# Eversight – Eyes Tissue Matching

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## Problem statement

Eversight has the daily task of matching eyes tissues from donors to surgeons.

Eye tissues become available throughout the United States as donors pass away. The list of available tissues along with its specificities get updated throughout the day.

Requests from surgeons come from different places in the United States and even from abroad. The list of requests along with surgeon preferences also get updated throughout the day.

Not every tissue attends all the surgeon’s preferences/requirements for a tissue request. For example, a surgeon may request a tissue from a donor that was between 58 and 72-years-old.

The goal is to match tissues to requests as to meet all the preferences as much as possible while accounting for multiple operational constraints, such as processing location and shipping time.

## Input data

In this section we describe some of the input data to the matching problem. We classify this data into two groups: tissues data and requests data.

#### Tissues Data

Tissue data includes all the specifications of each available tissue. Below is a list of common tissue specifications.

* *Tissue Number* – Unique identifier of the tissue.
* *Tissue Location* – Place where the tissue if currently located.
* *Returned* – Whether the tissue had been returned to the eye bank (for instance, because the surgery had been canceled).
* *Death Date* – Date (Eastern Time zone) when donor deceased.
* *Tissue Expiration Date* – Expiration date of the tissue.
* *Death to Recovery* – Number of hours between death and time of tissue recovery.
* *Donor Age* – Age of the tissue donor at the time of death.
* *Surgical Use* – Whether the tissue if eligible for surgical use.
* *Cell Count* – Cell density of the tissue.
* *PK* – Whether the tissue is rated for penetrating keratoplasty surgeries or not.
* *DSAEK* – Whether the tissue is rated for endothelial keratoplasty surgeries or not.
* *DMEK* – Whether the tissue is rated for endothelial keratoplasty surgeries or not.
* *Diabetes* – Whether the donor had history of diabetes or not.
* *Cancer* – Whether the donor had history of cancer or not.
* *Pseudo Phakic Aphakic Lens* – Whether artificial lens was found in the eyes of the donor or not.
* *Moderate Folds* – Whether folds were found the eyes of the donor or not.
* *LASIK Scar* – Whether LASIK scars were found the eyes of the donor or not.
* *Clear Zone* – Clear zone of the cornea.

#### Requests Data

Requests data can be further classified into two groups. The first group is the identification data. This includes the request number, surgeon identification, and its location. The second data group is composed by preferences. Below is a list of some of specifications against which surgeons communicate their preferences when sending a request to Eversight.

* *Surgery Date* – Scheduled date of the surgery.
* *Tentative Offer Date* – Date by which an offer is expected.
* *Exclude Tissue Returned* – Expected that the tissue had not been returned by another surgeon.
* *Tissue Direct* – Surgeon expects to see the tissue before it gets shipped.
* *Tissue Type* – Type of the donor tissue that is requested for.
* *Tissue Use* – Type of surgery that is going to be performed (PKP, DSAEK, DSAEK Preload, DMEK, DMEK Preload).
* *Age Min* – Minimum acceptable age of the donor.
* *Age Max* – Maximum acceptable age of the donor.
* *Cell Count Min* – Minimum cell density of the tissue.
* *Death to Preservation Max* – Maximum number of hours between death of the donor and time of recovery of the tissue.
* *Death to Surgery Max* – Maximum number of days between death of the donor and time of recovery of the surgery.
* *Clear Zone* – Minimum clear zone of the cornea.
* *Exclude Cancer* – Expected that the donor didn’t have history of cancer.
* *Exclude Diabetes* – Expected that the donor didn’t have history of diabetes.
* *Exclude LASIK Scars* – Expected that the donor didn’t have LASIK surgeries.
* *Exclude Mated Set* – If more than one eye tissue has been shipped to the same surgeon, it’s expected that every tissue comes from different donors. If one tissue causes an adverse reaction in the recipient, then there is a high change that the other tissue from the same donor will cause reaction to another recipient as well.
* *Exclude Moderated Folds* – Expected that FOLDS had not been reported from the evaluation of the donor eye.
* *Exclude Pseudo Phakic Aphakic Lens* – Expected that the donor never had its lens surgically replaced.

## Formulation

In this section we have the mathematical formulation of the matching problem to be solved.

### Input data model

We start by defining the set of indices and parameter that will be used in the formulation. The exact same notation adopted in here will the used in the implementation of the optimization model.

Set of indices

Set of available tissues.

Set of requests from surgeons.

Parameters

Cost ($) of shipping tissue to the surgery location of request

### Decision variables

Following are the decision variables of the formulation.

