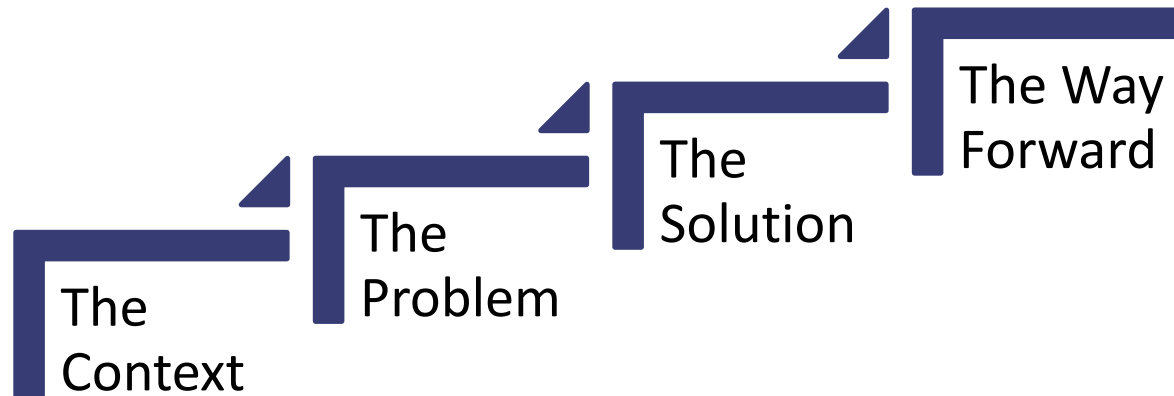


# A Quantitative Approach to Radiation Treatment Machine Allocation in Ontario

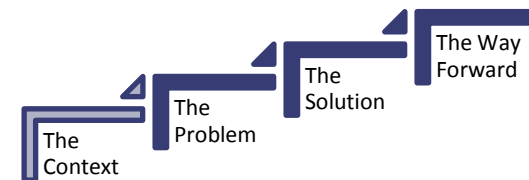
Applied Research in Cancer Control Conference 2014

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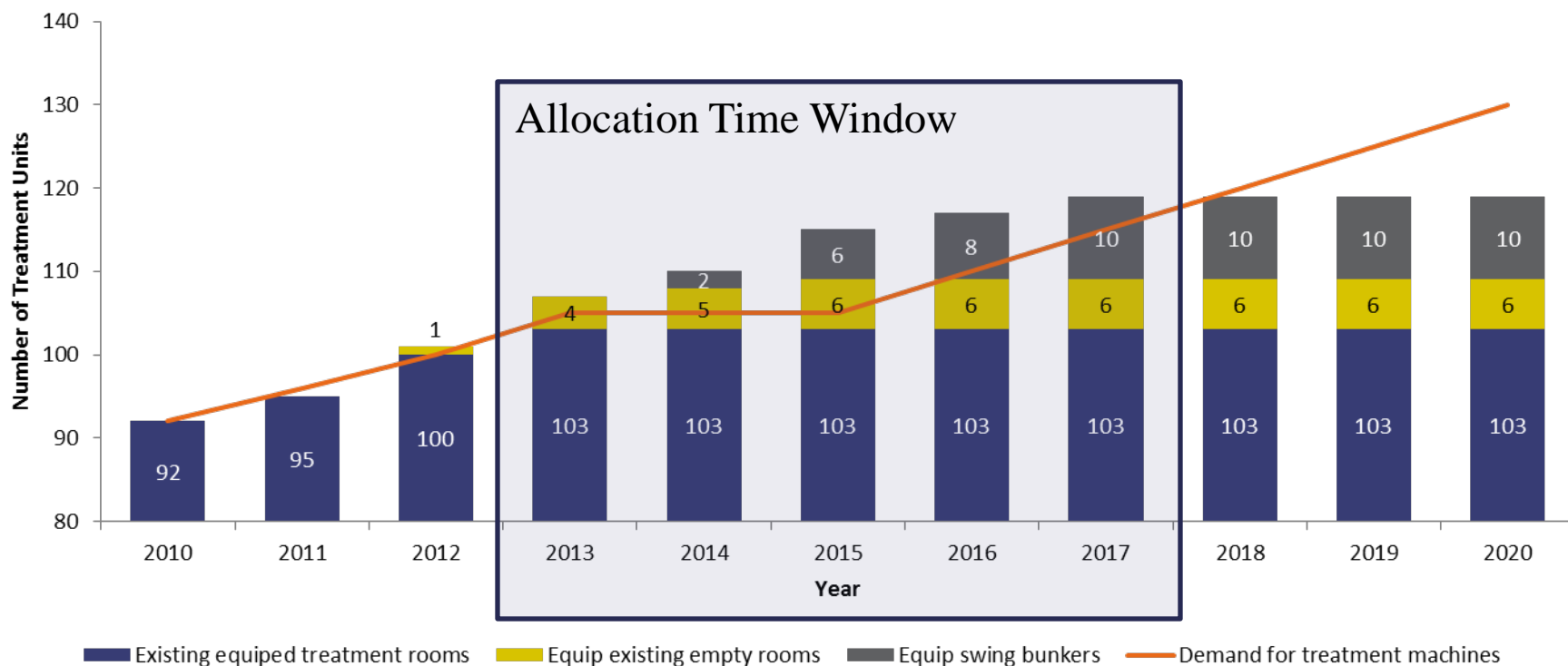
# Agenda



