School Time Tabling ITT software

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Abstract

We have developed software for automatic school timetable scheduling.
The system is flex and can handle different types of schools and requirements.
In addition, we developed complexity indicators for a given school. This may help to predict if there is any solution, as well as serve as a comparable tool.

School timetable scheduling characteristics, complexity indicators, cloud

1. Introduction:

School scheduling in our country (Israel) is usually performed manually by a school specialist. The process is assisted by a computer aided tool that performs validation tests at every step, as well as supplies variety of information to help the specialist with the tedious work. However, the actual scheduling steps are manually planned by the specialists themselves.
The specialist cannot predict, if there is any solution for a given school dataset. Usually, when they reach a dead-end, they simply replace the requirements.
We performed a full scheduling on several schools, supporting all their data flow: we got the data on papers, and delivered the final web timetables and reports. We found that we also could not predict the success of our software, when we got school dataset. Therefore, we suggest complexity indicator for a given dataset. These indicators may serve as a comparable tool, but they can also help school principal to prepare their data set, at the early stage.

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2. Problem characteristic description:

At this section, we describe the special characteristic that we had to contend with. For simplicity, we will refer to the case of 30 teachers, 6 days a week.

2.1. Teachers calendar system: a day-off for every teacher

In Israel schools run 6 days a week, but in our educational system all teachers have at least one day off. It is called a "free day." This has a major effect. Therefore, the scheduling task becomes dramatically harder.

2.2. General teachers weekly balancing:

In addition to the "free-day" system, in elementary schools teachers usually can't take their day- off on some of the days: global-meeting days (e.g. Sunday) as well as Friday. Therefore - instead of having in every day the same amount of available teachers - some of the days may be overloaded with "too many" teachers, and on other days there are "not enough" teachers to be scheduled for the required lessons time slots. To make scheduling possible, there must be minimum number of teachers that can work in every day. In addition to this, Friday is a short day. So, there are too many teachers, that are at school, but they "don’t have work" on this day.

2.3. Specific teachers weekly balancing:

In elementary schools teachers "days-off" scheduling and teachers substitutions have a major effect on each other. This happens because when the main teacher takes a day off, other teachers have to "fill" this day. Therefore, all other class teachers have to be at school on this day, and they cannot take this day off. Therefore, there is a long chain of effects between the teachers that teach in the same class. This problem is critical in middle size schools, while most of the class hours are taught by one teacher. The principle is that the teachers have to "help" each other to fill each others day-off. For example, we had a case that 2 sport teachers took the same day off. The result was that most of the home class teachers could not take this day off at all. This

caused a chain of other effects, and we had to perform a special algorithm to find a combination of possible teachers' days off (potential space of 6^{30} options).
Note, this would not happen, when class work load is divided among several teachers – as it is held in high schools and middle schools.

2.4. Part time teachers effect:

Part time professional teachers are frequently a bottle-neck: Arabic, Music and Sport and English (as a second language) teachers often come only for two-three days in a week. Also, these subjects usually must be taught in different days. Therefore, in many schools all school scheduling is determined majorly according to these teachers.

2.5. "Ofek Hadash" requirements:

Another new huge constraint was added recently: now in elementary schools teachers cannot start work at the second hour or later or leave school earlier, and their empty time slots must be minimized.

2.6. Classes calendars

In most of the classes at elementary schools the class calendar is fixed. Students must leave after 5 hours, and although the teacher is available, students are not there. Special education classes calendar is also fixed.

2.7. Split lessons and concurrent lessons

Recently, in some of the lessons, classes have to split into two groups with two teachers for different subjects. This constraint means that an hour that both teachers are available should be found. Another requirement is that sometimes lessons in different classes have to be concurrent: i.e. few classes have to be scheduled to the same time slot.

