LR;

set PianoSubjects := Piano1, Piano2, PianoL;

set KandK := Kayla, Karissa;

set KKandM := Kayla, Karissa, Micah;

param alpha := 10000;

param beta := 2;

param NumStudents := 4;

param D :=
[* , * , Monday]: Kayla Karissa      Micah Leah :=
Math 1      1      1      1
Piano1     1      1      0      0
Piano2     0      0      1      1
Devotions  0      0      0      0
BSandC     0      0      0      0
Choir1     1      0      0
DrumsL     0      0      0      0
PianoL     0      0      0      0
FWB        0      0      0      0
Swimming   0      0      0      0
```

|               |   |   |   |   |   |
|---------------|---|---|---|---|---|
| HH            | 0 | 0 | 0 | 0 |   |
| Readers       | 1 | 1 | 1 | 1 |   |
| ReadAloud     | 0 | 0 | 0 | 0 |   |
| ReadCompre    | 0 | 0 | 0 | 0 |   |
| History       | 1 | 1 | 1 | 1 |   |
| HistoryCompre | 0 | 0 | 0 | 0 | 0 |
| ScienceHS     | 1 | 1 | 0 | 0 |   |
| Science       | 0 | 0 | 0 | 1 | 1 |
| SciGradComp   | 0 | 0 | 0 | 0 | 0 |
| Grading       | 0 | 0 | 0 | 0 |   |
| Writing       | 1 | 1 | 1 | 1 |   |
| Drums         | 0 | 1 | 0 |   |   |
| Bible         | 1 | 1 | 1 |   |   |
| Memorywork    | 0 | 0 | 0 | 0 |   |
| MemoryRecite  | 0 | 0 | 0 | 0 | 0 |
| Typing        | 1 | 1 | 1 | 1 |   |
| Art1          | 0 | 0 | 0 | 0 |   |
| Art2          | 0 | 0 | 0 | 0 |   |
| PED1          | 1 | 1 | 0 | 0 |   |
| PED2          | 0 | 0 | 0 | 0 |   |
| PEDPrac       | 1 | 1 | 1 | 1 |   |

|                   |   |   |   |       |         |  |       |         |
|-------------------|---|---|---|-------|---------|--|-------|---------|
| [*, *, Tuesday] : |   |   |   | Kayla | Karissa |  | Micah | Leah := |
| Math              | 1 | 1 | 1 | 1     |         |  |       |         |
| Piano1            | 1 | 1 | 0 | 0     |         |  |       |         |
| Piano2            | 0 | 0 | 1 | 1     |         |  |       |         |
| Devotions         | 1 | 1 | 1 | 1     |         |  |       |         |
| BSandC            | 0 | 0 | 0 | 0     |         |  |       |         |
| Choir             | 0 | 0 | 0 | 0     |         |  |       |         |
| DrumsL            | 0 | 0 | 0 | 0     |         |  |       |         |
| PianoL            | 0 | 0 | 0 | 0     |         |  |       |         |
| FWB               | 0 | 0 | 0 | 0     |         |  |       |         |
| Swimming          | 0 | 0 | 0 | 0     |         |  |       |         |
| HH                | 0 | 0 | 0 | 0     |         |  |       |         |
| Readers           | 1 | 1 | 1 | 1     |         |  |       |         |
| ReadAloud         | 0 | 0 | 1 | 1     |         |  |       |         |
| ReadCompre        | 1 | 1 | 1 | 1     |         |  |       |         |
| History           | 1 | 1 | 1 | 1     |         |  |       |         |
| HistoryCompre     | 1 | 1 | 1 | 1     |         |  |       | 1       |
| ScienceHS         | 1 | 1 | 0 | 0     |         |  |       |         |
| Science           | 0 | 0 | 1 | 1     |         |  |       |         |
| SciGradComp       | 1 | 1 | 1 | 1     |         |  |       | 1       |
| Grading           | 0 | 0 | 0 | 0     |         |  |       |         |
| Writing           | 1 | 1 | 1 | 1     |         |  |       |         |
| Drums             | 0 | 0 | 1 | 0     |         |  |       |         |
| Bible             | 1 | 1 | 1 | 1     |         |  |       |         |
| Memorywork        | 0 | 0 | 0 | 0     |         |  |       |         |
| MemoryRecite      | 0 | 0 | 0 | 0     |         |  |       | 0       |
| Typing            | 1 | 1 | 1 | 1     |         |  |       |         |
| Art1              | 0 | 0 | 0 | 0     |         |  |       |         |
| Art2              | 0 | 0 | 0 | 0     |         |  |       |         |

|         |   |   |   |   |
|---------|---|---|---|---|
| PED1    | 1 | 1 | 0 | 0 |
| PED2    | 0 | 0 | 0 | 0 |
| PEDPrac | 1 | 1 | 1 | 1 |

|                     |   |   |   |   |               |               |
|---------------------|---|---|---|---|---------------|---------------|
| [*, *, Wednesday] : |   |   |   |   | Kayla Karissa | Micah Leah := |
| Math                | 1 | 1 | 1 |   |               |               |
| Piano1              | 1 | 1 | 0 | 0 |               |               |
| Piano2              | 0 | 0 | 1 | 1 |               |               |
| Devotions           | 1 | 1 | 1 | 1 |               |               |
| BSandC              | 0 | 0 | 0 | 0 |               |               |
| Choir               | 0 | 0 | 0 |   |               |               |
| DrumsL              | 0 | 0 | 0 | 0 |               |               |
| PianoL              | 0 | 0 | 0 | 0 |               |               |
| FWB                 | 0 | 0 | 0 |   |               |               |
| Swimming            | 0 | 0 | 0 | 0 |               |               |
| HH                  | 0 | 0 | 0 |   |               |               |
| Readers             | 1 | 1 | 1 | 1 |               |               |
| ReadAloud           | 0 | 0 | 1 | 1 |               |               |
| ReadCompre          | 1 | 1 | 1 | 1 |               |               |
| History             | 1 | 1 | 1 | 1 |               |               |
| HistoryCompre       | 1 | 1 | 1 | 1 | 1             |               |
| ScienceHS           | 1 | 1 | 0 | 0 |               |               |
| Science             | 0 | 0 | 1 | 1 |               |               |
| SciGradComp         | 1 | 1 | 1 | 1 | 1             |               |
| Grading             | 1 | 1 | 1 | 1 |               |               |
| Writing             | 1 | 1 | 1 | 1 |               |               |
| Drums               | 0 | 0 | 1 | 0 |               |               |
| Bible               | 1 | 1 | 1 |   |               |               |
| Memorywork          | 0 | 0 | 0 | 0 |               |               |
| MemoryRecite        | 0 | 0 | 0 | 0 | 0             |               |
| Typing              | 1 | 1 | 1 | 1 |               |               |
| Art1                | 0 | 0 | 0 |   |               |               |
| Art2                | 0 | 0 | 0 |   |               |               |
| PED1                | 1 | 1 | 0 | 0 |               |               |
| PED2                | 0 | 0 | 0 |   |               |               |
| PEDPrac             | 1 | 1 | 1 | 1 |               |               |

|                    |   |   |   |   |               |               |
|--------------------|---|---|---|---|---------------|---------------|
| [*, *, Thursday] : |   |   |   |   | Kayla Karissa | Micah Leah := |
| Math               | 1 | 1 | 1 |   |               |               |
| Piano1             | 1 | 1 | 0 | 0 |               |               |
| Piano2             | 0 | 0 | 1 | 1 |               |               |
| Devotions          | 0 | 0 | 0 | 0 |               |               |
| BSandC             | 0 | 0 | 0 | 0 |               |               |
| Choir              | 0 | 0 | 0 |   |               |               |
| DrumsL             | 0 | 0 | 1 | 0 |               |               |
| PianoL             | 0 | 0 | 0 | 0 |               |               |
| FWB                | 1 | 1 | 1 | 1 |               |               |
| Swimming           | 1 | 1 | 1 | 0 |               |               |
| HH                 | 1 | 1 | 0 | 0 |               |               |
| Readers            | 1 | 1 | 1 | 1 |               |               |

|               |   |   |   |   |   |
|---------------|---|---|---|---|---|
| ReadAloud     | 0 | 0 | 0 | 0 |   |
| ReadCompre    | 0 | 0 | 0 | 0 |   |
| History       | 1 | 1 | 1 | 1 |   |
| HistoryCompre | 0 | 0 | 0 | 0 | 0 |
| ScienceHS     | 1 | 1 | 0 | 0 |   |
| Science       | 0 | 0 | 0 | 0 |   |
| SciGradComp   | 0 | 0 | 0 | 0 | 0 |
| Grading       | 0 | 0 | 0 | 0 |   |
| Writing       | 0 | 0 | 0 | 0 |   |
| Drums         | 0 | 0 | 0 | 0 |   |
| Bible         | 1 | 1 | 1 |   |   |
| Memorywork    | 0 | 0 | 0 | 0 |   |
| MemoryRecite  | 0 | 0 | 0 | 0 | 0 |
| Typing        | 0 | 0 | 0 | 0 |   |
| Art1          | 0 | 0 | 0 | 0 |   |
| Art2          | 0 | 0 | 0 | 0 |   |
| PED1          | 1 | 1 | 0 | 0 |   |
| PED2          | 0 | 0 | 0 | 0 |   |
| PEDPrac       | 0 | 0 | 0 | 0 |   |

|                |   |               |   |   |               |
|----------------|---|---------------|---|---|---------------|
| [*, *, Friday] | : | Kayla Karissa |   |   | Micah Leah := |
| Math           | 1 | 1             | 1 |   |               |
| Piano1         | 0 | 0             | 0 | 0 |               |
| Piano2         | 0 | 0             | 0 | 0 |               |
| Devotions      | 1 | 1             | 1 | 1 |               |
| BSandC         | 0 | 0             | 0 | 0 |               |
| Choir          | 0 | 0             | 0 |   |               |
| DrumsL         | 0 | 0             | 0 | 0 |               |
| PianoL         | 0 | 0             | 0 | 0 |               |
| FWB            | 0 | 0             | 0 | 0 |               |
| Swimming       | 0 | 0             | 0 | 0 |               |
| HH             | 0 | 0             | 0 |   |               |
| Readers        | 1 | 1             | 1 | 1 |               |
| ReadAloud      | 0 | 0             | 1 | 1 |               |
| ReadCompre     | 1 | 1             | 1 | 1 |               |
| History        | 1 | 1             | 1 | 1 |               |
| HistoryCompre  | 1 | 1             | 1 | 1 | 1             |
| ScienceHS      | 1 | 1             | 0 | 0 |               |
| Science        | 0 | 0             | 1 | 1 |               |
| SciGradComp    | 1 | 1             | 1 | 1 | 1             |
| Grading        | 1 | 1             | 1 | 1 |               |
| Writing        | 1 | 1             | 1 | 1 |               |
| Drums          | 0 | 0             | 1 | 0 |               |
| Bible          | 1 | 1             | 1 |   |               |
| Memorywork     | 1 | 1             | 1 | 1 |               |
| MemoryRecite   | 1 | 1             | 1 | 1 | 1             |
| Typing         | 1 | 1             | 1 | 1 |               |
| Art1           | 0 | 0             | 0 | 0 |               |
| Art2           | 0 | 0             | 0 | 0 |               |
| PED1           | 1 | 1             | 0 | 0 |               |
| PED2           | 0 | 0             | 0 | 0 |               |



PEDPrac 1 1 1 1

```
[*, *, Sunday] : Kayla Karissa      Micah Leah :=
Math 0 0 0 0
Piano1 0 0 0 0
Piano2 0 0 0 0
Devotions 0 0 0 0
BSandC 1 1 1 1
Choir 0 0 0 0
DrumsL 0 0 0 0
PianoL 0 0 0 0
FWB 0 0 0 0
Swimming 0 0 0 0
HH 0 0 0 0
Readers 0 0 0 0
ReadAloud 0 0 1 1
ReadCompre 0 0 0 0
History 0 0 0 0
HistoryCompre 0 0 0 0
ScienceHS 0 0 0 0
Science 0 0 0 0
SciGradComp 0 0 0 0
Grading 0 0 0 0
Writing 0 0 0 0
Drums 0 0 0 0
Bible 0 0 0 0
Memorywork 0 0 0 0
MemoryRecite 0 0 0 0
Typing 0 0 0 0
Art1 0 0 0 0
Art2 0 0 0 0
PED1 0 0 0 0
PED2 0 0 0 0
PEDPrac 0 0 0 0
;
```

```
param NumDays : Kayla Karissa      Micah Leah :=
Math 5 5 5 5
Piano1 4 4 0 0
Piano2 0 0 4 4
Devotions 3 3 3 3
BSandC 1 1 1 1
Choir 1 0 0 0
DrumsL 0 0 1 0
PianoL 1 1 1 1
FWB 1 1 1 1
Swimming 1 1 1 0
HH 1 1 0 0
Readers 5 5 5 5
ReadAloud 0 0 4 4
ReadCompre 3 3 3 3
```

|               |   |   |   |   |   |
|---------------|---|---|---|---|---|
| History       | 5 | 5 | 5 | 5 |   |
| HistoryCompre | 3 | 3 | 3 | 3 | 3 |
| ScienceHS     | 5 | 5 | 0 | 0 |   |
| Science       | 0 | 0 | 4 | 4 |   |
| SciGradComp   | 3 | 3 | 3 | 3 | 3 |
| Grading       | 2 | 2 | 2 | 2 |   |
| Writing       | 4 | 4 | 4 | 4 |   |
| Drums 0       | 0 | 4 | 0 |   |   |
| Bible 5       | 5 | 5 | 5 |   |   |
| Memorywork    | 1 | 1 | 1 | 1 |   |
| MemoryRecite  | 1 | 1 | 1 | 1 | 1 |
| Typing        | 4 | 4 | 4 | 4 |   |
| Art1          | 3 | 3 | 0 | 3 |   |
| Art2          | 0 | 0 | 3 | 0 |   |
| PED1          | 5 | 5 | 0 | 0 |   |
| PED2          | 0 | 0 | 4 | 0 |   |
| PEDPrac       | 4 | 4 | 4 | 4 |   |

;

|                |     |   |   |   |    |
|----------------|-----|---|---|---|----|
| param NumDaysG | : 1 | 2 | 3 | 4 | := |
| Math           | 5   | 5 | 5 | 5 |    |
| Piano1         | 4   | 4 | 0 | 0 |    |
| Piano2         | 4   | 4 | 0 | 0 |    |
| Devotions      | 3   | 0 | 0 | 0 |    |
| BSandC         | 1   | 0 | 0 | 0 |    |
| Choir          | 1   | 0 | 0 |   |    |
| DrumsL         | 1   | 0 | 0 | 0 |    |
| PianoL         | 1   | 1 | 1 | 1 |    |
| FWB            | 1   | 0 | 0 | 0 |    |
| Swimming       | 1   | 0 | 0 | 0 |    |
| HH             | 1   | 0 | 0 | 0 |    |
| Readers        | 5   | 5 | 5 | 5 |    |
| ReadAloud      | 4   | 4 | 0 | 0 |    |
| ReadCompre     | 3   | 3 | 3 | 0 |    |
| History        | 5   | 5 | 5 | 5 |    |
| HistoryCompre  | 3   | 3 | 3 | 3 | 0  |
| ScienceHS      | 5   | 5 | 0 | 0 |    |
| Science        | 4   | 4 | 0 | 0 |    |
| SciGradComp    | 3   | 3 | 3 | 3 | 0  |
| Grading        | 2   | 2 | 2 | 2 |    |
| Writing        | 4   | 4 | 4 | 4 |    |
| Drums 4        | 0   | 0 | 0 |   |    |
| Bible 5        | 5   | 5 | 5 |   |    |
| Memorywork     | 1   | 1 | 1 | 1 |    |
| MemoryRecite   | 1   | 0 | 0 | 0 | 0  |
| Typing         | 4   | 4 | 4 | 4 |    |
| Art1           | 3   | 3 | 3 | 0 |    |
| Art2           | 3   | 0 | 0 | 0 |    |
| PED1           | 5   | 0 | 0 | 0 |    |
| PED2           | 4   | 0 | 0 | 0 |    |
| PEDPrac        | 4   | 4 | 4 | 4 |    |

;

```

param R : BR LR KT MBR OUT CR :=
Math 0 0 0 0 0 1
Piano1 0 0 1 0 0 0
Piano2 0 0 1 0 0 0
Devotions 0 1 0 0 0 0
BSandC 0 0 0 0 1 0
Choir 0 0 0 1 0
DrumsL 0 0 0 0 1 0
PianoL 0 0 1 0 0 0
FWB 0 0 0 0 1 0
Swimming 0 0 0 0 1 0
HH 0 0 0 1 0
Readers 1 1 0 0 0 0
ReadAloud 0 1 0 0 0 0
ReadCompre 0 0 1 0 0 0
History 1 1 0 0 0 0
HistoryCompre 0 1 1 0 0 0
ScienceHS 0 0 0 0 0 1
Science 0 1 1 0 0 0
SciGradComp 0 0 1 0 0 0
Grading 0 0 0 0 0 1
Writing 0 0 0 0 0 1
Drums 0 0 0 1 0 0
Bible 1 0 0 0 0 0
Memorywork 1 0 0 0 0 0
MemoryRecite 0 1 0 0 0 0
Typing 0 0 0 0 0 1
Art1 1 1 1 1 1 1
Art2 0 0 0 0 0 1
PED1 0 0 0 0 0 1
PED2 0 0 0 0 0 1
PEDPrac 0 1 0 0 1 0
;

```

```

param M : Monday Tuesday Wednesday Thursday Friday
Sunday:=
1 0 1 1 1 1 1
2 0 1 1 1 1 1
3 0 1 1 1 1 1
4 0 1 1 1 1 1
5 0 1 1 1 1 1
6 0 1 1 1 1 1
7 0 1 1 1 1 1
8 0 1 1 1 1 1
9 0 1 1 1 1 1
10 0 1 1 1 1 1
11 0 1 1 1 1 1
12 0 1 1 1 1 1
13 0 1 1 1 1 1
14 0 1 1 1 1 1
15 0 1 1 1 1 1

```

|    |   |   |   |   |   |    |
|----|---|---|---|---|---|----|
| 16 | 0 | 1 | 1 | 1 | 1 | 1  |
| 17 | 0 | 1 | 1 | 1 | 1 | 1  |
| 18 | 0 | 1 | 1 | 1 | 1 | 1  |
| 19 | 0 | 1 | 1 | 1 | 1 | 1  |
| 20 | 0 | 1 | 1 | 1 | 1 | 1  |
| 21 | 0 | 1 | 1 | 1 | 1 | 1  |
| 22 | 0 | 1 | 1 | 1 | 1 | 1  |
| 23 | 0 | 1 | 1 | 1 | 1 | 1  |
| 24 | 0 | 1 | 1 | 1 | 1 | 1  |
| 25 | 0 | 1 | 1 | 1 | 1 | 1  |
| 26 | 0 | 1 | 1 | 1 | 1 | 1  |
| 27 | 0 | 0 | 1 | 1 | 1 | 1  |
| 28 | 0 | 0 | 1 | 1 | 1 | 1  |
| 29 | 0 | 0 | 1 | 1 | 1 | 1  |
| 30 | 0 | 0 | 1 | 1 | 1 | 1  |
| 31 | 0 | 0 | 1 | 1 | 1 | 1  |
| 32 | 0 | 0 | 1 | 1 | 1 | 1  |
| 33 | 1 | 1 | 1 | 1 | 1 | 1  |
| 34 | 1 | 1 | 1 | 1 | 1 | 1  |
| 35 | 1 | 1 | 1 | 1 | 1 | 1  |
| 36 | 1 | 1 | 1 | 1 | 1 | 1  |
| 37 | 1 | 1 | 1 | 1 | 1 | 1  |
| 38 | 1 | 1 | 1 | 1 | 1 | 1  |
| 39 | 1 | 1 | 1 | 1 | 1 | 1  |
| 40 | 1 | 1 | 1 | 1 | 1 | 1  |
| 41 | 1 | 1 | 1 | 1 | 1 | 1  |
| 42 | 1 | 1 | 1 | 1 | 1 | 1  |
| 43 | 1 | 1 | 1 | 1 | 1 | 1  |
| 44 | 1 | 1 | 1 | 1 | 1 | 1  |
| 45 | 1 | 1 | 1 | 1 | 1 | 1  |
| 46 | 1 | 1 | 1 | 1 | 1 | 1  |
| 47 | 1 | 1 | 1 | 1 | 1 | 1  |
| 48 | 1 | 1 | 1 | 1 | 1 | 1  |
| 49 | 1 | 1 | 1 | 1 | 1 | 1  |
| 50 | 1 | 1 | 1 | 1 | 1 | 1  |
| 51 | 1 | 1 | 1 | 1 | 1 | 1  |
| 52 | 1 | 1 | 1 | 1 | 1 | 1; |