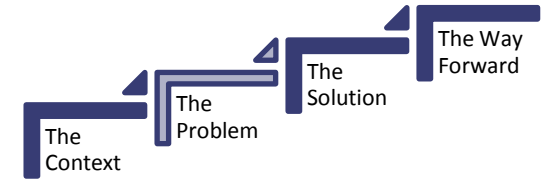
# The Context



- Published in April 2012, CCO's Radiation Treatment Capital Investment Strategy (RTCIS) recommends:



# The Problem

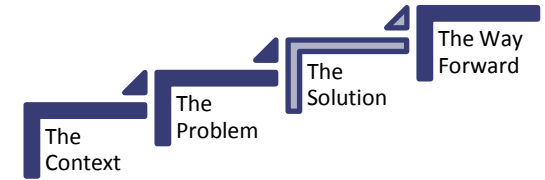


- RTCIS tells us how many rooms to fill each year until 2017
- But, it does not tell us **which rooms to fill** and **in what year** between 2013-2017 to fill them with radiation machines.

## **Problem statement:**

- Given the projected demand forecasts for radiotherapy in Ontario and the current capacity for radiotherapy, in **what order** and in **what year** should radiation machines be added to the cancer centres (CC), taking into account the **demand and capacity** for each CC?

# The Solution



- Intuitively, the allocation solution would search through the **set of all possible allocations** to find an allocation of radiation machines that minimizes the objective (in this case, the **demand to capacity ratio**) while following any constraints on the problem
- This is easy to do by hand, when the problem is small.

## Allocations

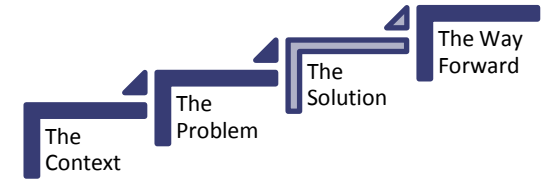
	2013	2014
CC 1		
CC 2		

Constraints: Fill all rooms.

	# Empty	# Swing
CC 1	1	1
CC 2	2	1



# The Solution



But, what if the problem gets too large to solve by hand?

Small Allocation Problem:

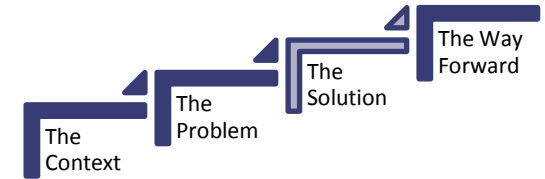
	2013	2014
CC 1		
CC 2		



Large Allocation Problem:

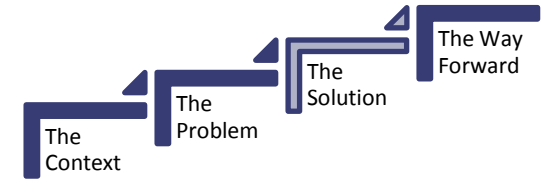
	2013	2014	2015	2016	2017
CC 1					
CC 2					
CC 3					
CC 4					
CC 5					
CC 6					
CC 7					
CC 8					
CC 9					
CC 10					
CC 11					
CC 12					
CC 13					
CC 14					
CC 15					
CC 16					

# The Solution



- Non-Linear Integer Programming (NLIP) used to solve this allocation problem
- NLIP is a mathematical optimization method that is used to minimize (or maximize) a particular objective given a set of constraints
- Intuitively, this method searches through the set of possible allocations to find an allocation of radiation machines that minimizes the objective (in this case, the demand to capacity ratio)
  - Very powerful method for solving large allocation problems

# The Solution



Allocate radiation machines to CCs in a given year where:

## Verbal Formulation:

**Minimize** the sum of the CMI-adjusted demand to capacity ratio over all years at each CC.

### Such that:

- (1) The number of empty rooms in 2013 and 2014 equals the total number of available empty rooms in the province
- (2) The number of swing rooms in 2014-2017 equals the total number of available swing rooms in the province
- (3) The total number of empty and swing rooms in each year equals the number of rooms to be filled in each year
- (4) The number of empty rooms and swing rooms to be assigned are integer values, as you cannot have a fraction of a room