2.8. Grouping, clusters of courses and splits lessons:

In high schools in Israel, in contrast to other countries, schools classes continue to be held as "home classes". But, most of the lessons are not delivered to the class: N classes are grouped together, and then they are split to M different group classes. M can be > N, < N or == N. This is a complex system, and the description of this system is behind the scope of this article.

Fig 1. Example: 'second language' cluster displayed in home classes view.

Combining home-classes scheduling system with course classes scheduling is needed, and we developed a hybrid model that combines two scheduling systems.

3. Complexity measuring

While looking at different schools, we wanted indicators to be able to compare between schools complexity, as well as to be able to compare between two algorithms, or even between two specialists.

We look at problem complexity measurement not as one calculated number, but as a vector of complexity separate indicators: $\langle I1, I2, I3, \ldots In \rangle$

A school may be complex in some of the indicators, while it is simple in other indicators. Therefore, we don't want to "smash" them all to one "average" number.

3.1. I_1 - <u>cluster lessons participants counter</u>

This Factor takes into account the complexity of the cluster lessons.

$\mathrm{Re}\ qL$ Group of all required lessons.

Cij Number of classes that participate in lesson li

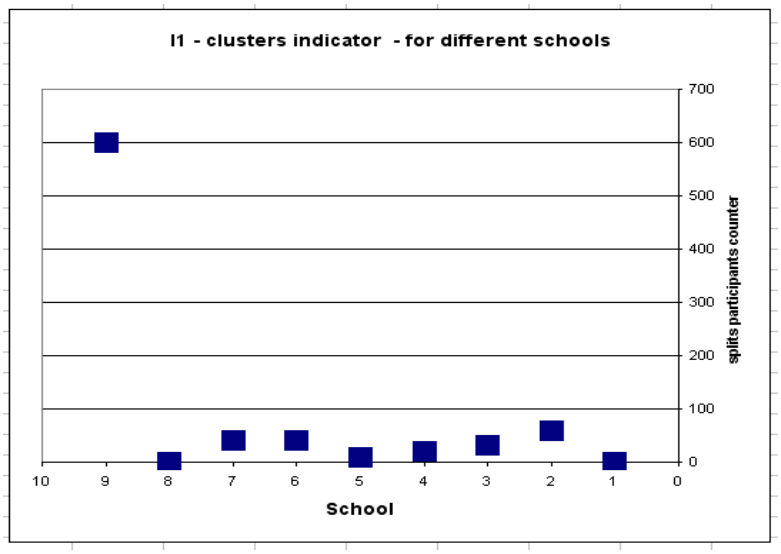
Tik Number of teachers that participate in lesson li

$$TLMcMt = \sum_{li}\left(\sum_{Cij \in li}(Cij) \times \sum_{Tik \in li}(Tik)\right) li \in \mathrm{Re}\ qL$$

$$L_{total} = \sum_{li} | li \in \mathrm{Re}\ qL$$

$$I_1 = \frac{TLMcMt}{L_{total}}$$

- For schools, that has no clusters the value of this indicator is 0
- Complex clusters with, say 10 classed grouped into 12 teachers has major effect on this complexity indicator.
- A lesson that is split to two teachers or two classes has a small effect on this indicator.



3.2. I_2 - <u>requirements to availability to ratio</u>

This factor computes a weighted average of the ratio between each *teacher* $\cap$ *class* availability to the *teacher* $\cap$ *class* total required hours.

L_{total} Total number of all required lessons at school

$$\text{THRij} = \sum_{hour\ h_k} \left(\text{Re}q\left(t_i, c_j \right) \right)$$

Total required hours of teacher t_i to class c_j

$$\text{THAij} = \sum_{hour\ h_k} \left(\left(Available\left(t_i , h_k \right) \right) \wedge \left(Available\left(c_j , h_k \right) \right) \right)$$