Decision variables:

equals if tissue is assigned to request , otherwise.

### Constraints

Next are the constraint of the formulation.

Constraints – Each tissue can be assigned to at most one tissue request:

Constraints – Each request must be assigned to exactly one tissue:

### Objective

The objective function.

Objective:

### Final formulation

Put everything together.

Final formulation:

## Extra Complexities

In this section we model complexities that are not captured in the base formulation.

### Alternative assignments

The base model assigns exactly one tissue to each request. And if there is no tissue that meet all requirements of a given request, the model becomes infeasible. To prevent infeasibility and to report alternative assignments (when possible), we modify the original formulation by turning the request constraint into a soft constraint.

To achieve that we first introduce two parameters:

number of tissues that we would like to have assigned to each request.

penalty for each tissue not assigned to a request.

Notice that equals one in the base model. And the penalty will ensure that tissues get assigned to every request whenever possible (current implementation allows to be either or ).

We also need slack variables (to capture assignment shortfalls) that we define as follows.

number of tissues (out of ) not assigned to request .

Next, we modify the right-hand-side of the request constraint as follows.

Constraint – Each request must be assigned to at most tissue:

Finally, we add the following term to the objective function.

### Scoring System

The assumption in the base model is that every requirement must be met exactly for a tissue to be assigned to a request. And if all the requirements are met, the transportation cost is the only key factor that determines the assignment.

Example 1: Suppose that two tissue requests require the cell count to be at least . And suppose that only one of all the available tissues happen to meet this requirement. In this case, one of the requests get the tissue and the other one doesn’t get assigned to any tissue.

Example 2: Consider the same scenario of Example 1 but this time assume that there are two tissues with at least cell count. Which tissue get assigned to which request in this case? This is determined by the transportation cost. And if the transportation cost leads to a tie, then the assignment happens quite randomly.

The scoring system relax the hard constraint illustrated in Example 1 and improve the assignment in case of a tie as illustrated in Example 2.

Each request gets a “budget” to be distributed across a pre-defined set of requirements, i.e., the relaxed requirements. Surgeons will then allocate more reward to the requirements that matter the most for them.

To implement the scoring system, we first introduce the score parameters:

list of requirements to be relaxed.

reward of request that has been allocated to requirement .

We will address the “relaxation” of each type of requirement separately.

#### Cell count

Cell count is minimum requirement. For example, if a tissue request comes with a cell count requirement of , this means that a tissue with cell count of at least is preferred. If a tissue has cell count slightly below the assignment might still be acceptable.

We address the cell count requirement by adding a new term to the objective function. This term will encourage (with a fixed reward, ) assignments that meet the cell count requirements and penalize (with a variable penalty that is proportional the size of the violation) assignments that violate the cell count requirement.

Let’s define a few parameters:

Cell count of tissue .

Cell count lower bound of tissue request .

Fixed reward:

Dynamic reward:

Finally, we add the following term to the objective function:

#### Age Range

The age of the donor is expected to be in a range specified by the surgeon. If the age of the donor is slightly below the minimum age or above the maximum age specified in the tissue request, the assignment might still be acceptable.

We address the age range requirement in a similar way we addressed the cell count requirement, i.e. by adding a new term to the objective function. This term will encourage (with a fixed reward, ) assignments that meet the age range requirements and penalize (with a variable penalty that is proportional the size of the violation) assignments that violate the age range requirement.

Let’s define a few parameters:

Age of the donor of tissue .

Donor age lower bound (min age) of tissue request .

Donor age upper bound (max age) of tissue request .

Finally, we add the following term to the objective function:

#### Death to Recovery Max

Death to recovery is maximum requirement. For example, if a tissue request requires a max of 1 hours, this means that a tissue that has been recovered within hours from the time that the donor deceased is preferred. If it took slightly more than 1 hours, the assignment might still be acceptable.

We address death to recovery max requirement in a similar way we did with cell count, i.e., by adding a new term to the objective function. This term will encourage (with a fixed reward, ) assignments that meet the death to recovery max requirements and penalize (with a variable penalty that is proportional the size of the violation) assignments that violate the death to recovery max requirement.

Let’s define a few parameters:

Death to recover time (hours) of tissue .

Death to recover upper bound of tissue request .

Fixed reward:

Dynamic reward:

Finally, we add the following term to the objective function:

#### Death to Surgery Max

Very similar to *Death to Recovery Max*.

#### Death to Cooling Max

Very similar to *Death to Recovery Max*.