```

param C :=
Math 3
Piano1 3
Piano2 2
Devotions 2
BSandC 14
Choir 7
DrumsL 3
PianoL 2
FWB 4
Swimming 2
HH 12
Readers 2
ReadAloud 3

```

ReadCompre 2  
 History 2  
 HistoryCompre 2  
 ScienceHS 2  
 Science 3  
 SciGradComp 1  
 Grading 3  
 Writing 1  
 Drums 2  
 Bible 2  
 Memorywork 1  
 MemoryRecite 1  
 Typing 1  
 Art1 2  
 Art2 2  
 PED1 2  
 PED2 2  
 PEDPrac 3  
 ;

| param T :     | 1 | 2 | 3 | 4 | := |
|---------------|---|---|---|---|----|
| Math 0        | 0 | 0 | 0 |   |    |
| Piano1        | 0 | 0 | 0 | 0 |    |
| Piano2        | 0 | 0 | 0 | 0 |    |
| Devotions     | 1 | 0 | 0 | 0 |    |
| BSandC        | 1 | 0 | 0 | 0 |    |
| Choir 1       | 0 | 0 | 0 |   |    |
| DrumsL        | 0 | 0 | 0 | 0 |    |
| PianoL        | 1 | 1 | 1 | 1 |    |
| FWB 1         | 0 | 0 | 0 |   |    |
| Swimming      | 1 | 0 | 0 | 0 |    |
| HH 0          | 0 | 0 | 0 |   |    |
| Readers       | 0 | 0 | 0 | 0 |    |
| ReadAloud     | 1 | 1 | 0 | 0 |    |
| ReadCompre    | 1 | 1 | 1 | 0 |    |
| History       | 0 | 0 | 0 | 1 |    |
| HistoryCompre | 0 | 0 | 0 | 0 | 0  |
| ScienceHS     | 0 | 0 | 0 | 0 |    |
| Science       | 1 | 1 | 0 | 0 |    |
| SciGradComp   | 1 | 1 | 1 | 1 | 0  |
| Grading       | 1 | 1 | 1 | 1 |    |
| Writing       | 0 | 0 | 0 | 0 |    |
| Drums 0       | 0 | 0 | 0 |   |    |
| Bible 1       | 1 | 1 | 1 |   |    |
| Memorywork    | 1 | 1 | 1 | 1 |    |
| MemoryRecite  | 1 | 0 | 0 | 0 | 0  |
| Typing        | 0 | 0 | 0 | 0 |    |
| Art1 0        | 0 | 0 | 0 |   |    |
| Art2 0        | 0 | 0 | 0 |   |    |
| PED1 0        | 0 | 0 | 0 |   |    |
| PED2 0        | 0 | 0 | 0 |   |    |

```

PEDPrac    1    0    0    0
;

param G :=
[*, *, Math]:  1    2    3    4 :=
Kayla 1    0    0    0
Karissa 0    1    0    0
Micah 0    0    1    0
Leah 0    0    0    1

[*, *, Piano1]: 1    2    3    4 :=
Kayla 1    0    0    0
Karissa 0    1    0    0
Micah 0    0    0    0
Leah 0    0    0    0

[*, *, Piano2]: 1    2    3    4 :=
Kayla 0    0    0    0
Karissa 0    0    0    0
Micah 1    0    0    0
Leah 0    1    0    0

[*, *, Devotions]: 1    2    3    4 :=
Kayla 1    0    0    0
Karissa 1    0    0    0
Micah 1    0    0    0
Leah 1    0    0    0

[*, *, BSandC]: 1    2    3    4 :=
Kayla 1    0    0    0
Karissa 1    0    0    0
Micah 1    0    0    0
Leah 1    0    0    0

[*, *, Choir]: 1    2    3    4 :=
Kayla 1    0    0    0
Karissa 1    0    0    0
Micah 0    0    0    0
Leah 0    0    0    0

[*, *, DrumsL]: 1    2    3    4 :=
Kayla 0    0    0    0
Karissa 0    0    0    0
Micah 1    0    0    0
Leah 0    0    0    0

[*, *, PianoL]: 1    2    3    4 :=
Kayla 1    0    0    0
Karissa 0    1    0    0
Micah 0    0    1    0
Leah 0    0    0    1

```

|                        |   |   |   |      |
|------------------------|---|---|---|------|
| [*, *, FWB]:           | 1 | 2 | 3 | 4 := |
| Kayla 1                | 0 | 0 | 0 |      |
| Karissa                | 1 | 0 | 0 | 0    |
| Micah 1                | 0 | 0 | 0 |      |
| Leah 1                 | 0 | 0 | 0 |      |
| [*, *, Swimming]:      | 1 | 2 | 3 | 4 := |
| Kayla 1                | 0 | 0 | 0 |      |
| Karissa                | 1 | 0 | 0 | 0    |
| Micah 1                | 0 | 0 | 0 |      |
| Leah 0                 | 0 | 0 | 0 |      |
| [*, *, HH]:            | 1 | 2 | 3 | 4 := |
| Kayla 1                | 0 | 0 | 0 |      |
| Karissa                | 1 | 0 | 0 | 0    |
| Micah 0                | 0 | 0 | 0 |      |
| Leah 0                 | 0 | 0 | 0 |      |
| [*, *, Readers]:       | 1 | 2 | 3 | 4 := |
| Kayla 1                | 0 | 0 | 0 |      |
| Karissa                | 0 | 1 | 0 | 0    |
| Micah 0                | 0 | 1 | 0 |      |
| Leah 0                 | 0 | 0 | 1 |      |
| [*, *, ReadAloud]:     | 1 | 2 | 3 | 4 := |
| Kayla 0                | 0 | 0 | 0 |      |
| Karissa                | 0 | 0 | 0 | 0    |
| Micah 1                | 0 | 0 | 0 |      |
| Leah 0                 | 1 | 0 | 0 |      |
| [*, *, ReadCompre]:    | 1 | 2 | 3 | 4 := |
| Kayla 1                | 0 | 0 | 0 |      |
| Karissa                | 1 | 0 | 0 | 0    |
| Micah 0                | 1 | 0 | 0 |      |
| Leah 0                 | 0 | 1 | 0 |      |
| [*, *, History]:       | 1 | 2 | 3 | 4 := |
| Kayla 1                | 0 | 0 | 0 |      |
| Karissa                | 0 | 1 | 0 | 0    |
| Micah 0                | 0 | 1 | 0 |      |
| Leah 0                 | 0 | 0 | 1 |      |
| [*, *, HistoryCompre]: | 1 | 2 | 3 | 4 := |
| Kayla 1                | 0 | 0 | 0 |      |
| Karissa                | 1 | 0 | 0 | 0    |
| Micah 0                | 1 | 0 | 0 |      |
| Leah 0                 | 0 | 1 | 0 |      |
| [*, *, ScienceHS]:     | 1 | 2 | 3 | 4 := |
| Kayla 1                | 0 | 0 | 0 |      |
| Karissa                | 0 | 1 | 0 | 0    |

|                       |   |   |   |      |
|-----------------------|---|---|---|------|
| Micah                 | 0 | 0 | 0 |      |
| Leah                  | 0 | 0 | 0 |      |
|                       |   |   |   |      |
| [*, *, Science]:      | 1 | 2 | 3 | 4 := |
| Kayla                 | 0 | 0 | 0 |      |
| Karissa               | 0 | 0 | 0 | 0    |
| Micah                 | 1 | 0 | 0 |      |
| Leah                  | 0 | 1 | 0 | 0    |
|                       |   |   |   |      |
| [*, *, SciGradComp]:  | 1 | 2 | 3 | 4 := |
| Kayla                 | 1 | 0 | 0 |      |
| Karissa               | 1 | 0 | 0 | 0    |
| Micah                 | 0 | 1 | 0 |      |
| Leah                  | 0 | 0 | 1 | 0    |
|                       |   |   |   |      |
| [*, *, Grading]:      | 1 | 2 | 3 | 4 := |
| Kayla                 | 1 | 0 | 0 |      |
| Karissa               | 0 | 1 | 0 | 0    |
| Micah                 | 0 | 0 | 1 | 0    |
| Leah                  | 0 | 0 | 0 | 1    |
|                       |   |   |   |      |
| [*, *, Writing]:      | 1 | 2 | 3 | 4 := |
| Kayla                 | 1 | 0 | 0 |      |
| Karissa               | 0 | 1 | 0 | 0    |
| Micah                 | 0 | 0 | 1 | 0    |
| Leah                  | 0 | 0 | 0 | 1    |
|                       |   |   |   |      |
| [*, *, Drums]:        | 1 | 2 | 3 | 4 := |
| Kayla                 | 0 | 0 | 0 |      |
| Karissa               | 0 | 0 | 0 | 0    |
| Micah                 | 1 | 0 | 0 |      |
| Leah                  | 0 | 0 | 0 | 0    |
|                       |   |   |   |      |
| [*, *, Bible]:        | 1 | 2 | 3 | 4 := |
| Kayla                 | 1 | 0 | 0 |      |
| Karissa               | 0 | 1 | 0 | 0    |
| Micah                 | 0 | 0 | 1 | 0    |
| Leah                  | 0 | 0 | 0 | 1    |
|                       |   |   |   |      |
| [*, *, Memorywork]:   | 1 | 2 | 3 | 4 := |
| Kayla                 | 1 | 0 | 0 |      |
| Karissa               | 0 | 1 | 0 | 0    |
| Micah                 | 0 | 0 | 1 | 0    |
| Leah                  | 0 | 0 | 0 | 1    |
|                       |   |   |   |      |
| [*, *, MemoryRecite]: | 1 | 2 | 3 | 4 := |
| Kayla                 | 1 | 0 | 0 |      |
| Karissa               | 1 | 0 | 0 | 0    |
| Micah                 | 1 | 0 | 0 |      |
| Leah                  | 1 | 0 | 0 | 0    |
|                       |   |   |   |      |
| [*, *, Typing]:       | 1 | 2 | 3 | 4 := |



```

Kayla 1    0    0    0
Karissa 0    1    0    0
Micah 0    0    1    0
Leah 0     0    0    1

[*, *, Art1]: 1 2 3 4 :=
Kayla 1    0    0    0
Karissa 0    1    0    0
Micah 0    0    0    0
Leah 0     0    1    0

[*, *, Art2]: 1 2 3 4 :=
Kayla 0    0    0    0
Karissa 0    0    0    0
Micah 1    0    0    0
Leah 0     0    0    0

[*, *, PED1]: 1 2 3 4 :=
Kayla 1    0    0    0
Karissa 1    0    0    0
Micah 0    0    0    0
Leah 0     0    0    0

[*, *, PED2]: 1 2 3 4 :=
Kayla 0    0    0    0
Karissa 0    0    0    0
Micah 1    0    0    0
Leah 0     0    0    0

[*, *, PEDPrac]: 1 2 3 4 :=
Kayla 1    0    0    0
Karissa 1    0    0    0
Micah 1    0    0    0
Leah 1     0    0    0
;

param Numgroups :=
Math 4
Piano1 2
Piano2 2
Devotions 1
BSandC 1
Choir 1
DrumsL 1
PianoL 4
FWB 1
Swimming 1
HH 1
Readers 4
ReadAloud 3
ReadCompre 3
History 4

```

|               |   |
|---------------|---|
| HistoryCompre | 3 |
| ScienceHS     | 2 |
| Science       | 2 |
| SciGradComp   | 3 |
| Grading       | 4 |
| Writing       | 4 |
| Drums         | 1 |
| Bible         | 4 |
| Memorywork    | 4 |
| MemoryRecite  | 1 |
| Typing        | 4 |
| Art1          | 3 |
| Art2          | 1 |
| PED1          | 1 |
| PED2          | 1 |
| PEDPrac       | 1 |

;

## APPENDIX 2: DATASETS USED FOR THE TESTING PROCESS

### **Dataset 1:**

```
set STUDENT := Kayla, Karissa, Micah, Leah;

set SUBJECT := Piano1;

set DAY := Monday;

set ROOM := LR, KT, CR;

set TIME := 1, 2, 3, 4;

set GROUP := 1, 2, 3, 4;

set PianoRooms := KT, LR;

set PianoSubjects := Piano1;

param alpha := 9999999;

param beta := 2;

param NumStudents := 4;

param D :=
[*, *, Monday]:      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0;

param NumDays :      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0;

param NumDaysG: 1 2 3 4 :=
Piano1 1 1 0 0;

param R : LR      KT      CR :=
Piano1      0      1      0;

param M : Monday:=
1      0
2      1
```

```

3      1
4      1;

param P:  Kayla      Karissa  Micah      Leah :=
Piano1   0      0      0      0;

param C :=
Piano1   2;

param T : 1      2      3      4 :=
Piano1   0      0      0      0;

param G :=
[*, *, Piano1]:      1      2      3      4 :=
Kayla      1      0      0      0
Karissa    0      1      0      0
Micah      0      0      0      0
Leah 0      0      0      0;

param Numgroups :=
Piano1   2;

```

### **Dataset 2:**

```

set STUDENT := Kayla, Karissa, Micah, Leah;

set SUBJECT := Piano1, Piano2;

set DAY := Monday;

set ROOM := LR, KT, CR;

set TIME := 1, 2, 3, 4, 5, 6, 7, 8;

/*set COMPSUB := PED1;*/

set GROUP := 1, 2, 3, 4;

set PianoRooms := KT, LR;

set PianoSubjects := Piano1, Piano2;

param alpha := 9999999;

param beta := 2;

```

```

param NumStudents := 4;

param D :=
[*, *, Monday]:      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0
Piano2      0      0      1      1;

param NumDays :      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0
Piano2      0      0      1      1;

param NumDaysG:      1      2      3      4 :=
Piano1      1      1      0      0
Piano2      1      1      0      0;

param R : LR      KT      CR :=
Piano1      0      1      0
Piano2      0      1      0;

param M : Monday:=
1      0
2      1
3      1
4      1
5      1
6      1
7      1
8      1;

param C :=
Piano1      2
Piano2      2;

param T : 1      2      3      4 :=
Piano1      0      0      0      0
Piano2      0      0      0      0;

param G :=
[*, *, Piano1]:      1      2      3      4 :=
Kayla      1      0      0      0
Karissa    0      1      0      0
Micah      0      0      0      0
Leah      0      0      0      0

[*, *, Piano2]:      1      2      3      4 :=
Kayla      0      0      0      0

```

```

Karissa 0 0 0 0
Micah 1 0 0 0
Leah 0 1 0 0;

```

```

param Numgroups :=
Piano1 2
Piano2 2;

```

### **Dataset 3:**

```

set STUDENT := Kayla, Karissa, Micah, Leah;

set SUBJECT := Math;

set DAY := Monday;

set ROOM := BR, KT, CR;

set TIME := 1, 2, 3;

set COMPSUB := Math;

set GROUP := 1, 2, 3, 4;

param alpha := 9999999;

param beta := 2;

param NumStudents := 4;

param D :=
[*, *, Monday]:      Kayla      Karissa      Micah      Leah :=
Math 1      1      1      1;

param NumDays :      Kayla      Karissa      Micah      Leah :=
Math 1      1      1      1;

param NumDaysG:      1      2      3      4:=
Math 1      1      1      1;

param R : BR      KT      CR :=
Math 1      0      1;

param M : Monday:=
1      0

```

```

2      1
3      1;

param P:  Kayla      Karissa  Micah      Leah :=
Math 0    0      0      0;

param C :=
Math 1;

param T : 1      2      3      4 :=
Math 0    0      0      0;

param G :=
[*, *, Math]: 1      2      3      4 :=
Kayla      1      0      0      0
Karissa    0      1      0      0
Micah      0      0      1      0
Leah 0      0      0      1;

param Numgroups :=
Math 4;

```

#### **Dataset 4:**

```

set STUDENT := Kayla, Karissa, Micah, Leah;

set SUBJECT := Piano1, Piano2, Math;

set DAY := Monday;

set ROOM := LR, KT, CR;

set TIME := 1, 2, 3, 4, 5, 6, 7, 8;

set COMPSUB := Math;

set GROUP := 1, 2, 3, 4;

set PianoRooms := KT, LR;

set PianoSubjects := Piano1, Piano2;

param alpha := 9999999;

param beta := 2;

```

```

param NumStudents := 4;

param D :=
[* , * , Monday]:      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0
Piano2      0      0      1      1
Math 1      1      1      1;

param NumDays :      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0
Piano2      0      0      1      1
Math 1      1      1      1;

param NumDaysG:      1      2      3      4 :=
Piano1      1      1      0      0
Piano2      1      1      0      0
Math 1      1      1      1;

param R : LR      KT      CR :=
Piano1      0      1      0
Piano2      0      1      0
Math 1      0      1;

param M : Monday :=
1      0
2      1
3      1
4      1
5      1
6      1
7      1
8      1;

param C :=
Piano1      2
Piano2      2
Math 1;

param T : 1      2      3      4 :=
Piano1      0      0      0      0
Piano2      0      0      0      0
Math 0      0      0      0;

param G :=
[* , * , Piano1]:      1      2      3      4 :=
Kayla      1      0      0      0
Karissa      0      1      0      0

```



```

Micah      0    0    0    0
Leah 0     0    0    0

[*, *, Piano2]:      1    2    3    4 :=
Kayla      0    0    0    0
Karissa    0    0    0    0
Micah      1    0    0    0
Leah 0     1    0    0

[*, *, Math]:      1    2    3    4 :=
Kayla      1    0    0    0
Karissa    0    1    0    0
Micah      0    0    1    0
Leah 0     0    0    1;

param Numgroups :=
Piano1      2
Piano2      2
Math 4;

```

### **Dataset 5:**

```

set STUDENT := Kayla, Karissa, Micah, Leah;

set SUBJECT := Piano1, Piano2, Math;

set DAY := Monday, Tuesday;

set ROOM := KT, CR, BR;

set TIME := 1, 2, 3, 4, 5, 6, 7, 8;

set COMPSUB := Math;

set GROUP := 1, 2, 3, 4;

set PianoRooms := KT, LR;

set PianoSubjects := Piano1, Piano2;

param alpha := 9999999;

param beta := 2;

param NumStudents := 4;

```

```

param D :=
[*, *, Monday]:      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0
Piano2      0      0      1      1
Math 1      1      1      1

```

```

[*, *, Tuesday]:     Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0
Piano2      0      0      1      1
Math 1      1      1      1;

```