Total available hours intersection

$$T_{ij} = \frac{\text{THRij}}{\text{THAij}}$$

$$\text{TR}i_{total} = \sum_{\text{cj}} \text{THRij}$$

Total teacher t_i required hours in all classes

$$\text{TTi} = \sum_{\text{j}} \text{Tij} \times \left(\frac{\text{THRij}}{\text{TR}i_{total}} \right) \text{, } only\ if\ \ \text{THR}ij \neq 0$$

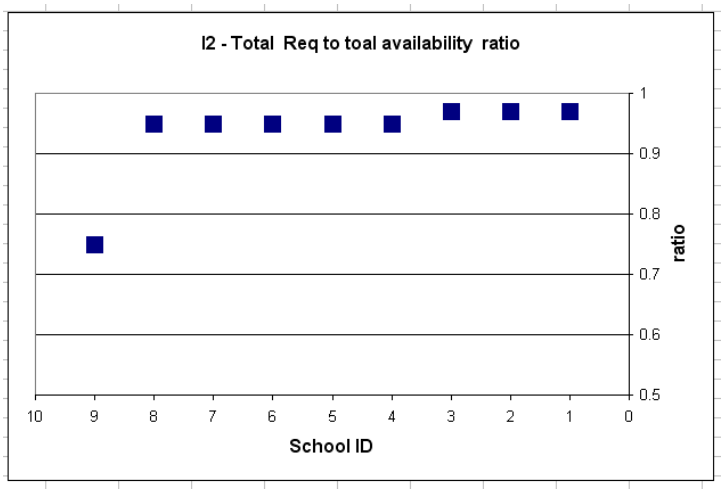
The average of specific teacher

$$I_2 = \sum_{\text{i}} \text{TTi} \times \left(\frac{\text{TR}i_{total}}{\text{L}_{\text{total}}} \right)$$

Average of all teachers

First, for every couple, $\left\langle teacher\ t_i\ ,\ class\ c_j \right\rangle$ the ratio is computed. Then an average is computed.

Here, for simplicity, the graph we show the ratio for the school as total number:



3.3. I_3 - rooms requirements to availability to ratio

Similar factor, that computes a weighted average on all the rooms of the ratio between each $class \cap room$ availability to the $class \cap room$ total required hours.

3.4. I_4 -

This factor takes into account only the max of the ratio between each $teacher \cap class$ availability to the $teacher \cap class$ total required hours.

$$\text{THRij} = \sum_{hour\ h_k} \left(\text{Req}\left(t_i, c_j \right) \right)$$

Total required hours of teacher t_i to class c_j

$$\text{THAij} = \sum_{hour\ h_k} \left(\left(Available\left(t_i, h_k \right) \right) \wedge \left(Available\left(c_j, h_k \right) \right) \right)$$

Total available hours intersection

$$\text{Tij} = \frac{\text{THRij}}{\text{THAij}}$$

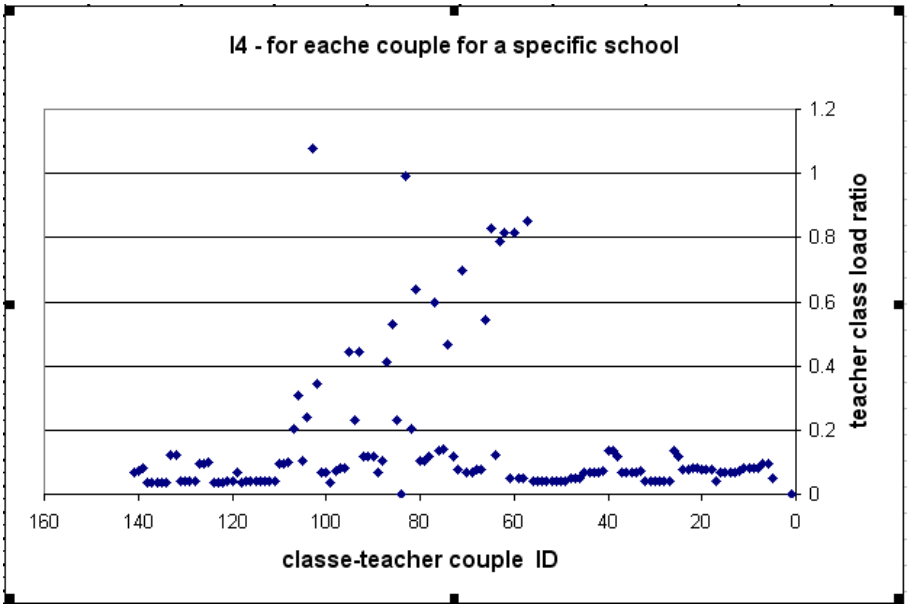
$$M_{cj} = \text{Max}\left\{ ij \mid \text{Req}(t_i, c_j) \right\}$$ Max ratio for specific class