```

param NumDays :      Kayla      Karissa      Micah      Leah :=
Piano1      2      2      0      0
Piano2      0      0      2      2
Math 2      2      2      2;

```

```

param NumDaysG:      1      2      3      4:=
Piano1      2      2      0      0
Piano2      2      2      0      0
Math 2      2      2      2;

```

```

param R : KT      CR      BR:=
Piano1      1      0      0
Piano2      1      0      0
Math 0      1      1;

```

```

param M : Monday      Tuesday:=
1      0      1
2      1      1
3      1      1
4      1      1
5      1      1
6      1      1
7      1      1
8      1      1;

```

```

param C :=
Piano1      2
Piano2      2
Math 1;

```

```

param T : 1      2      3      4 :=
Piano1      0      0      0      0
Piano2      0      0      0      0
Math 0      0      0      0;

```

```

param G :=
[*, *, Piano1]:      1      2      3      4 :=
Kayla      1      0      0      0
Karissa    0      1      0      0
Micah      0      0      0      0
Leah 0      0      0      0

[*, *, Piano2]:      1      2      3      4 :=
Kayla      0      0      0      0
Karissa    0      0      0      0
Micah      1      0      0      0
Leah 0      1      0      0

[*, *, Math]:      1      2      3      4 :=
Kayla      1      0      0      0
Karissa    0      1      0      0
Micah      0      0      1      0
Leah 0      0      0      1;

param Numgroups :=
Piano1      2
Piano2      2
Math 4;

```

### **Dataset 6**

```

set STUDENT := Kayla, Karissa, Micah, Leah;

set SUBJECT := Piano1, Piano2, PianoL, Math;

set DAY := Monday;

set ROOM := LR, BR, KT, CR;

set TIME := 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12;

set COMPSUB := Math;

set GROUP := 1, 2, 3, 4;

set PianoRooms := KT, LR;

set PianoSubjects := Piano1, Piano2, PianoL;

param alpha := 9999999;

```

```

param beta := 2;

param NumStudents := 4;

param D :=
[* , *, Monday]:      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0
Piano2      0      0      1      1
PianoL      1      1      1      1
Math 1      1      1      1;

param NumDays :      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0
Piano2      0      0      1      1
PianoL      1      1      1      1
Math 1      1      1      1;

param NumDaysG:      1      2      3      4 :=
Piano1      1      1      0      0
Piano2      1      1      0      0
PianoL      1      1      1      1
Math 1      1      1      1;

param R : LR      BR      KT      CR :=
Piano1      0      0      1      0
Piano2      0      0      1      0
PianoL      0      0      1      0
Math 0      1      0      1;

param M : Monday:=
1      0
2      1
3      1
4      1
5      1
6      1
7      1
8      1
9      1
10     1
11     1
12     1;

param C :=
Piano1      2
Piano2      2

```

```

PianoL    1
Math 1;

param T : 1    2    3    4 :=
Piano1    0    0    0    0
Piano2    0    0    0    0
PianoL    1    1    1    1
Math 0    0    0    0;

param G :=
[* , * , Piano1]:    1    2    3    4 :=
Kayla    1    0    0    0
Karissa  0    1    0    0
Micah    0    0    0    0
Leah 0    0    0    0

[* , * , Piano2]:    1    2    3    4 :=
Kayla    0    0    0    0
Karissa  0    0    0    0
Micah    1    0    0    0
Leah 0    1    0    0

[* , * , PianoL]:    1    2    3    4 :=
Kayla    1    0    0    0
Karissa  0    1    0    0
Micah    0    0    1    0
Leah 0    0    0    1

[* , * , Math]:    1    2    3    4 :=
Kayla    1    0    0    0
Karissa  0    1    0    0
Micah    0    0    1    0
Leah 0    0    0    1;

param Numgroups :=
Piano1    2
Piano2    2
PianoL    4
Math 4;

```

### **Dataset 7:**

```

set STUDENT := Kayla, Karissa, Micah, Leah;

set SUBJECT := Piano1, Piano2, PianoL, Math;

```

```

set DAY := Monday, Tuesday;

set ROOM := LR, KT, CR, BR;

set TIME := 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12;

set COMPSUB := Math;

set GROUP := 1, 2, 3, 4;

set PianoRooms := KT, LR;

set PianoSubjects := Piano1, Piano2, PianoL;

param alpha := 9999999;

param beta := 2;

param NumStudents := 4;

param D :=
[*, *, Monday]:      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0
Piano2      0      0      1      1
PianoL      1      1      1      1
Math 1      1      1      1

[*, *, Tuesday]:      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0
Piano2      0      0      1      1
PianoL      1      1      1      1
Math 1      1      1      1;

param NumDays :      Kayla      Karissa      Micah      Leah :=
Piano1      2      2      0      0
Piano2      0      0      2      2
PianoL      2      2      2      2
Math 2      2      2      2;

param NumDaysG:      1      2      3      4 :=
Piano1      2      2      0      0
Piano2      2      2      0      0
PianoL      2      2      2      2
Math 2      2      2      2;

param R : LR      KT      CR      BR :=
Piano1      0      1      0      0

```

```

Piano2    0    1    0    0
PianoL    0    1    0    0
Math 0    0    1    1;

```

```

param M : Monday    Tuesday:=
1    0    1
2    1    1
3    1    1
4    1    1
5    1    1
6    1    1
7    1    1
8    1    1
9    1    1
10   1    1
11   1    1
12   1    1;

```

```

param C :=
Piano1    2
Piano2    2
PianoL    1
Math 1;

```

```

param T : 1    2    3    4 :=
Piano1    0    0    0    0
Piano2    0    0    0    0
PianoL    1    1    1    1
Math 0    0    0    0;

```

```

param G :=
[*, *, Piano1]:    1    2    3    4 :=
Kayla    1    0    0    0
Karissa  0    1    0    0
Micah    0    0    0    0
Leah 0    0    0    0

```

```

[*, *, Piano2]:    1    2    3    4 :=
Kayla    0    0    0    0
Karissa  0    0    0    0
Micah    1    0    0    0
Leah 0    1    0    0

```

```

[*, *, PianoL]:    1    2    3    4 :=
Kayla    1    0    0    0
Karissa  0    1    0    0
Micah    0    0    1    0

```

```

Leah 0    0    0    1

[* , * , Math]: 1    2    3    4 :=
Kayla    1    0    0    0
Karissa  0    1    0    0
Micah    0    0    1    0
Leah 0    0    0    1;

```

```

param Numgroups :=
Piano1    2
Piano2    2
PianoL    4
Math 4;

```

### **Dataset 8:**

```

set STUDENT := Kayla, Karissa, Micah, Leah;

set SUBJECT := Piano1, Piano2, PianoL, Devotions, Math;

set DAY := Monday;

set ROOM := LR, KT, CR, BR;

set TIME := 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13;

set COMPSUB := Math;

set GROUP := 1, 2, 3, 4;

set PianoRooms := KT, LR;

set PianoSubjects := Piano1, Piano2, PianoL;

param alpha := 9999999;

param beta := 2;

param NumStudents := 4;

param D :=
[* , * , Monday]:      Kayla    Karissa    Micah    Leah :=
Piano1    1    1    0    0
Piano2    0    0    1    1
PianoL    1    1    1    1
Devotions 1    1    1    1

```



```

Math 1      1      1      1;

param NumDays :      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0
Piano2      0      0      1      1
PianoL      1      1      1      1
Devotions 1      1      1      1
Math 1      1      1      1;

param NumDaysG:      1      2      3      4 :=
Piano1      1      1      0      0
Piano2      1      1      0      0
PianoL      1      1      1      1
Devotions 1      0      0      0
Math 1      1      1      1;

param R : LR      KT      CR      BR :=
Piano1      0      1      0      0
Piano2      0      1      0      0
PianoL      0      1      0      0
Devotions 1      0      0      0
Math 0      0      1      1;

param M : Monday:=
1      0
2      1
3      1
4      1
5      1
6      1
7      1
8      1
9      1
10     1
11     1
12     1
13     1;

param C :=
Piano1      2
Piano2      2
PianoL      1
Devotions 1
Math 1;

param T : 1      2      3      4 :=

```

```

Piano1    0    0    0    0
Piano2    0    0    0    0
PianoL    0    0    0    0
Devotions 1    0    0    0
Math 0    0    0    0;

param G :=
[* , * , Piano1]:    1    2    3    4 :=
Kayla    1    0    0    0
Karissa  0    1    0    0
Micah    0    0    0    0
Leah 0    0    0    0

[* , * , Piano2]:    1    2    3    4 :=
Kayla    0    0    0    0
Karissa  0    0    0    0
Micah    1    0    0    0
Leah 0    1    0    0

[* , * , PianoL]:    1    2    3    4 :=
Kayla    1    0    0    0
Karissa  0    1    0    0
Micah    0    0    1    0
Leah 0    0    0    1

[* , * , Devotions]: 1    2    3    4 :=
Kayla    1    0    0    0
Karissa  1    0    0    0
Micah    1    0    0    0
Leah 1    0    0    0

[* , * , Math]:    1    2    3    4 :=
Kayla    1    0    0    0
Karissa  0    1    0    0
Micah    0    0    1    0
Leah 0    0    0    1;

param Numgroups :=
Piano1    2
Piano2    2
PianoL    4
Devotions 1
Math 4;

```

### Dataset 9:

```
set STUDENT := Kayla, Karissa, Micah, Leah;

set SUBJECT := Piano1, Piano2, PianoL, Devotions, Math;

set DAY := Monday, Tuesday;

set ROOM := LR, KT, CR, BR;

set TIME := 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13;

set COMPSUB := Math;

set GROUP := 1, 2, 3, 4;

set PianoRooms := KT, LR;

set PianoSubjects := Piano1, Piano2, PianoL;

param alpha := 9999999;

param beta := 2;

param NumStudents := 4;

param D :=
[* , * , Monday]:      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0
Piano2      0      0      1      1
PianoL      1      1      1      1
Devotions  1      1      1      1
Math 1      1      1      1
[* , * , Tuesday]:      Kayla      Karissa      Micah      Leah :=
Piano1      1      1      0      0
Piano2      0      0      1      1
PianoL      1      1      1      1
Devotions  0      0      0      0
Math 1      1      1      1;

param NumDays :      Kayla      Karissa      Micah      Leah :=
Piano1      2      2      0      0
Piano2      0      0      2      2
PianoL      2      2      2      2
Devotions  1      1      1      1
Math 2      2      2      2;
```

```

param NumDaysG:      1      2      3      4 :=
Piano1      2      2      0      0
Piano2      2      2      0      0
PianoL      2      2      2      2
Devotions 1      0      0      0
Math 2      2      2      2;

```

```

param R : LR      KT      CR      BR :=
Piano1      0      1      0      0
Piano2      0      1      0      0
PianoL      0      1      0      0
Devotions 1      0      0      0
Math 0      0      1      1;

```

```

param M : Monday      Tuesday :=
1      0      1
2      1      1
3      1      1
4      1      1
5      1      1
6      1      1
7      1      1
8      1      1
9      1      1
10     1      1
11     1      1
12     1      1
13     1      1;

```

```

param C :=
Piano1      2
Piano2      2
PianoL      1
Devotions 1
Math 1;

```

```

param T : 1      2      3      4 :=
Piano1      0      0      0      0
Piano2      0      0      0      0
PianoL      0      0      0      0
Devotions 1      0      0      0
Math 0      0      0      0;

```

```

param G :=
[*, *, Piano1]:      1      2      3      4 :=
Kayla      1      0      0      0
Karissa    0      1      0      0

```

```

Micah      0    0    0    0
Leah 0     0    0    0

[* , * , Piano2]:      1    2    3    4 :=
Kayla      0    0    0    0
Karissa    0    0    0    0
Micah      1    0    0    0
Leah 0     1    0    0

[* , * , PianoL]:     1    2    3    4 :=
Kayla      1    0    0    0
Karissa    0    1    0    0
Micah      0    0    1    0
Leah 0     0    0    1

[* , * , Devotions]:  1    2    3    4 :=
Kayla      1    0    0    0
Karissa    1    0    0    0
Micah      1    0    0    0
Leah 1     0    0    0

[* , * , Math]:      1    2    3    4 :=
Kayla      1    0    0    0
Karissa    0    1    0    0
Micah      0    0    1    0
Leah 0     0    0    1;

param Numgroups :=
Piano1      2
Piano2      2
PianoL      4
Devotions   1
Math        4;

```

### **Dataset 10:**

```

set STUDENT := Kayla, Karissa, Micah, Leah;

set SUBJECT := Readers, ReadAloud, ReadCompre, History,
HistoryCompre, Math, ScienceHS, Science, SciGradComp,
Piano1, Piano2, Devotions, BSandC, Choir, DrumsL, PianoL,
FWB, Swimming, HH;

set DAY := Monday, Tuesday, Wednesday, Thursday, Friday,
Sunday;

```

```

set ROOM := LR, BR, KT, MBR, OUT, CR;

set TIME := 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14,
15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29,
30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44,
45, 46, 47, 48, 49, 50, 51, 52;

set COMPSUB := Math, ScienceHS;

set GROUP := 1, 2, 3, 4;

set PianoRooms := KT, LR;

set PianoSubjects := Piano1, Piano2, PianoL;

set KandK := Kayla, Karissa;

set KKandM := Kayla, Karissa, Micah;

param alpha := 10000;

param beta := 2;

param NumStudents := 4;

param D :=
[* , *, Monday]:      Kayla      Karissa      Micah      Leah :=
Math 1      1      1      1
Piano1      1      1      0      0
Piano2      0      0      1      1
Devotions  0      0      0      0
BSandC      0      0      0      0
Choir       1      1      0      0
DrumsL      0      0      0      0
PianoL      0      0      0      0
FWB         0      0      0      0
Swimming    0      0      0      0
HH          0      0      0      0
Readers     1      1      1      1
ReadAloud   0      0      0      0
ReadCompre  0      0      0      0
History     1      1      1      1
HistoryCompre 0      0      0      0
ScienceHS   1      1      0      0
Science     0      0      1      1
SciGradComp 0      0      0      0
;

```

```

[* , *, Tuesday] : Kayla      Karissa      Micah      Leah :=
Math 1      1      1      1
Piano1     1      1      0      0
Piano2     0      0      1      1
Devotions  1      1      1      1
BSandC     0      0      0      0
Choir      0      0      0      0
DrumsL     0      0      0      0
PianoL     0      0      0      0
FWB        0      0      0      0
Swimming   0      0      0      0
HH         0      0      0      0
Readers    1      1      1      1
ReadAloud  0      0      1      1
ReadCompre 1      1      1      1      1
History    1      1      1      1
HistoryCompre 1      1      1      1      1
ScienceHS  1      1      0      0
Science    0      0      1      1
SciGradComp 1      1      1      1      1
;

```

```

[* , *, Wednesday] : Kayla      Karissa      Micah      Leah :=
Math 1      1      1      1
Piano1     1      1      0      0
Piano2     0      0      1      1
Devotions  1      1      1      1
BSandC     0      0      0      0
Choir      0      0      0      0
DrumsL     0      0      0      0
PianoL     0      0      0      0
FWB        0      0      0      0
Swimming   0      0      0      0
HH         0      0      0      0
Readers    1      1      1      1
ReadAloud  0      0      1      1
ReadCompre 1      1      1      1      1
History    1      1      1      1
HistoryCompre 1      1      1      1      1
ScienceHS  1      1      0      0
Science    0      0      1      1
SciGradComp 1      1      1      1      1
;

```

```

[* , *, Thursday] : Kayla      Karissa      Micah      Leah :=
Math 1      1      1      1

```

```

Piano1      1      1      0      0
Piano2      0      0      1      1
Devotions   0      0      0      0
BSandC      0      0      0      0
Choir       0      0      0      0
DrumsL      0      0      1      0
PianoL      0      0      0      0
FWB 1       1      1      1
Swimming    1      1      1      0
HH 1        1      0      0
Readers     1      1      1      1
ReadAloud   0      0      0      0
ReadCompre  0      0      0      0      0
History     1      1      1      1
HistoryCompre 0      0      0      0      0
ScienceHS   1      1      0      0
Science     0      0      0      0
SciGradComp 0      0      0      0      0
;

```

```

[* , * , Friday] : Kayla      Karissa      Micah      Leah :=
Math 1      1      1      1
Piano1 0      0      0      0
Piano2 0      0      0      0
Devotions 1      1      1      1
BSandC 0      0      0      0
Choir 0      0      0      0
DrumsL 0      0      0      0
PianoL 0      0      0      0
FWB 0      0      0      0
Swimming 0      0      0      0
HH 0      0      0      0
Readers 1      1      1      1
ReadAloud 0      0      1      1
ReadCompre 1      1      1      1      1
History 1      1      1      1
HistoryCompre 1      1      1      1      1
ScienceHS 1      1      0      0
Science 0      0      1      1
SciGradComp 1      1      1      1      1
;

```

```

[* , * , Sunday] : Kayla      Karissa      Micah      Leah :=
Math 0      0      0      0
Piano1 0      0      0      0
Piano2 0      0      0      0

```



|               |   |   |   |   |   |
|---------------|---|---|---|---|---|
| Devotions     | 0 | 0 | 0 | 0 |   |
| BSandC        | 1 | 1 | 1 | 1 |   |
| Choir         | 0 | 0 | 0 | 0 |   |
| DrumsL        | 0 | 0 | 0 | 0 |   |
| PianoL        | 0 | 0 | 0 | 0 |   |
| FWB           | 0 | 0 | 0 |   |   |
| Swimming      | 0 | 0 | 0 | 0 |   |
| HH            | 0 | 0 | 0 |   |   |
| Readers       | 0 | 0 | 0 | 0 |   |
| ReadAloud     | 0 | 0 | 1 | 1 |   |
| ReadCompre    |   | 0 | 0 | 0 | 0 |
| History       | 0 | 0 | 0 | 0 |   |
| HistoryCompre | 0 | 0 | 0 | 0 | 0 |
| ScienceHS     | 0 | 0 | 0 | 0 |   |
| Science       | 0 | 0 | 0 | 0 |   |
| SciGradComp   | 0 | 0 | 0 | 0 | 0 |

;

|                 |   |       |         |       |         |
|-----------------|---|-------|---------|-------|---------|
| param NumDays : |   | Kayla | Karissa | Micah | Leah := |
| Math 5          | 5 | 5     | 5       |       |         |
| Piano1          | 4 | 4     | 0       | 0     |         |
| Piano2          | 0 | 0     | 4       | 4     |         |
| Devotions       | 3 | 3     | 3       | 3     |         |
| BSandC          | 1 | 1     | 1       | 1     |         |
| Choir           | 1 | 1     | 0       | 0     |         |
| DrumsL          | 0 | 0     | 1       | 0     |         |
| PianoL          | 1 | 1     | 1       | 1     |         |
| FWB             | 1 | 1     | 1       |       |         |
| Swimming        | 1 | 1     | 1       | 0     |         |
| HH              | 1 | 1     | 0       | 0     |         |
| Readers         | 5 | 5     | 5       | 5     |         |
| ReadAloud       | 0 | 0     | 4       | 4     |         |
| ReadCompre      |   | 3     | 3       | 3     | 3       |
| History         | 5 | 5     | 5       | 5     |         |
| HistoryCompre   | 3 | 3     | 3       | 3     | 3       |
| ScienceHS       | 5 | 5     | 0       | 0     |         |
| Science         | 0 | 0     | 4       | 4     |         |
| SciGradComp     | 3 | 3     | 3       | 3     | 3       |

;

|                  |   |   |   |      |
|------------------|---|---|---|------|
| param NumDaysG : | 1 | 2 | 3 | 4 := |
| Math 5           | 5 | 5 | 5 |      |
| Piano1           | 4 | 4 | 0 | 0    |
| Piano2           | 4 | 4 | 0 | 0    |
| Devotions        | 3 | 0 | 0 | 0    |
| BSandC           | 1 | 0 | 0 | 0    |
| Choir            | 1 | 0 | 0 | 0    |

```

DrumsL      1    0    0    0
PianoL      1    1    1    1
FWB 1       0    0    0
Swimming    1    0    0    0
HH 1        0    0    0
Readers     5    5    5    5
ReadAloud   4    4    0    0
ReadCompre  3    3    3    0
History     5    5    5    5
HistoryCompre 3    3    3    0
ScienceHS   5    5    0    0
Science     4    4    0    0
SciGradComp 3    3    3    0
;

```

```

param R : BR    LR    KT    MBR    OUT    CR :=
Math 0    0    0    0    1
Piano1 0    0    1    0    0    0
Piano2 0    0    1    0    0    0
Devotions 0    1    0    0    0    0
BSandC 0    0    0    0    1    0
Choir 0    0    0    0    1    0
DrumsL 0    0    0    0    1    0
PianoL 0    0    1    0    0    0
FWB 0    0    0    0    1    0
Swimming 0    0    0    0    1    0
HH 0    0    0    0    1    0
Readers 1    1    0    0    0    0
ReadAloud 0    1    0    0    0    0
ReadCompre 0    0    1    0    0    0
History 1    1    0    0    0    0
HistoryCompre 0    1    1    0    0    0
ScienceHS 0    0    0    0    0    1
Science 0    1    1    0    0    0
SciGradComp 0    0    1    0    0    0
;

```

```

param M : Monday    Tuesday    Wednesday    Thursday    Friday
Sunday:=
1    0    1    1    1    1    1
2    0    1    1    1    1    1
3    0    1    1    1    1    1
4    0    1    1    1    1    1
5    0    1    1    1    1    1
6    0    1    1    1    1    1
7    0    1    1    1    1    1
8    0    1    1    1    1    1

```

```
9    0    1    1    1    1    1
10   0    1    1    1    1    1
11   0    1    1    1    1    1
12   0    1    1    1    1    1
13   0    1    1    1    1    1
14   0    1    1    1    1    1
15   0    1    1    1    1    1
16   0    1    1    1    1    1
17   0    1    1    1    1    1
18   0    1    1    1    1    1
19   0    1    1    1    1    1
20   0    1    1    1    1    1
21   0    1    1    1    1    1
22   0    1    1    1    1    1
23   0    1    1    1    1    1
24   0    1    1    1    1    1
25   0    1    1    1    1    1
26   0    1    1    1    1    1
27   0    0    1    1    1    1
28   0    0    1    1    1    1
29   0    0    1    1    1    1
30   0    0    1    1    1    1
31   0    0    1    1    1    1
32   0    0    1    1    1    1
33   1    1    1    1    1    1
34   1    1    1    1    1    1
35   1    1    1    1    1    1
36   1    1    1    1    1    1
37   1    1    1    1    1    1
38   1    1    1    1    1    1
39   1    1    1    1    1    1
40   1    1    1    1    1    1
41   1    1    1    1    1    1
42   1    1    1    1    1    1
43   1    1    1    1    1    1
44   1    1    1    1    1    1
45   1    1    1    1    1    1
46   1    1    1    1    1    1
47   1    1    1    1    1    1
48   1    1    1    1    1    1
49   1    1    1    1    1    1
50   1    1    1    1    1    1
51   1    1    1    1    1    1
52   1    1    1    1    1    1;
```

```
param C :=  
Math 3
```

```

Piano1      3
Piano2      2
Devotions   2
BSandC      14
Choir       7
DrumsL      3
PianoL      2
FWB         4
Swimming    2
HH          12
Readers     2
ReadAloud   3
ReadCompre  2
History     2
HistoryCompre 2
ScienceHS   2
Science     3
SciGradComp 1
;

```

```

param T : 1 2 3 4 :=
Math 0 0 0 0
Piano1 0 0 0 0
Piano2 0 0 0 0
Devotions 1 0 0 0
BSandC 1 0 0 0
Choir 1 0 0 0
DrumsL 0 0 0 0
PianoL 1 1 1 1
FWB 1 0 0 0
Swimming 1 0 0 0
HH 0 0 0 0
Readers 0 0 0 0
ReadAloud 1 1 0 0
ReadCompre 1 1 1 0
History 0 0 0 1
HistoryCompre 0 0 0 0
ScienceHS 0 0 0 0
Science 1 1 0 0
SciGradComp 1 1 1 0
;

```

```

param G :=
[*, *, Math]: 1 2 3 4 :=
Kayla 1 0 0 0

```

|                    |   |   |   |   |    |
|--------------------|---|---|---|---|----|
| Karissa            | 0 | 1 | 0 | 0 |    |
| Micah              | 0 | 0 | 1 | 0 |    |
| Leah               | 0 | 0 | 0 | 1 |    |
|                    |   |   |   |   |    |
| [*, *, Piano1]:    | 1 | 2 | 3 | 4 | := |
| Kayla              | 1 | 0 | 0 | 0 |    |
| Karissa            | 0 | 1 | 0 | 0 |    |
| Micah              | 0 | 0 | 0 | 0 |    |
| Leah               | 0 | 0 | 0 | 0 |    |
|                    |   |   |   |   |    |
| [*, *, Piano2]:    | 1 | 2 | 3 | 4 | := |
| Kayla              | 0 | 0 | 0 | 0 |    |
| Karissa            | 0 | 0 | 0 | 0 |    |
| Micah              | 1 | 0 | 0 | 0 |    |
| Leah               | 0 | 1 | 0 | 0 |    |
|                    |   |   |   |   |    |
| [*, *, Devotions]: | 1 | 2 | 3 | 4 | := |
| Kayla              | 1 | 0 | 0 | 0 |    |
| Karissa            | 1 | 0 | 0 | 0 |    |
| Micah              | 1 | 0 | 0 | 0 |    |
| Leah               | 1 | 0 | 0 | 0 |    |
|                    |   |   |   |   |    |
| [*, *, BSandC]:    | 1 | 2 | 3 | 4 | := |
| Kayla              | 1 | 0 | 0 | 0 |    |
| Karissa            | 1 | 0 | 0 | 0 |    |
| Micah              | 1 | 0 | 0 | 0 |    |
| Leah               | 1 | 0 | 0 | 0 |    |
|                    |   |   |   |   |    |
| [*, *, Choir]:     | 1 | 2 | 3 | 4 | := |
| Kayla              | 1 | 0 | 0 | 0 |    |
| Karissa            | 1 | 0 | 0 | 0 |    |
| Micah              | 0 | 0 | 0 | 0 |    |
| Leah               | 0 | 0 | 0 | 0 |    |
|                    |   |   |   |   |    |
| [*, *, DrumsL]:    | 1 | 2 | 3 | 4 | := |
| Kayla              | 0 | 0 | 0 | 0 |    |
| Karissa            | 0 | 0 | 0 | 0 |    |
| Micah              | 1 | 0 | 0 | 0 |    |
| Leah               | 0 | 0 | 0 | 0 |    |
|                    |   |   |   |   |    |
| [*, *, PianoL]:    | 1 | 2 | 3 | 4 | := |
| Kayla              | 1 | 0 | 0 | 0 |    |
| Karissa            | 0 | 1 | 0 | 0 |    |
| Micah              | 0 | 0 | 1 | 0 |    |
| Leah               | 0 | 0 | 0 | 1 |    |
|                    |   |   |   |   |    |
| [*, *, FWB]:       | 1 | 2 | 3 | 4 | := |

|         |   |   |   |   |
|---------|---|---|---|---|
| Kayla   | 1 | 0 | 0 | 0 |
| Karissa | 1 | 0 | 0 | 0 |
| Micah   | 1 | 0 | 0 | 0 |
| Leah    | 1 | 0 | 0 | 0 |

|                   |   |   |   |      |
|-------------------|---|---|---|------|
| [*, *, Swimming]: | 1 | 2 | 3 | 4 := |
| Kayla             | 1 | 0 | 0 | 0    |
| Karissa           | 1 | 0 | 0 | 0    |
| Micah             | 1 | 0 | 0 | 0    |
| Leah              | 0 | 0 | 0 | 0    |

|             |   |   |   |      |
|-------------|---|---|---|------|
| [*, *, HH]: | 1 | 2 | 3 | 4 := |
| Kayla       | 1 | 0 | 0 | 0    |
| Karissa     | 1 | 0 | 0 | 0    |
| Micah       | 0 | 0 | 0 | 0    |
| Leah        | 0 | 0 | 0 | 0    |

|                  |   |   |   |      |
|------------------|---|---|---|------|
| [*, *, Readers]: | 1 | 2 | 3 | 4 := |
| Kayla            | 1 | 0 | 0 | 0    |
| Karissa          | 0 | 1 | 0 | 0    |
| Micah            | 0 | 0 | 1 | 0    |
| Leah             | 0 | 0 | 0 | 1    |

|                    |   |   |   |      |
|--------------------|---|---|---|------|
| [*, *, ReadAloud]: | 1 | 2 | 3 | 4 := |
| Kayla              | 0 | 0 | 0 | 0    |
| Karissa            | 0 | 0 | 0 | 0    |
| Micah              | 1 | 0 | 0 | 0    |
| Leah               | 0 | 1 | 0 | 0    |

|                     |   |   |   |      |
|---------------------|---|---|---|------|
| [*, *, ReadCompre]: | 1 | 2 | 3 | 4 := |
| Kayla               | 1 | 0 | 0 | 0    |
| Karissa             | 1 | 0 | 0 | 0    |
| Micah               | 0 | 1 | 0 | 0    |
| Leah                | 0 | 0 | 1 | 0    |

|                  |   |   |   |      |
|------------------|---|---|---|------|
| [*, *, History]: | 1 | 2 | 3 | 4 := |
| Kayla            | 1 | 0 | 0 | 0    |
| Karissa          | 0 | 1 | 0 | 0    |
| Micah            | 0 | 0 | 1 | 0    |
| Leah             | 0 | 0 | 0 | 1    |

|                        |   |   |   |      |
|------------------------|---|---|---|------|
| [*, *, HistoryCompre]: | 1 | 2 | 3 | 4 := |
| Kayla                  | 1 | 0 | 0 | 0    |
| Karissa                | 1 | 0 | 0 | 0    |
| Micah                  | 0 | 1 | 0 | 0    |
| Leah                   | 0 | 0 | 1 | 0    |

```

[* , *, ScienceHS]: 1 2 3 4 :=
Kayla 1 0 0 0
Karissa 0 1 0 0
Micah 0 0 0 0
Leah 0 0 0 0

[* , *, Science]: 1 2 3 4 :=
Kayla 0 0 0 0
Karissa 0 0 0 0
Micah 1 0 0 0
Leah 0 1 0 0

[* , *, SciGradComp]: 1 2 3 4 :=
Kayla 1 0 0 0
Karissa 1 0 0 0
Micah 0 1 0 0
Leah 0 0 1 0

[* , *, Grading]: 1 2 3 4 :=
Kayla 1 0 0 0
Karissa 0 1 0 0
Micah 0 0 1 0
Leah 0 0 0 1

;