$$I_4 = \sum_{cj \forall cj} if\ (Mcj \geq 0.8)$$

Total number of all classes, with "bad" M_{cj}

First, for every couple, $\langle teacher\ t_i\ ,\ class\ c_j \rangle$ the ratio is computed.

Then, only the max for each class is taken. Then the total number of the classes, that their ratio is >= 0.80 , is counted. This is computed only for teachers that don't work every day.



3.5. I_5 - <u>class-lesson-day- constraints counter</u>

Number of lessons that cannot be scheduled at the same day / L_{total} (E.g. sport). Here, we only count lessons of different teacher.

3.6. I_6 - <u>percentage of constraints second indicator:</u>

Number of lessons that must be scheduled in sequence / L_{total} (e.g. science lab). Here, we only count lessons of different teacher.

3.7. I_7 - <u>Spreading of class Load:</u>

Total number of classes that home class teacher has a day off, and that the ratio between home teacher total hours to the total class hours is ≥ 0.8

3.8. I_8 - days effect

This factor is relevant for the teachers "free-day" system.
Count for all classes that home class teacher has a day off: How many different teachers must be at school, in the day-off of the home class teacher. To calculate it, we use a simple method.
Example: if the home class teacher teaches 23/29 class lessons; and all other lessons cannot be taught at the same day, then all other 5 teachers must be at school at her day of. So, this class increases I_8 by 5. Note, I_8 is not normalized.

3.9. I_9 - Data flexibility –

there are cases that data case be changed easily (like switching between teachers or replays working days) , while in other cases the data requirements are fixed. This indicator may be input to a table manually by the user. We can't calculate in for a specific input data.

This indicators vector should be further investigated and improved.

4. Results , the software and conclusions

4.1. The existing process

Today, in our country, the scheduling tasks lasts a long time and it is performed either by a dedicated internal school specialist - at high schools - or it is outsourced to a specialist for a fee. Usually, the constraints are so difficult, that the problem is not solved. Therefore, when the specialist reaches a dead-end, (consulting with the school principal), he changes some of the input data. In other words, in order to solve the problem, the problem is changed. This trial by error process continues. Accordingly, during this procedure, the input data is changed: some courses are re-substituted, some

teachers are switched, and some teachers' working days are changed. When the scheduling reaches a dead-end, the specialist knows how to choose which data re is a wide range of options to choose from, to replace the input data. Specialists have developed heuristics not only to choose the next scheduling steps: they also developed heuristics to choose which and how input data should be replaced to make the scheduling "work".
This is one of the reasons why they don't believe that this process can be automatic.

In addition to this, there are also external sources for input data changes: During the scheduling process, teachers' total hours budgets are often increased or decreased by external cause.
Another common problem is that data is often updated after scheduling is done: re-scheduling, is usually out of question, and therefore the "old" tables are used ,and the new teachers cannot be utilized to the system efficiently.