param Numgroups :=
Math 4
Piano1 2
Piano2 2
Devotions 1
BSandC 1
Choir 1
DrumsL 1
PianoL 4
FWB 1
Swimming 1
HH 1
Readers 4
ReadAloud 3
ReadCompre 3
History 4
HistoryCompre 3
ScienceHS 2
Science 2
SciGradComp 3

```

APPENDIX 3 : RAW DATA

| A  | B                      | C | D | E | F   | G | H | I | J  | K    | L  | M               | N               | O        | P  | Q  |          |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
|----|------------------------|---|---|---|-----|---|---|---|----|------|----|-----------------|-----------------|----------|----|----|----------|-------|---------|-------|------|----------|-------|----------|----|----|----|----|----|----|----|----|----|----|----|----|----|--|--|
|    |                        |   |   |   |     |   |   |   |    |      |    |                 |                 |          |    |    | Subjects | Kayla | Karissa | Micah | Leah | Duration | Venue | Computer |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 1  | 2                      | 3 | 4 | 5 | 6   | 7 | 8 | 9 | 10 | 11   | 12 | 13              | 14              | 15       | 16 | 17 | 18       | 19    | 20      | 21    | 22   | 23       | 24    | 25       | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 |  |  |
|    |                        |   |   |   |     |   |   |   |    | Days |    |                 |                 |          |    |    |          |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
|    |                        |   |   |   |     |   |   | M | T  | W    | R  | F               | S               | SU       |    |    |          |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 4  | Readers                | Y | Y | Y | 30  |   | Y | Y | Y  | Y    | Y  | N               | N               | BR1/LR   |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 5  | Read-a-loud            | N | Y | Y | 45  |   | N | Y | N  | N    | Y  | N               | Y               | LR       |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 6  | Reading Comprehension  | Y | Y | Y | 30  |   | N | Y | N  | N    | Y  | N               | N               | K        |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 7  | History                | Y | Y | Y | 30  |   | Y | Y | Y  | Y    | Y  | N               | N               | BR1/LR   |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 8  | History Comprehension  | Y | Y | Y | 30  |   | N | Y | N  | N    | Y  | N               | N               | K/LR     |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 9  | Math                   | Y | Y | Y | 45  |   | Y | Y | Y  | Y    | Y  | N               | N               | BR2      |    |    | Y        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 10 | Grammar                | N | N | Y |     |   |   |   |    |      |    |                 |                 |          |    |    |          |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 11 | Science HS             | Y | Y | N | 30  |   | Y | Y | Y  | Y    | Y  | N               | N               | BR2      |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 12 | Science                | N | Y | Y | 45  |   | Y | Y | N  | N    | Y  | N               | N               | K/LR     |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 13 | Science Grading/Comp   | Y | Y | Y | 15  |   | N | Y | N  | N    | Y  | N               | N               | K        |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 14 | Piano 1                | Y | Y | N | 45  |   | Y | Y | Y  | Y    | Y  | N               | N               | K        |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 15 | Piano 2                | N | Y | Y | 30  |   | Y | Y | Y  | Y    | Y  | N               | N               | K        |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 16 | Piano Lesson           | Y | Y | Y | 30  |   | N | Y | N  | N    | Y  | N               | N               | K        |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 17 | Drums                  | N | Y | N | 30  |   | Y | Y | Y  | Y    | Y  | N               | N               | BR3      |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 18 | Bible                  | Y | Y | Y | 30  |   | Y | Y | Y  | Y    | Y  | N               | N               | BR1      |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 19 | Devotions/Planning     | Y | Y | Y | 30  |   | Y | Y | Y  | Y    | Y  | N               | N               | LR       |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 20 | Memory Work            | Y | Y | Y | 15  |   | Y | N | N  | N    | Y  | N               | N               | BR1      |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 21 | Recitation of memory   | Y | Y | Y | 15  |   | Y | N | N  | N    | Y  | N               | N               | LR       |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 22 | Typing                 | Y | Y | Y | 15  |   | Y | Y | Y  | Y    | Y  | N               | N               | BR2      |    |    | Y        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 23 | Art 1                  | Y | Y | Y | 30  |   | Y | Y | Y  | Y    | Y  | ANY 3 DAYS WEEK | ANY 3 DAYS WEEK | Anywhere |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 24 | Art 2                  | N | Y | N | 30  |   | Y | Y | Y  | Y    | Y  | ANY 3 DAYS WEEK | ANY 3 DAYS WEEK | BR2      |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 25 | Spanish                | Y | Y | N |     |   |   | Y | Y  | Y    | Y  | N               | N               | BR2      |    |    | Y        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 26 | Physical Education 1   | N | Y | N | 30  |   | Y | Y | Y  | Y    | Y  | ANY 3 DAYS WEEK | ANY 3 DAYS WEEK | BR2      |    |    | Y        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 27 | Physical Education 2   | N | Y | N | 30  |   | Y | Y | Y  | Y    | Y  | ANY 3 DAYS WEEK | ANY 3 DAYS WEEK | BR2      |    |    | Y        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 28 | Phys. Ed Practice      | Y | Y | Y | 45  |   | Y | Y | N  | N    | Y  | N               | N               | LR/OUT   |    |    | Y        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 29 | Writing                | Y | Y | Y | 15  |   | Y | Y | Y  | Y    | Y  | N               | N               | BR2      |    |    | Y        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 30 | Grading                | Y | Y | Y | 45  |   | N | Y | Y  | Y    | Y  | N               | N               | BR2      |    |    | Y        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 31 |                        |   |   |   |     |   |   |   |    |      |    |                 |                 |          |    |    |          |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 32 | Fixed Time Subjects    |   |   |   |     |   |   |   |    |      |    |                 |                 |          |    |    |          |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 33 | Bible study and church | Y | Y | Y | 210 |   | N | N | N  | N    | N  | N               | Y               | FCC      |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 34 | Choir                  | Y | Y | N | 105 |   | Y | N | N  | N    | N  | N               | N               | KE       |    |    | Y        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 35 | Drums Lesson           | N | Y | N | 45  |   | N | N | Y  | Y    | N  | N               | N               | FCC      |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 36 | Fitness with Brittany  | Y | Y | Y | 60  |   | N | N | Y  | Y    | N  | N               | N               | FCC      |    |    | N        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 37 | Swimming               | Y | Y | Y | 30  |   | N | N | Y  | Y    | N  | N               | N               | FCC      |    |    | Y        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |
| 38 | Heavenly Hoofs         | Y | Y | N | 180 |   | N | N | N  | Y    | N  | N               | N               | FCC      |    |    | Y        |       |         |       |      |          |       |          |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |



|   |   | Mom   |         |       |      | Subjects               |   |   |   | Total No. of days in a week a subject should be studied |         |       |      |            |
|---|---|-------|---------|-------|------|------------------------|---|---|---|---|---------|-------|------|------------|
|   |   | Kayla | Karissa | Micah | Leah |                        |   |   |   | Kayla   | Karissa | Micah | Leah | TIME       |
| N | N | N     | N       | N     | N    | Readers                | 5 | 5 | 5 | 5   | 5       | 5     | 5    |            |
| N | N | Y     | Y       | Y     | Y    | Read-a-loud            | 0 | 0 | 4 | 4   | 4       | 4     | 4    |            |
| Y | Y | Y     | Y       | Y     | Y    | Reading Comprehension  | 3 | 3 | 3 | 3   | 3       | 3     | 3    |            |
| N | N | N     | N       | N     | N    | History                | 5 | 5 | 5 | 5   | 5       | 5     | 5    |            |
| N | N | N     | N       | N     | N    | History Comprehension  | 3 | 3 | 3 | 3   | 3       | 3     | 3    | Dad on M   |
| N | N | N     | N       | N     | N    | Math                   | 5 | 5 | 5 | 5   | 5       | 5     | 5    |            |
|   |   |       |         |       |      | Grammar                |   |   |   |   |         |       |      |            |
| N | N | N     | N       | N     | N    | Science HS             | 5 | 5 | 0 | 0   | 0       | 0     | 0    |            |
| N | N | Y     | Y       | Y     | Y    | Science                | 0 | 0 | 4 | 4   | 4       | 4     | 4    |            |
| Y | Y | Y     | Y       | Y     | Y    | Science Grading/Compl  | 3 | 3 | 3 | 3   | 3       | 3     | 3    |            |
| N | N | N     | N       | N     | N    | Piano 1                | 4 | 4 | 0 | 0   | 0       | 0     | 0    |            |
| N | N | N     | N       | N     | N    | Piano 2                | 0 | 0 | 4 | 4   | 4       | 4     | 4    |            |
| Y | Y | Y     | Y       | Y     | Y    | Piano Lesson           | 1 | 1 | 1 | 1   | 1       | 1     | 1    |            |
| N | N | Y     | Y       | Y     | Y    | Drums                  | 0 | 0 | 4 | 4   | 4       | 4     | 4    |            |
| Y | Y | Y     | Y       | Y     | Y    | Bible                  | 5 | 5 | 5 | 5   | 5       | 5     | 5    | Dad on M   |
| Y | Y | Y     | Y       | Y     | Y    | Devotions/Planning     | 3 | 3 | 3 | 3   | 3       | 3     | 3    |            |
| Y | Y | Y     | Y       | Y     | Y    | Memory Work            | 1 | 1 | 1 | 1   | 1       | 1     | 1    |            |
| Y | Y | Y     | Y       | Y     | Y    | Recitation of memory   | 1 | 1 | 1 | 1   | 1       | 1     | 1    |            |
| N | N | N     | N       | N     | N    | Typing                 | 4 | 4 | 4 | 4   | 4       | 4     | 4    |            |
| N | N | N     | N       | N     | N    | Art 1                  | 3 | 3 | 0 | 0   | 0       | 0     | 0    |            |
| N | N | N     | N       | N     | N    | Art 2                  | 0 | 0 | 3 | 3   | 3       | 3     | 3    |            |
|   |   |       |         |       |      | Spanish                |   |   |   |   |         |       |      |            |
| N | N | N     | N       | N     | N    | Physical Education 1   | 5 | 5 | 0 | 0   | 0       | 0     | 0    |            |
| N | N | N     | N       | N     | N    | Physical Education 2   | 0 | 0 | 3 | 3   | 3       | 3     | 3    |            |
| Y | Y | Y     | Y       | Y     | Y    | Phys. Ed Practice      | 4 | 4 | 4 | 4   | 4       | 4     | 4    |            |
| N | N | N     | N       | N     | N    | Writing                | 4 | 4 | 4 | 4   | 4       | 4     | 4    |            |
| Y | Y | Y     | Y       | Y     | Y    | Grading                | 2 | 2 | 2 | 2   | 2       | 2     | 2    |            |
|   |   |       |         |       |      |                        |   |   |   |   |         |       |      |            |
| Y | Y | Y     | Y       | Y     | Y    | Bible study and church | 1 | 1 | 1 | 1   | 1       | 1     | 1    | 9:00-12:30 |
| Y | Y | N     | N       | N     | N    | Choir                  | 1 | 1 | 0 | 0   | 0       | 0     | 0    | 6:30-8:15  |
| N | N | N     | N       | N     | N    | Drums Lesson           | 0 | 0 | 1 | 1   | 1       | 1     | 1    | 4:00-4:30  |
| Y | Y | Y     | Y       | Y     | Y    | Fitness with Brittany  | 1 | 1 | 1 | 1   | 1       | 1     | 1    | 12:30-1:30 |
| Y | Y | Y     | Y       | Y     | Y    | Swimming               | 1 | 1 | 1 | 1   | 1       | 1     | 1    | 1:30-2:00  |
| N | N | N     | N       | N     | N    | Heavenly Hoofs         | 1 | 1 | 1 | 1   | 1       | 1     | 1    | 2:30-6:00  |

LR – Living Room (LR)

K – Kitchen (K)

BR1 – Bedroom (BR)

BR2 – Computer room (CR)

BR3 – Master Bedroom (MBR)

OUT – Lawn

|    | A                      | B | C               | D | E                 | F | G | H | I | J | K | L | M | N |
|----|------------------------|---|-----------------|---|-------------------|---|---|---|---|---|---|---|---|---|
| 1  | Subjects               |   | Number in group |   | Students in group |   |   |   |   |   |   |   |   |   |
| 2  |                        |   |                 |   |                   |   |   |   |   |   |   |   |   |   |
| 3  | Readers                |   | 1               |   |                   |   |   |   |   |   |   |   |   |   |
| 4  | Read-a-loud            |   | 1\1\2           |   | L/M/Ky and Ks     |   |   |   |   |   |   |   |   |   |
| 5  | ReadingComprehension   |   | 1\1\2           |   | L/M/Ky and Ks     |   |   |   |   |   |   |   |   |   |
| 6  | History                |   | 1               |   |                   |   |   |   |   |   |   |   |   |   |
| 7  | History Comprehension  |   | 1\1\2           |   | L/M/Ky and Ks     |   |   |   |   |   |   |   |   |   |
| 8  | Math                   |   | 1               |   |                   |   |   |   |   |   |   |   |   |   |
| 9  | Grammar                |   | 2               |   | M and L           |   |   |   |   |   |   |   |   |   |
| 10 | Science                |   | 1               |   |                   |   |   |   |   |   |   |   |   |   |
| 11 | Science Grading/Compr. |   | 1\1\2           |   | L/M/Ky and Ks     |   |   |   |   |   |   |   |   |   |
| 12 | Piano                  |   | 1               |   |                   |   |   |   |   |   |   |   |   |   |
| 13 | Piano Lesson           |   | 1               |   |                   |   |   |   |   |   |   |   |   |   |
| 14 | Drums                  |   | 1               |   | M                 |   |   |   |   |   |   |   |   |   |
| 15 | Bible                  |   | 1               |   |                   |   |   |   |   |   |   |   |   |   |
| 16 | Devotions/Planning     |   | 4               |   | All               |   |   |   |   |   |   |   |   |   |
| 17 | Memory Work            |   | 1               |   |                   |   |   |   |   |   |   |   |   |   |
| 18 | Recitation of memory   |   | 4               |   | All               |   |   |   |   |   |   |   |   |   |
| 19 | Typing                 |   | 1               |   |                   |   |   |   |   |   |   |   |   |   |
| 20 | Art                    |   | 1               |   |                   |   |   |   |   |   |   |   |   |   |
| 21 | Phys. Ed Practice      |   | 1               |   |                   |   |   |   |   |   |   |   |   |   |
| 22 | Writing                |   | 1               |   |                   |   |   |   |   |   |   |   |   |   |
| 23 | Grading                |   | 1               |   |                   |   |   |   |   |   |   |   |   |   |
| 24 | Bible study and church |   | 4               |   | All               |   |   |   |   |   |   |   |   |   |
| 25 | Choir                  |   | 2               |   | Ky and Ks         |   |   |   |   |   |   |   |   |   |
| 26 | Drums Lesson           |   | 1               |   | M                 |   |   |   |   |   |   |   |   |   |
| 27 | Fitness with Brittany  |   | 4               |   |                   |   |   |   |   |   |   |   |   |   |
| 28 | Swimming               |   | 3               |   |                   |   |   |   |   |   |   |   |   |   |
| 29 | Heavenly Hoofs         |   | 2               |   | Ky and Ks         |   |   |   |   |   |   |   |   |   |
| 30 |                        |   |                 |   |                   |   |   |   |   |   |   |   |   |   |

1/1/2 - Three groups with one student in group 1 and 2 and two students in group 3.  
 1 - Individual not in group.  
 4 - all in one group  
 2 - 2 students only in group 1

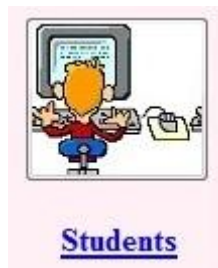
## Introduction and Navigation

1. Double click on the “Homeschool Timetabling” software icon to launch it. A welcome screen appears as shown below.

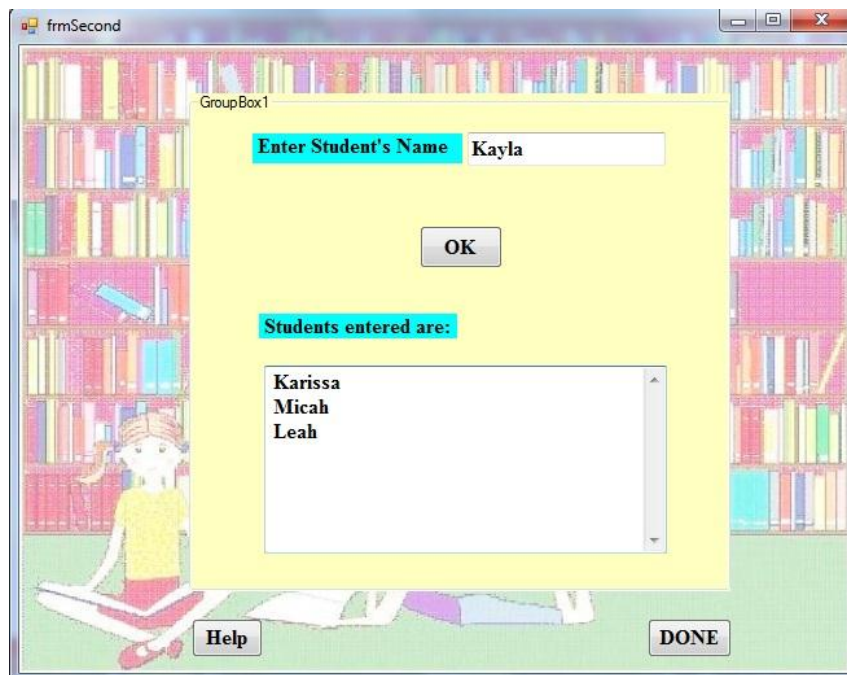


2. The software is designed to get all the necessary information from the user so that it can generate an optimal timetable for a student if one exists.
3. The timetable generator collects information from the user in five sections. In order to generate a timetable the user must complete entering information in all these sections.

4. The first section is “Students”. Here the user must enter the names of all the students for whom the timetable is to be prepared.



5. When the “Students” button is clicked a page appears where the names of all the students can be entered.



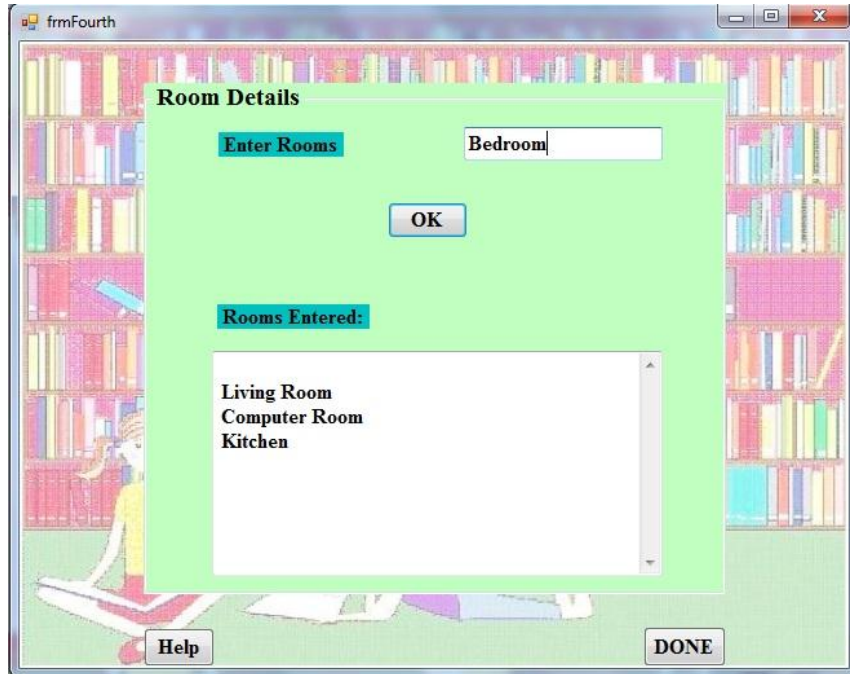
6. In the “Enter Student’s Name” text box type the name of the student and then click on the “OK” button or hit enter. The name now automatically appears on the

“Students entered are” list box. Once all the names have been entered click on the “DONE” button.

7. In the next section information about the rooms can be entered. To do so, click on the “Rooms” button on the welcome page.



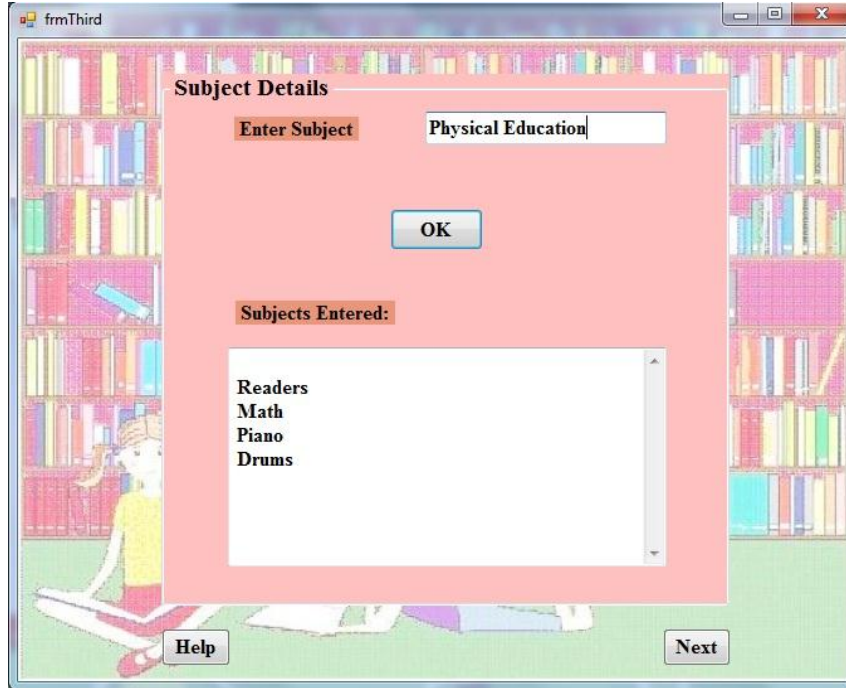
8. In the page that appears, enter the names of all the rooms where students are allowed to learn their subjects. To do so, in the “Enter Rooms” textbox type the name of the room and hit enter or click on the “OK” button. Once this is done the name of the room automatically appears on the “Rooms Entered” list box. Once the names of all the rooms have been entered click on “DONE”.



9. The next section requests information about all the subjects that is to be taken by the students. When the “Subjects” button on the welcome page is clicked, the subject details page appears on the screen.

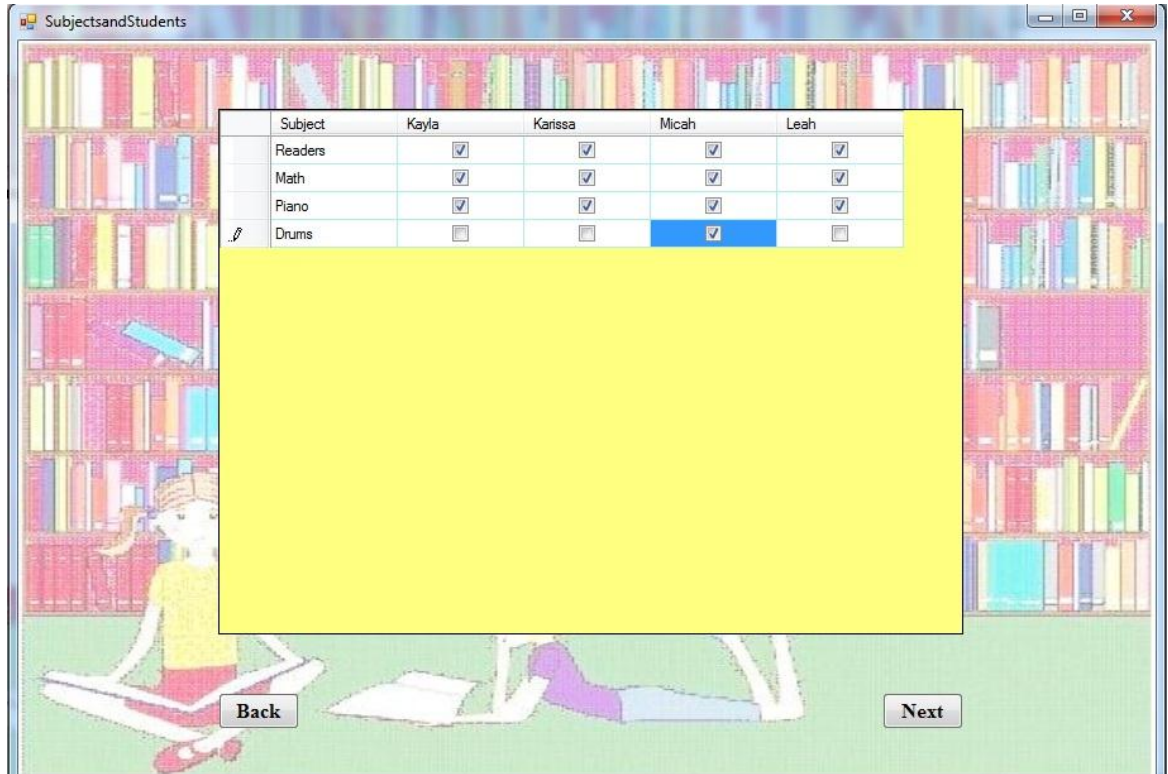


10. In the subject details page enter the name of each subject one by one. After entering a subject in the “Enter Subject” text box hit enter or click on the “OK” button. As the subjects are entered it automatically appears in the “Subjects Entered” list box. Once all the subjects are entered click on the “Next” button.



11. Once the “Next” button is clicked a page appears on the screen with all the subjects that were entered previously. Across each subject there appears some checkboxes for each student. If a student is required to study a certain subject then mark that checkbox otherwise leave it blank. Once this information is entered for all the subjects click on the “Next” button.





For example: The above picture shows that Kayla, Karissa, Micah and Leah must study subjects Readers, Math and Piano. But drums must be taken only by Micah.

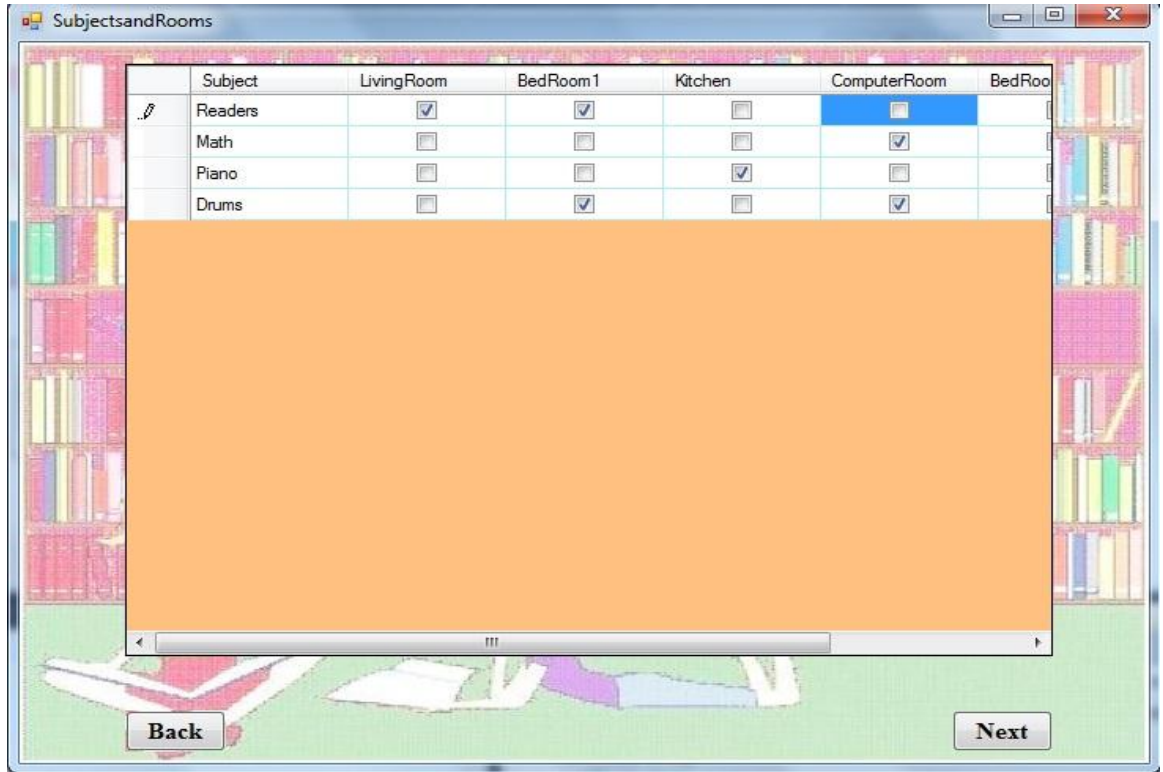
- In the next page that appears information about the days when a subject must be taken should be entered. Across each subject there appears checkboxes for each day. Mark the checkbox if a subject is to be taken on that day similar to the one shown below.



| Subject | Monday                              | Tuesday                             | Wednesday                           | Thursday                            | Friday                              | Sunday                   |
|---------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|--------------------------|
| Readers | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| Math    | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| Piano   | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/> |
| Drums   | <input type="checkbox"/>            | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> |

Back Next

13. Once this is completed click on the “Next” button. In the page that appears, choose the rooms where each subject could be studied by marking the corresponding checkboxes. After this click on the “Next” button.



14. In the following page enter information about the number of times in a week each subject must be taken and whether each subject must be studied in groups or individually.

| Subject | Kayla | Karissa | Micah | Leah |
|---------|-------|---------|-------|------|
| Readers | 4     | 4       | 4     | 4    |
| Math    | 5     | 5       | 5     | 5    |
| Piano   | 2     | 2       | 2     | 2    |
| Drums   | 1     | 0       | 0     | 0    |

| Subject | G1 | G2 | G3 | G4 |
|---------|----|----|----|----|
| Readers | 1  | 1  | 1  | 1  |
| Math    | 1  | 1  | 1  | 1  |
| Piano   | 1  | 1  | 1  | 1  |
| Drums   | 1  | 0  | 0  | 0  |

15. In the above picture, the table on the left is used to indicate the number of times in a week a subject must be taken by a student. The table on the right is used to indicate number of students present in each group. If a subject is to be studied in groups then a more than one should be indicated in the appropriate groups G1, G2, G3 or G4.
16. Click on the “Add” button once each table is completed. If there are any changes that you would like to make, simply enter the changes and click on the “Add” button once again. Click on the “Next” button after completing the form.
17. In the page that appears enter information about the number of 15 minute time slots required for each subject on the left table and the total number of groups present for each subject on the right table.

**Number of times slots required per subject**

| Subject | NumberofTimeslots |
|---------|-------------------|
| Readers | 3                 |
| Math    | 3                 |
| Piano   | 2                 |
| ▶ Drums | 3                 |

**Add**

**Number of Groups present for each subject**

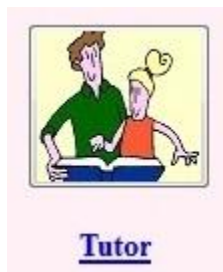
| Subject | NumberofGroups |
|---------|----------------|
| Readers | 4              |
| Math    | 4              |
| Piano   | 4              |
| ▶ Drums | 1              |
| *       |                |

**Add**

**Back**
**Next**

18. After completing both tables click on the corresponding “Add” button. Then click on the “Next” button.

19. Now on the welcome page, click on “Tutor”. The tutor availability form appears and here the timings when mother is available to guide the students can be entered.

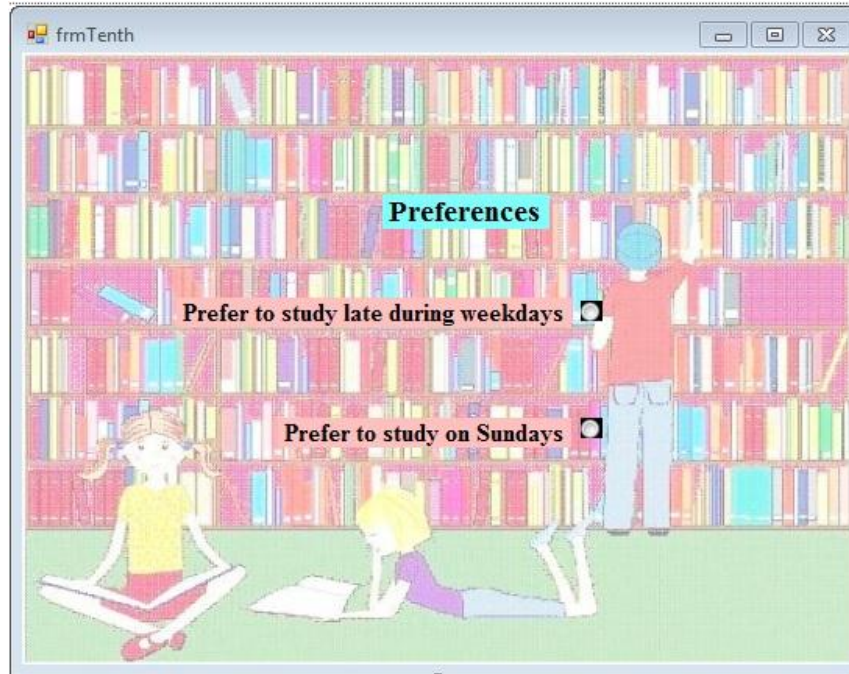


20. Each checkbox across a 15 minutes timeslot on any day is marked, if mother is available to guide a student or a group in studying a subject. For example, if mother is available to teach the students from 10:00 am to 11:00 am on Monday then the four checkboxes across the timeslots 9, 10, 11 and 12 under Monday is marked. Once the form is complete click the “OK” button.

| Time Slots           | Monday                              | Tuesday                  | Wednesday                | Thursday                 | Friday                   |
|----------------------|-------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 01 (08:00 - 08:15am) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 02 (08:15 - 08:30am) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 03 (08:30 - 08:45am) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 04 (08:45 - 09:00am) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 05 (09:00 - 09:15am) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 06 (09:15 - 09:30am) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 07 (09:30 - 09:45am) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 08 (09:45 - 10:00am) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 09 (10:00 - 10:15am) | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 10 (10:15 - 10:30am) | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 11 (10:30 - 10:45am) | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 12 (10:45 - 11:00am) | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 13 (11:00 - 11:15am) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 14 (11:15 - 11:30am) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 15 (11:30 - 11:45am) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 16 (11:45 - 12:00pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 17 (01:00 - 01:15pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 18 (01:15 - 01:30pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 19 (01:30 - 01:45pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 20 (01:45 - 02:00pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 21 (02:00 - 02:15pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 22 (02:15 - 02:30pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 23 (02:30 - 02:45pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 24 (02:45 - 03:00pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 25 (03:00 - 03:15pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 26 (03:15 - 03:30pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 27 (03:30 - 03:45pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 28 (03:45 - 04:00pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 29 (04:00 - 04:15pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 30 (04:15 - 04:30pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 31 (04:30 - 04:45pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 32 (04:45 - 05:00pm) | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

21. On the welcome page, now click on “Preferences”. The preference form appears on the screen to indicate studying preferences.





22. In the above form, select one of the two given options to indicate if a student should study late during the weekdays and not study during Sundays or vice versa.
23. After entering this information close the form.

All the information that is required to generate the timetable has been saved from time to time in the form of .csv files at each step in the GUI. The GLPK model automatically uses this information directly from the files when the model is run.

## Running the GLPK model

To download GLPK, use link <http://gnuwin32.sourceforge.net/packages/glpk.htm> and download the setup file from the link. Follow the instructions to install GLPK into your system. Once installed go to the command prompt and change your root folder to where GLPK is installed. For example: C:\ProgramFiles\GnuWin32\bin. Then enter the following:

```
glpsol --model FullModel.mod --data FullData.dat --solution timetable.sol
```

## Instructions to convert the solution file to a readable format

1. The solution provided by GLPK is available under Program Files → GnuWin32 → bin as a .SOL file. Right click on the solution file and open with WordPad.
2. In the solution file, remove all the constraints and leave the variables X, Y and Z as shown below.

```

NewSoln - WordPad
Home View
Clipboard Font Paragraph Insert Editing
Courier New 11
B I U abc Xs X'
Picture Paint drawing Date and time Insert object Find Replace Select all

From here.
Problem: NewFullModel
Rows: 4209
Columns: 2304 (2304 integer, 2304 binary)
Non-zeros: 14656
Status: INTEGER OPTIMAL
Objective: obj = 80000024 (MINimum)

No. Row name Activity Lower bound Upper bound
-----
1 obj 8.00000e+007
2 constraint1[Piano1,Kayla,Monday] 1 1
3 constraint1[Piano1,Kayla,Tuesday] 1 1
4 constraint1[Piano1,Karissa,Monday] 1 1
5 constraint1[Piano1,Karissa,Tuesday] 1 1
6 constraint1[Piano1,Micah,Monday] 0 -0
7 constraint1[Piano1,Micah,Tuesday] 0 -0
8 constraint1[Piano1,Leah,Monday] 0 -0
9 constraint1[Piano1,Leah,Tuesday] 0 -0
10 constraint1[Piano2,Kayla,Monday] 0 -0

```

```

NewSoln - WordPad
Home View
Clipboard Font Paragraph Insert Editing
Courier New 11
B I U abc Xs X'
Picture Paint drawing Date and time Insert object Find Replace Select all

Till here.
4203 constraint13[Tuesday,2] 1 1
4204 constraint13[Tuesday,3] 1 1
4205 constraint13[Tuesday,4] 1 1
4206 constraint13[Tuesday,5] 1 1
4207 constraint13[Tuesday,6] 1 1
4208 constraint13[Tuesday,7] 1 1
4209 constraint13[Tuesday,8] 1 1

No. Column name Activity Lower bound Upper bound
-----
1 X[Piano1,Kayla,Monday,LR,1] 0 0 1
2 X[Piano1,Kayla,Monday,LR,2] 0 0 1
3 X[Piano1,Kayla,Monday,LR,3] 0 0 1
4 X[Piano1,Kayla,Monday,LR,4] 0 0 1
5 X[Piano1,Kayla,Monday,LR,5] 0 0 1
6 X[Piano1,Kayla,Monday,LR,6] 0 0 1

```

- Also remove the integer feasibility conditions at the very end of the solution file as shown below and save the file.



```

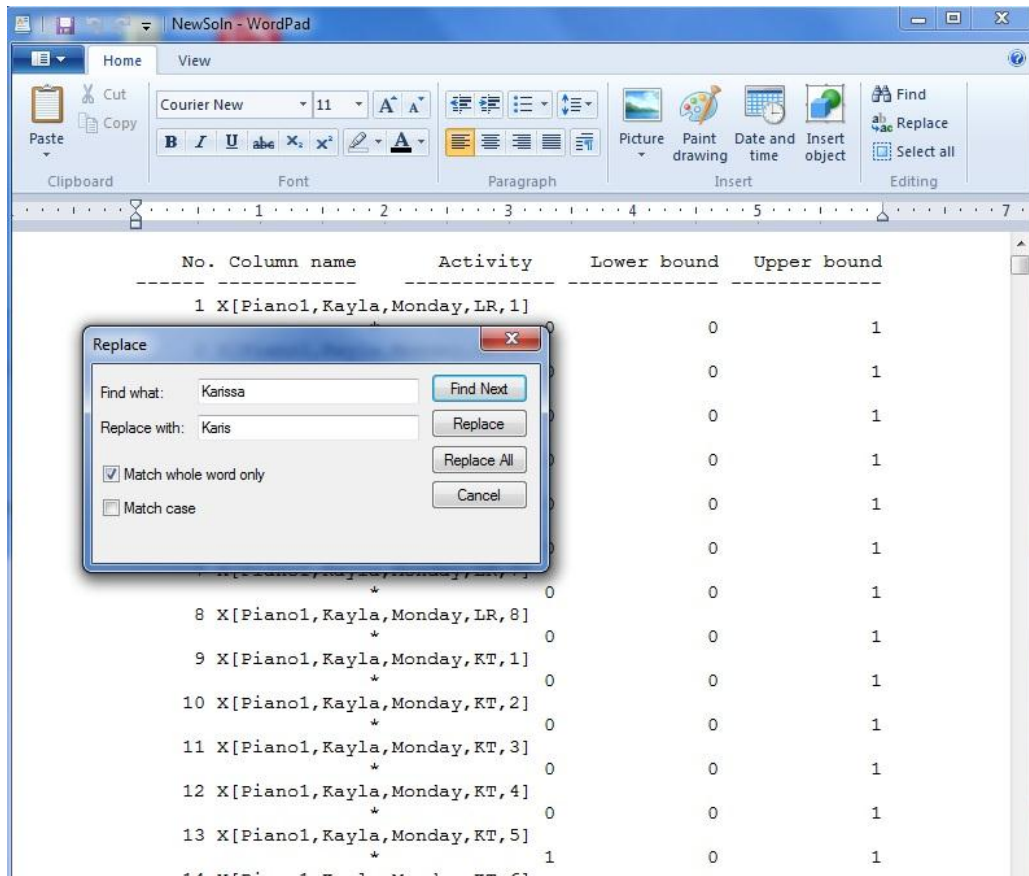
2293 Y[Math,4,Tuesday,CR,5]      0      0      1
      *
2294 Y[Math,4,Tuesday,CR,6]      0      0      1
      *
2295 Y[Math,4,Tuesday,CR,7]      0      0      1
      *
2296 Y[Math,4,Tuesday,CR,8]      0      0      1
      *
2297 Y[Math,4,Tuesday,BR,1]      0      0      1
      *
2298 Y[Math,4,Tuesday,BR,2]      1      0      1
      *
2299 Y[Math,4,Tuesday,BR,3]      0      0      1
      *
2300 Y[Math,4,Tuesday,BR,4]      0      0      1
      *
2301 Y[Math,4,Tuesday,BR,5]      0      0      1
      *
2302 Y[Math,4,Tuesday,BR,6]      0      0      1
      *
2303 Y[Math,4,Tuesday,BR,7]      0      0      1
      *
2304 Y[Math,4,Tuesday,BR,8]      0      0      1
      *
Integer feasibility conditions:
INT.PE: max.abs.err. = 0.00e+000 on row 0
max.rel.err. = 0.00e+000 on row 0
High quality
INT.PB: max.abs.err. = 0.00e+000 on row 0
max.rel.err. = 0.00e+000 on row 0
High quality
End of output

```

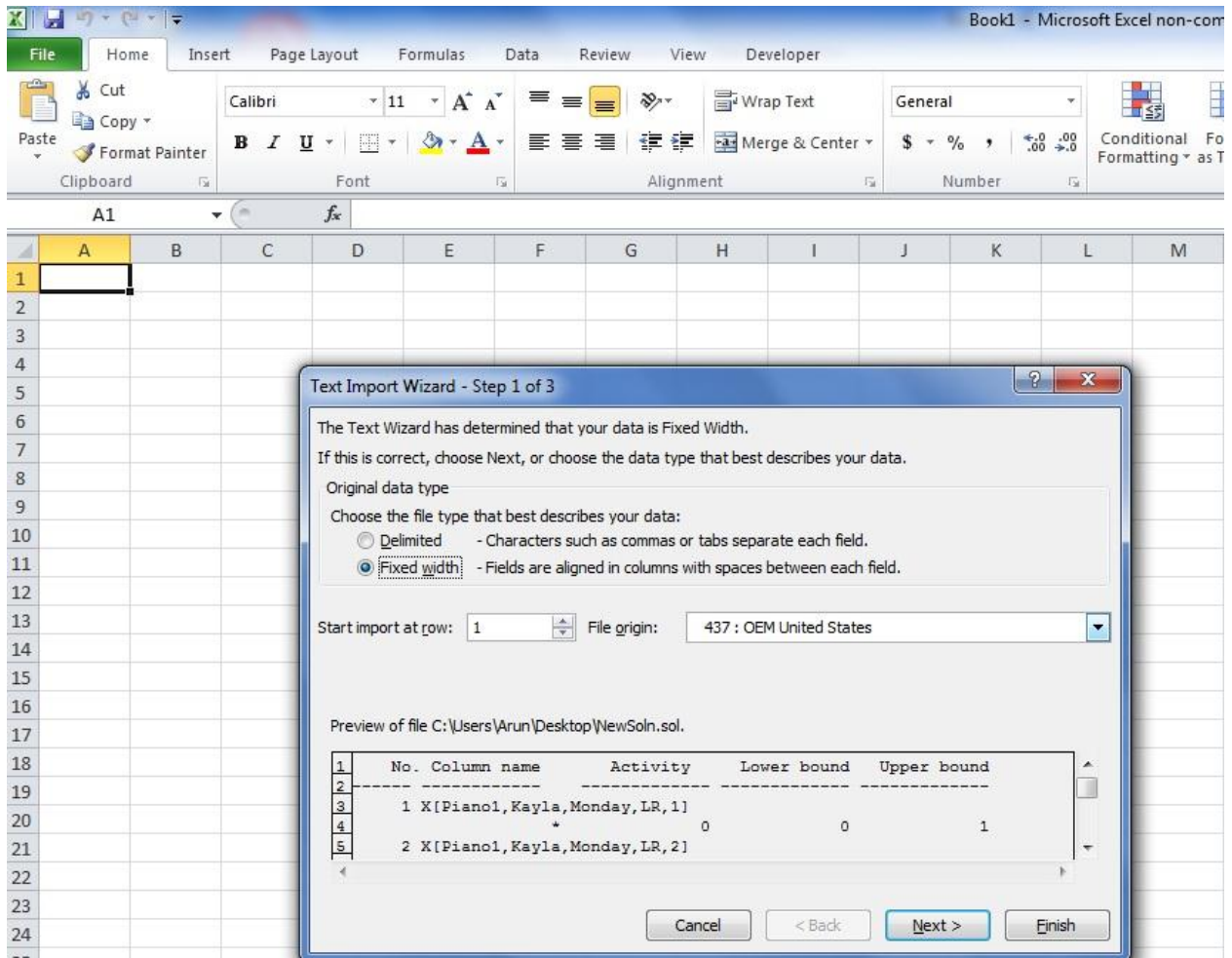
4. In this file the maximum number of characters that can be present under column name is 27 beginning at X and ending with the closed square brackets.

X[Piano1,Kayla,Monday,LR,1]. Hence we need to replace longer names with shorter ones. For example: Karissa can be replaced with “Karis”, Wednesday could be replaced with “Wed” and so on.

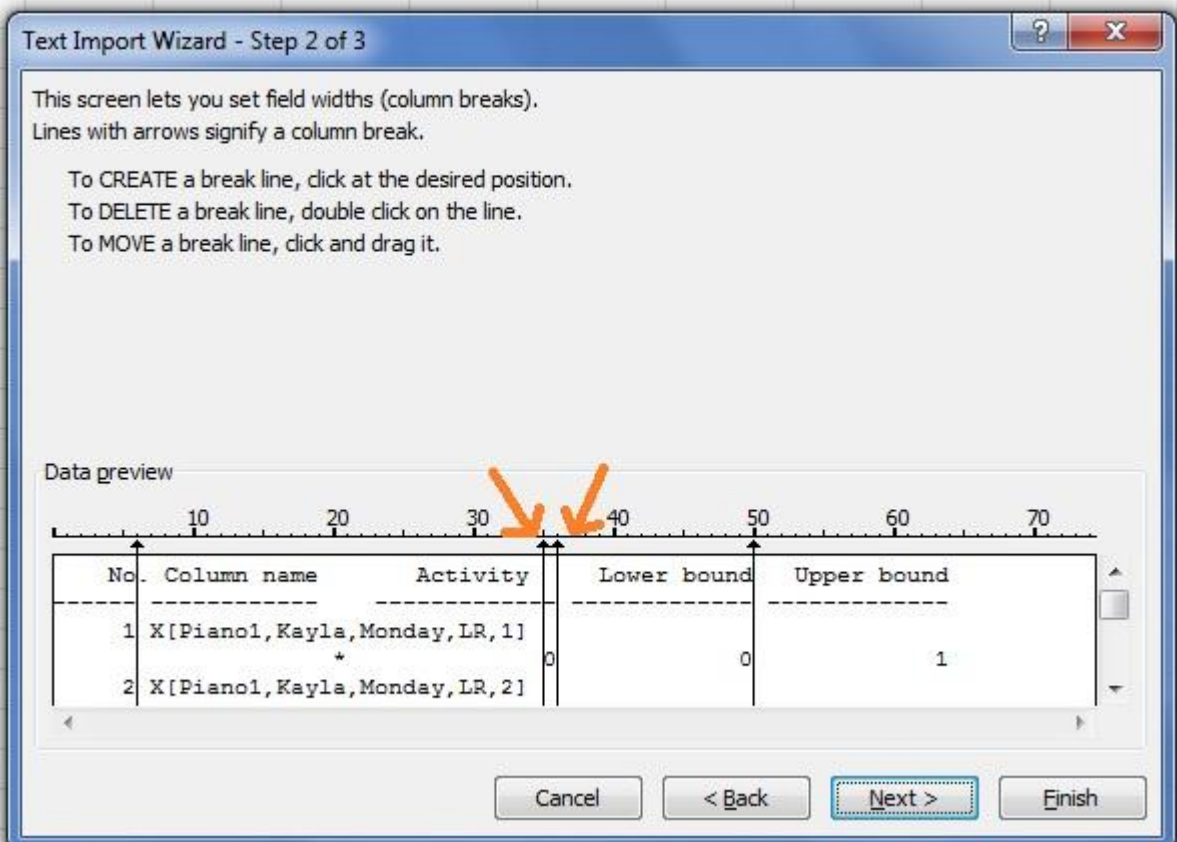
5. In this file: Karissa is replaced with “Karis”. Go to Replace option in WordPad and type “Karissa” in the Find box and “Karis” in the Replace box. And click on “Replace All” button as shown below. Then save the file.



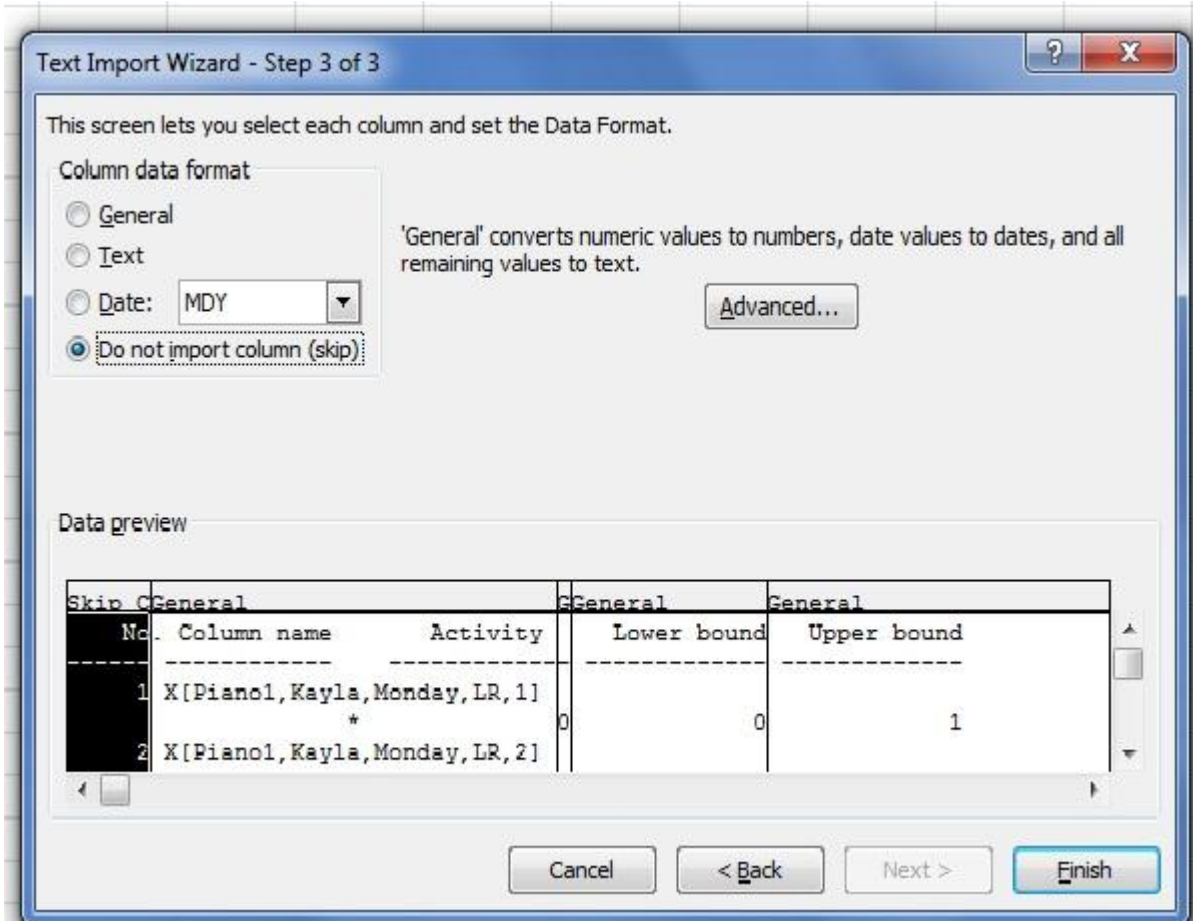
- Open MS Excel and go to File → Open and open the solution file. A screen as shown below appears on the screen.



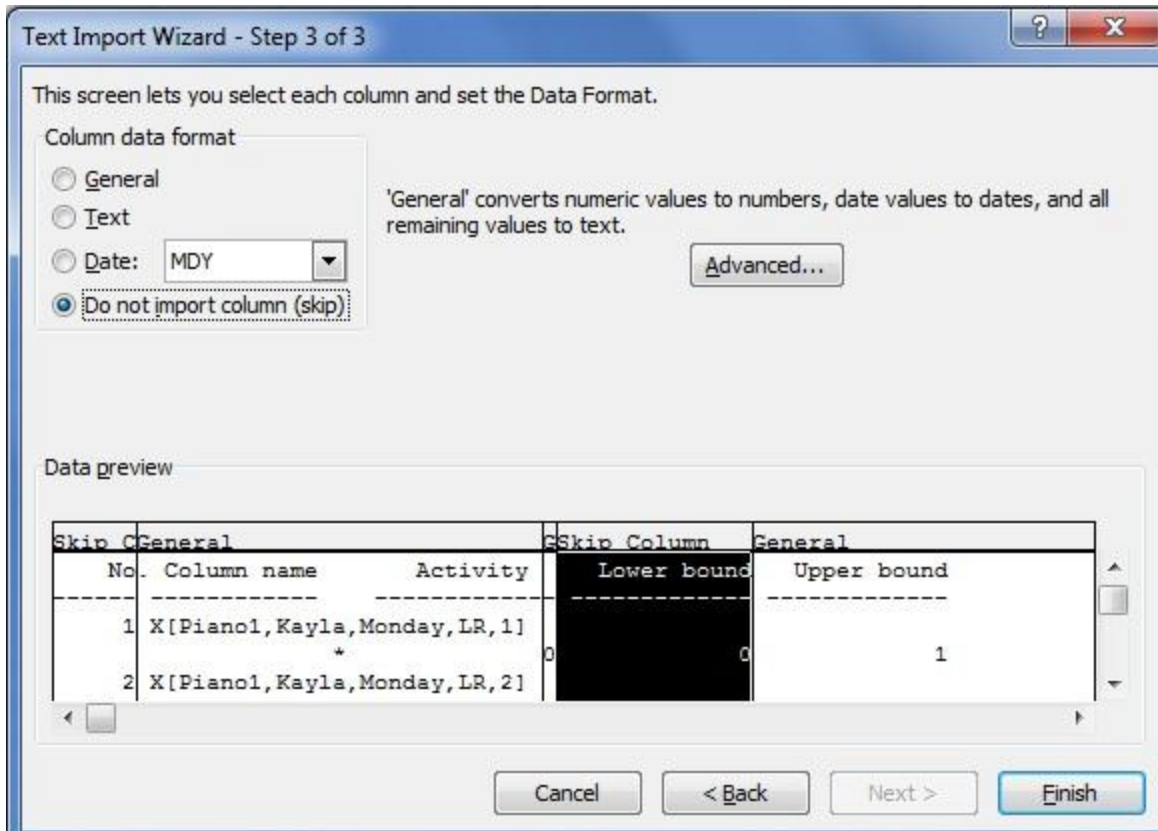
7. With “Fixed width” option selected in the “Text Import Wizard” window, change the “Start import at row” to where No.1 starts in the preview window of the solution file. In this case the No.1 is at row 3. So here we change it to 3. Then click on “Next” button.
8. Next is an important step in the process. Make sure that only the first number is placed between the two break lines without any spaces exactly as shown below. Then click on the “Next” button.

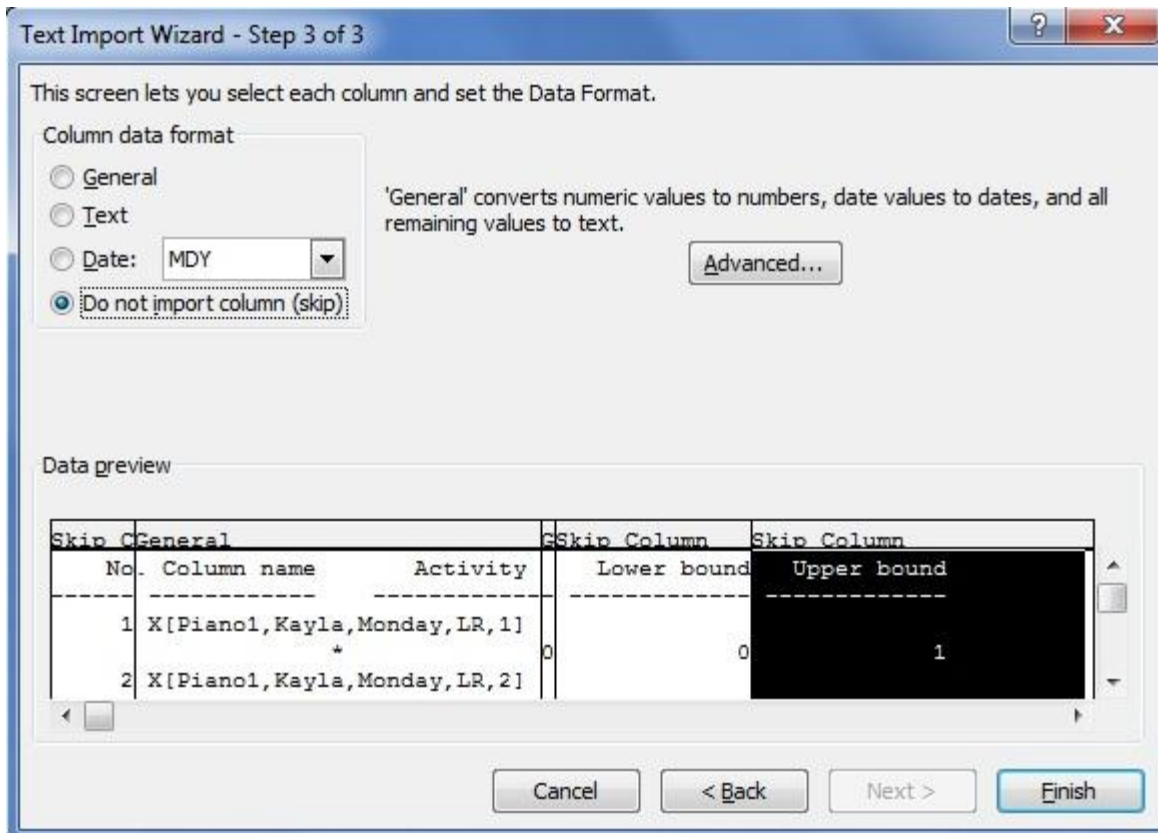


9. In the next window, With column “No.” highlighted in black select the option “Do not import column (skip)” in the “Column Data Format” group box as shown below.



10. Similarly, highlight the columns “Lower bound” and “Upper bound” and change the “Column data format” option to “Do not import column (skip)” as shown below. Then click on the “Finish” button.

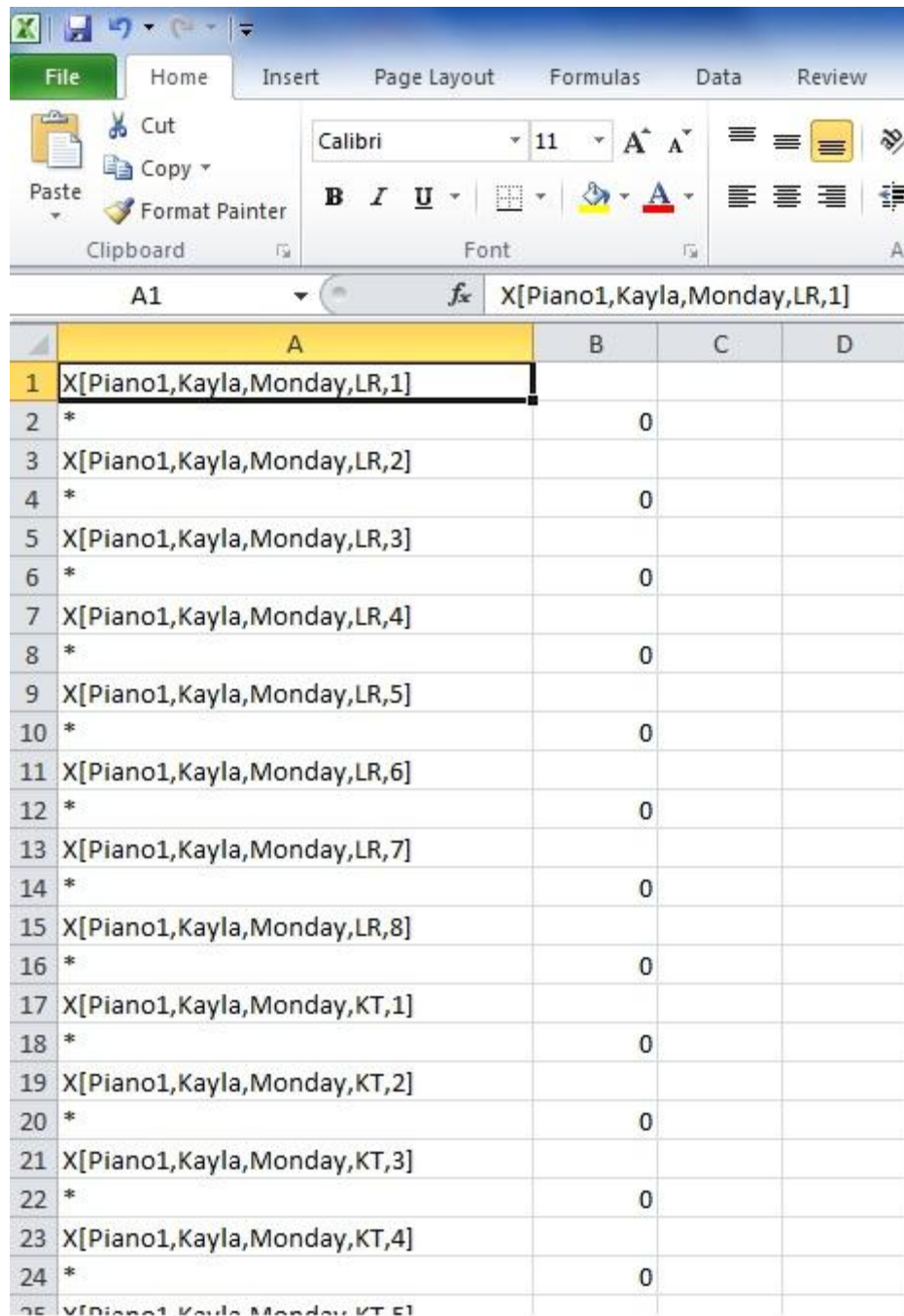




11. When the “Finish” button is clicked the imported data appears on the screen.

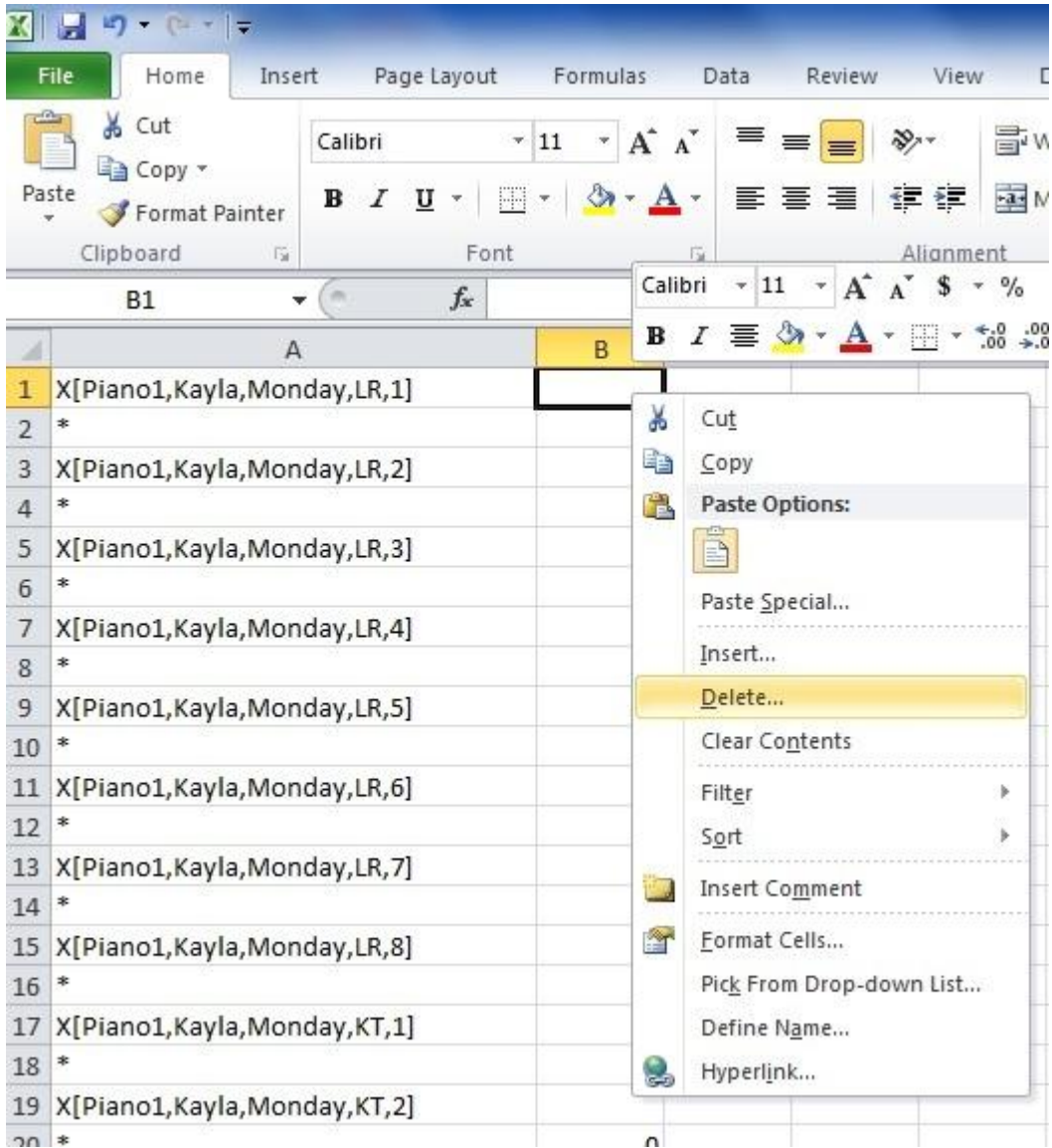
Expand the columns A and B so that it looks like the one shown below.



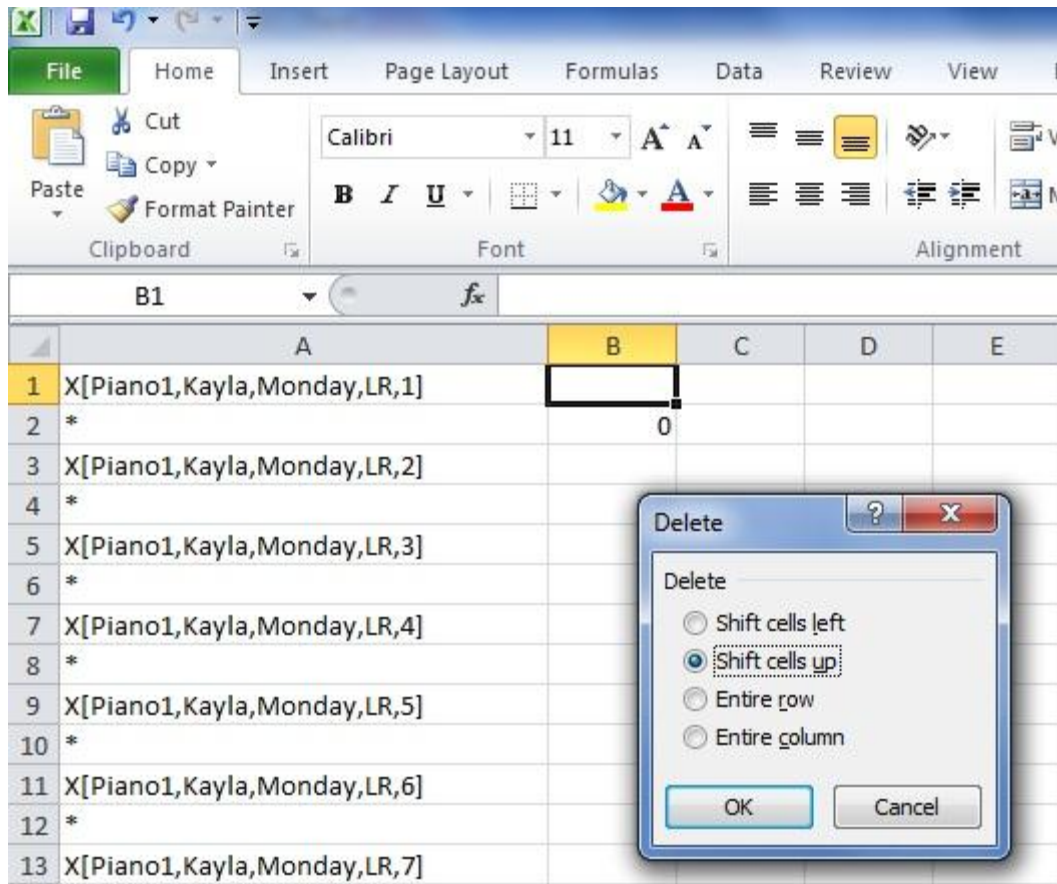


12. In the Excel sheet click on Row 1 in column B, then right click and select the delete option as shown below.





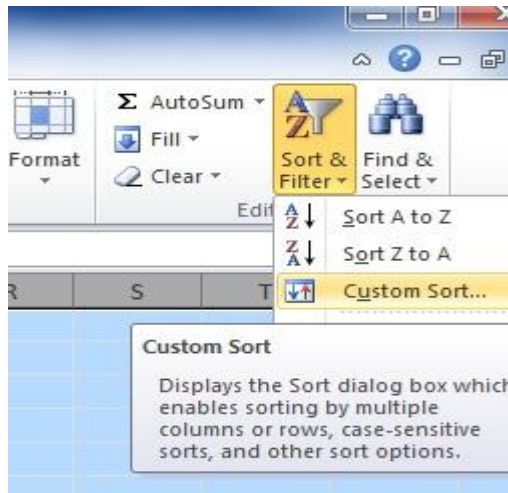
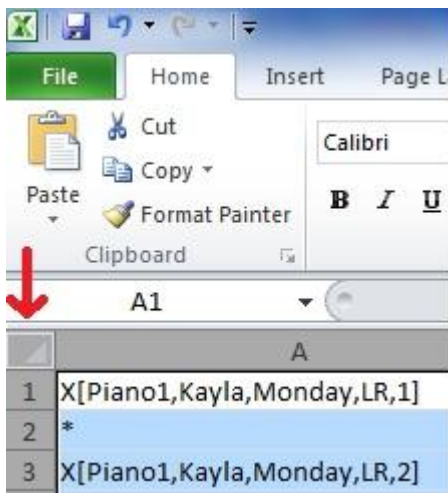
13. Now in the next window that appears select the “shift cells up” option and click on “OK”.



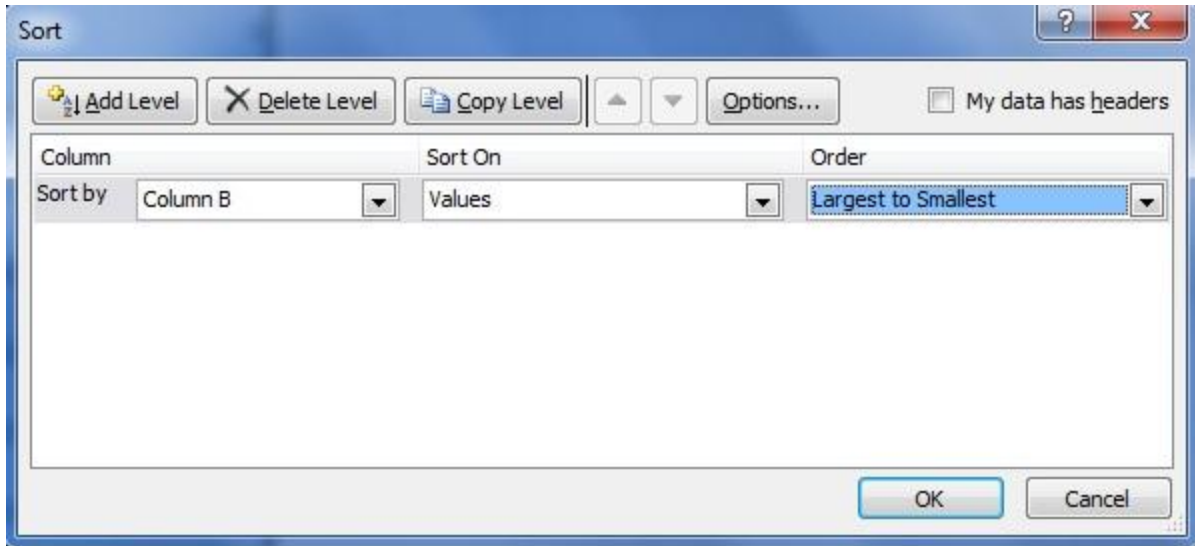
14. Now the Excel sheet appears as shown below.

|    | A                           | B | C |
|----|-----------------------------|---|---|
| 1  | X[Piano1,Kayla,Monday,LR,1] | 0 |   |
| 2  | *                           |   |   |
| 3  | X[Piano1,Kayla,Monday,LR,2] | 0 |   |
| 4  | *                           |   |   |
| 5  | X[Piano1,Kayla,Monday,LR,3] | 0 |   |
| 6  | *                           |   |   |
| 7  | X[Piano1,Kayla,Monday,LR,4] | 0 |   |
| 8  | *                           |   |   |
| 9  | X[Piano1,Kayla,Monday,LR,5] | 0 |   |
| 10 | *                           |   |   |
| 11 | X[Piano1,Kayla,Monday,LR,6] | 0 |   |
| 12 | *                           |   |   |
| 13 | X[Piano1,Kayla,Monday,LR,7] | 0 |   |
| 14 | *                           |   |   |