4.2. Our Test cases

IttTimeTable has performed a full scheduling on several schools, including all their data flow, and generated the tables, posters and reports. We got the data on papers, and delivered the final timetables
Using this system enabled the schools to change the input data many times . This would never be possible with the existing manual procedure. That is, because of the clear fact that the specialist would not "throw away" all the work he/she has already done, and re start it all over.

4.3. Results, and success ratio

External vendor scheduling specialists claim to promise to satisfy at least 80% of the school requirements and constraints. We don't know the actual success ratio.
IttTimeTable has scheduled 97%-99% of all the cells (a cell per hour) in the tables. The remaining 1-2% were scheduled manually, using IttTimeTable commands language.

One of the surprises was that the size of the school had no effect on the success ratio: larger schools did not result in lower success ratio. It seems that the size of the problem was not a factor for the software success ratio.

4.4. The Software

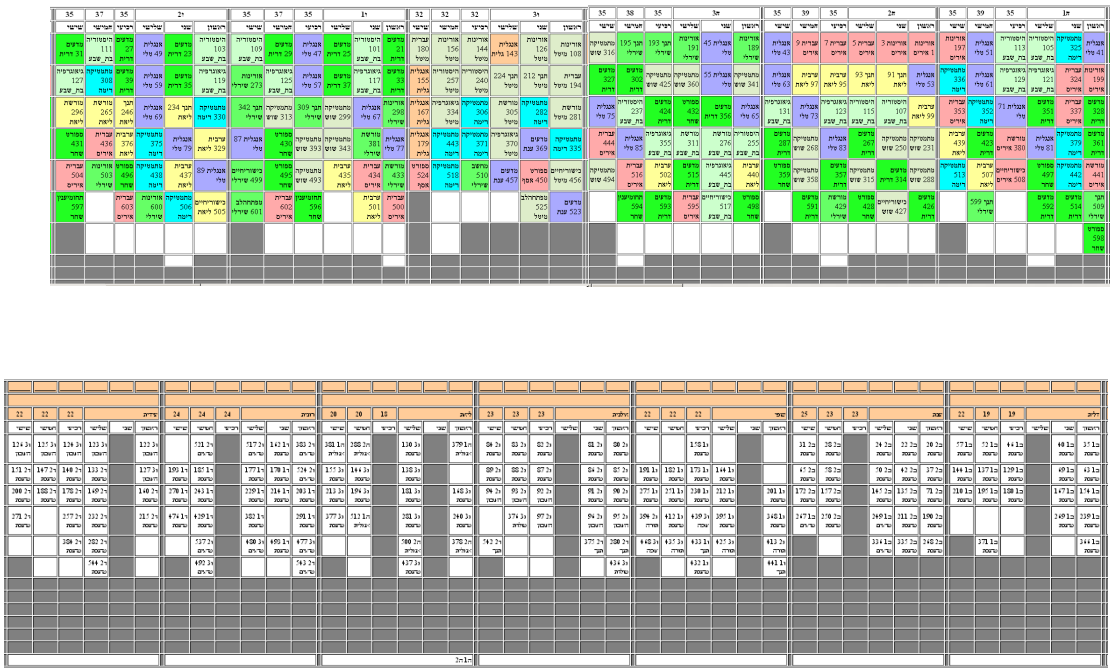


Fig 2: example of a peace from the results

- The software can, also, get any given partial tables as input, and start the algorithm from there.
- The software infrastructure is algorithm independent : We can replace the algorithm. We have used it with several algorithms.
- The software is wrapped with another software, that helps the user to enter the input in a simple way. It prepares templates for the specific type of data, keeping the "engine" software as a general tool.
- The system functions as a **cloud application** (Software as Service). The web site is does not fully function yet.

4.5. Conclusion

- Today, in our country, school scheduling specialists do not believe that a computer program can perform the scheduling, and replace their wisdom.
- IttTimeTable success ratio is 97%-99%.
- IttTimeTable is currently being converted to a cloud application.
- IttTimeTable software is at beta phase, and we hope to be of valuable service in this area.