| 15 | X[Piano1,Kayla,Monday,LR,8] | 0 |   |
| 16 | *                           |   |   |
| 17 | X[Piano1,Kayla,Monday,KT,1] | 0 |   |
| 18 | *                           |   |   |

15. Now select the entire sheet by clicking on the left corner button as shown below and click on the “Sort & Filter” button and choose the custom sort option.



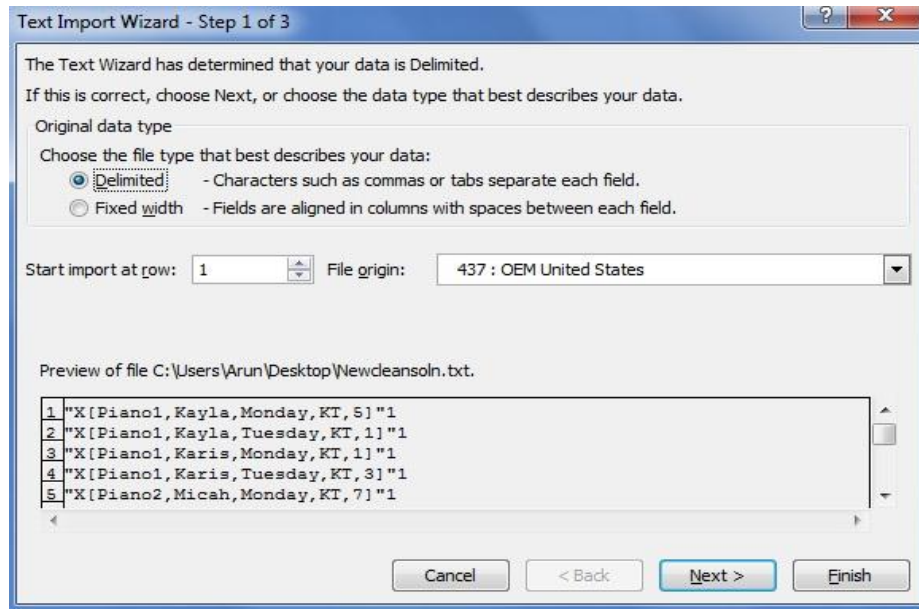
16. In the window that appears select “Sort by” Column B and “Sort On” values and select “Order” as largest to smallest and click on “OK”.



17. The sorted Excel sheet now appears as shown below.

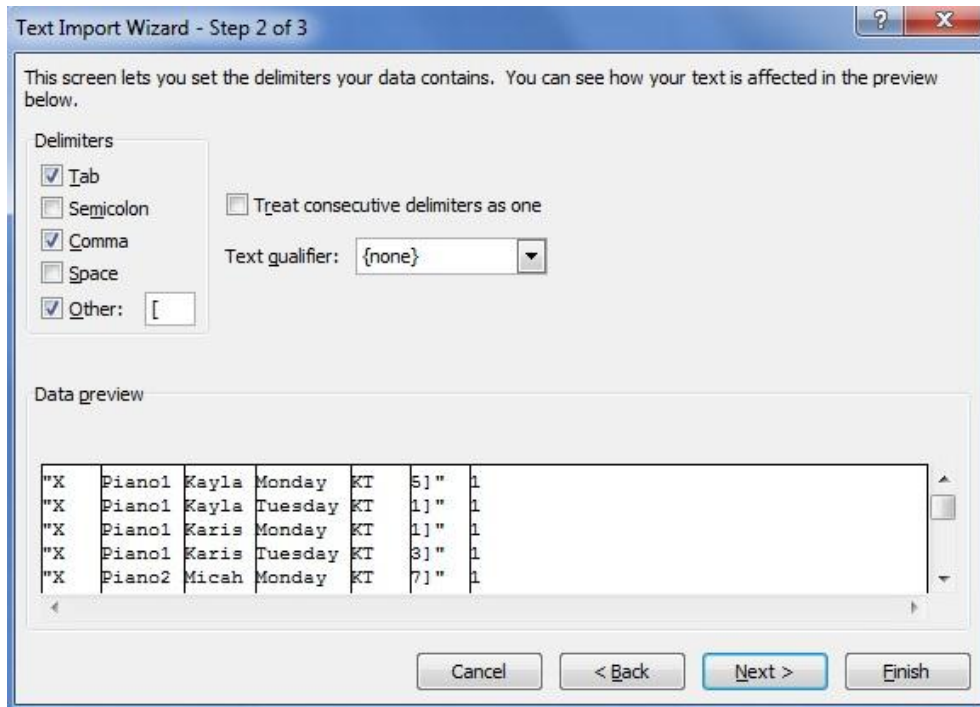
|    | A                            | B | C |
|----|------------------------------|---|---|
| 1  | X[Piano1,Kayla,Monday,KT,5]  | 1 |   |
| 2  | X[Piano1,Kayla,Tuesday,KT,1] | 1 |   |
| 3  | X[Piano1,Karis,Monday,KT,1]  | 1 |   |
| 4  | X[Piano1,Karis,Tuesday,KT,3] | 1 |   |
| 5  | X[Piano2,Micah,Monday,KT,7]  | 1 |   |
| 6  | X[Piano2,Micah,Tuesday,KT,5] | 1 |   |
| 7  | X[Piano2,Leah,Monday,KT,3]   | 1 |   |
| 8  | X[Piano2,Leah,Tuesday,KT,7]  | 1 |   |
| 9  | X[Math,Kayla,Monday,CR,8]    | 1 |   |
| 10 | X[Math,Kayla,Tuesday,CR,3]   | 1 |   |
| 11 | X[Math,Karis,Monday,BR,4]    | 1 |   |
| 12 | X[Math,Karis,Tuesday,BR,2]   | 1 |   |
| 13 | X[Math,Micah,Monday,BR,3]    | 1 |   |

18. Now select all the rows with column B values as 1 and transfer it to a new excel workbook and save it as .txt file.
19. Now once again open this .txt file in MS Excel and select Delimited option and Click “Next”

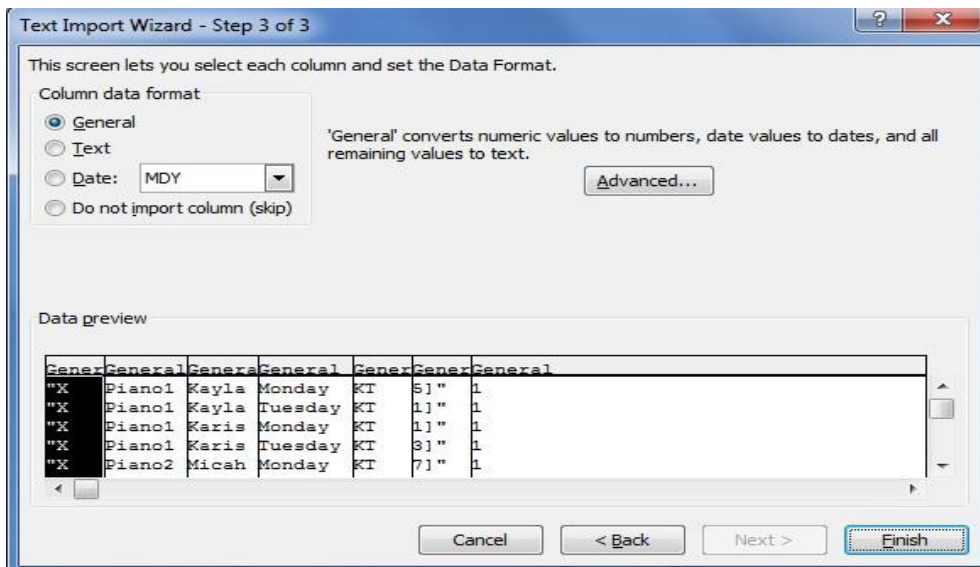


20. In the next step select the delimiters tab, comma and in the other box type the open square brackets “[”. In the Text qualifier list box, select “{none}”. Now click on the “Next” button.





21. Finally click on the “Finish” button in the window that appears.



22. The formatted solution appears as shown below and the unwanted columns could be removed or merely ignored. For the timings, the timeslots (1, 2, 3..) could be replaced with the actual timings using the Find & Replace option.

|    | A  | B      | C     | D       | E  | F    | G | H | I | J | K |
|----|----|--------|-------|---------|----|------|---|---|---|---|---|
| 1  | "X | Piano1 | Kayla | Monday  | KT | 5]"  | 1 |   |   |   |   |
| 2  | "X | Piano1 | Kayla | Tuesday | KT | 9:00 | 1 |   |   |   |   |
| 3  | "X | Piano1 | Karis | Monday  | KT | 9:00 | 1 |   |   |   |   |
| 4  | "X | Piano1 | Karis | Tuesday | KT | 3]"  | 1 |   |   |   |   |
| 5  | "X | Piano2 | Micah | Monday  | KT | 7]"  | 1 |   |   |   |   |
| 6  | "X | Piano2 | Micah | Tuesday | KT | 5]"  | 1 |   |   |   |   |
| 7  | "X | Piano2 | Leah  | Monday  | KT | 3]"  | 1 |   |   |   |   |
| 8  | "X | Piano2 | Leah  | Tuesday | KT | 7]"  | 1 |   |   |   |   |
| 9  | "X | Math   | Kayla | Monday  | CR | 8]"  | 1 |   |   |   |   |
| 10 | "X | Math   | Kayla | Tuesday | CR | 3]"  | 1 |   |   |   |   |
| 11 | "X | Math   | Karis | Monday  |    |      |   |   |   |   |   |
| 12 | "X | Math   | Karis | Tuesday |    |      |   |   |   |   |   |
| 13 | "X | Math   | Micah | Monday  |    |      |   |   |   |   |   |
| 14 | "X | Math   | Micah | Tuesday |    |      |   |   |   |   |   |
| 15 | "X | Math   | Leah  | Monday  |    |      |   |   |   |   |   |
| 16 | "X | Math   | Leah  | Tuesday |    |      |   |   |   |   |   |
| 17 | "Z | Piano1 | Kayla | Monday  |    |      |   |   |   |   |   |
| 18 | "Z | Piano1 | Kayla | Monday  |    |      |   |   |   |   |   |
| 19 | "Z | Math   | Kayla | Monday  |    |      |   |   |   |   |   |
| 20 | "Z | Piano1 | Kayla | Tuesday |    |      |   |   |   |   |   |
| 21 | "Z | Piano1 | Kayla | Tuesday | KT | 2]"  | 1 |   |   |   |   |
| 22 | "Z | Math   | Kayla | Tuesday | CR | 3]"  | 1 |   |   |   |   |
| 23 | "Z | Piano1 | Karis | Monday  | KT | 9:00 | 1 |   |   |   |   |
| 24 | "Z | Piano1 | Karis | Monday  | KT | 3]"  | 1 |   |   |   |   |

Find and Replace

Find what: 2]"

Replace with: 9:15

Options >>

Replace All   Replace   Find All   Find Next   Close