## Mathematical Formulation:

### Minimize:

$$\sum_i \sum_j \frac{D_{ij}}{(2 - CMI_i) \times C_{ij}}$$

### Such that:

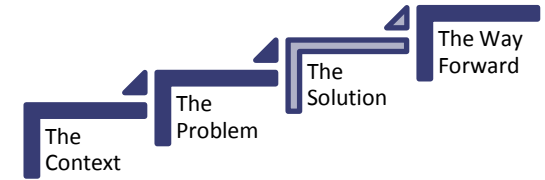
$$(1) \quad \sum_{j=1}^2 x_{ij} = R_i, \quad \forall i$$

$$(2) \quad \sum_{j=2}^5 y_{ij} = S_i, \quad \forall i$$

$$(3) \quad \sum_i (x_{ij} + y_{ij}) = Y_j, \quad \forall j$$

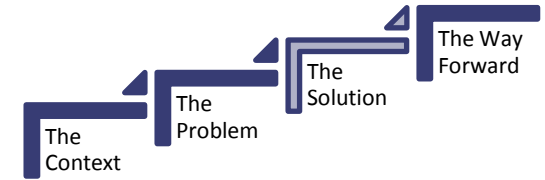
$$(4) \quad x_{ij}, y_{ij} \in \mathbb{Z}$$

# The Solution



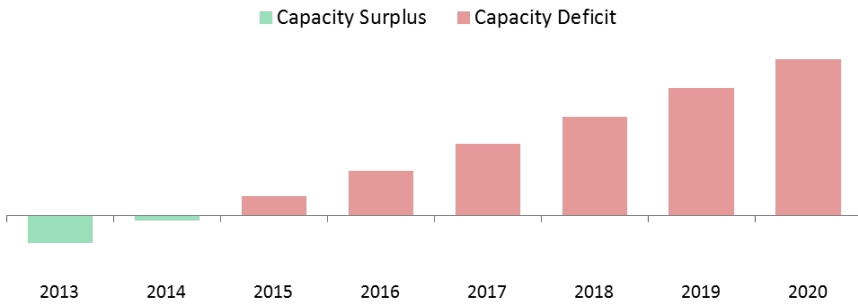
- The algorithm stopped looking for a new allocation strategy when the change in the **objective function was less than 0.01**
- Once an optimal solution was found, the solution was presented as a **starting point for discussion** with the clinical and business experts
  - Solution had face validity with the clinical and business groups
  - Capital funding requests to the provincial government were aligned to reflect the model's outcomes
- A **graphical user interface** was created to assist the experts by showing how the adjustments will affect the demand to capacity ratio at each CC over time
  - This also allows for **allocation scenario exploration**
  - Adjustments can be made to the allocation to account for **factors** that are more **difficult to quantify** such as political factors or on-the-ground knowledge about the readiness of a particular centre

# The Solution



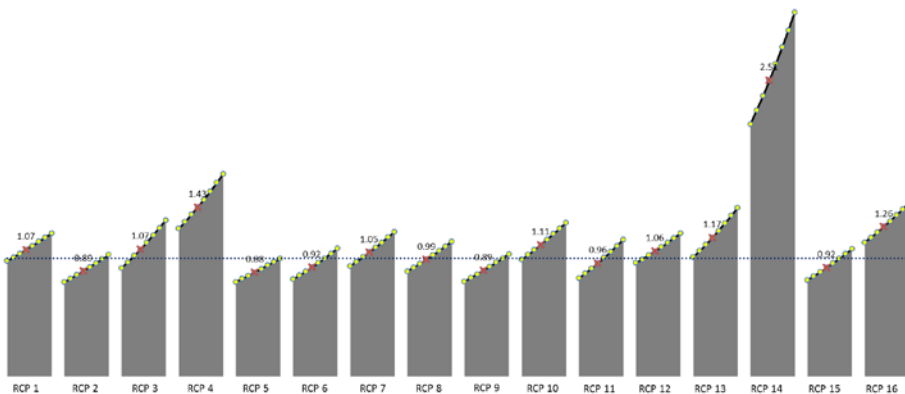
## Baseline – No Machines Allocated

Provincial Picture - # of Patients Over or Under Total Provincial Capacity



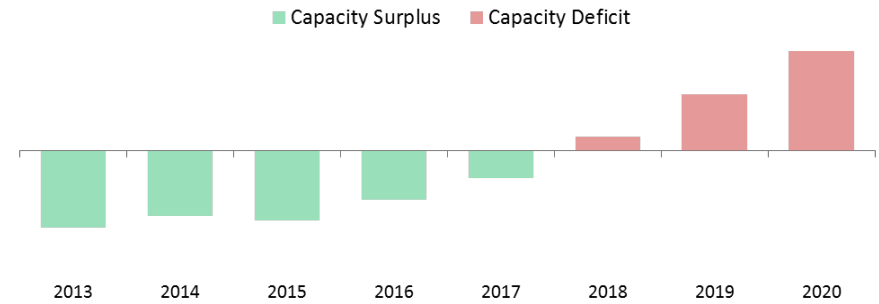
Demand to Capacity Ratio for Each CC - Scaled CMI

— Demand to Capacity Ratio by Year    x Tracer    ..... Demand / Capacity = 1



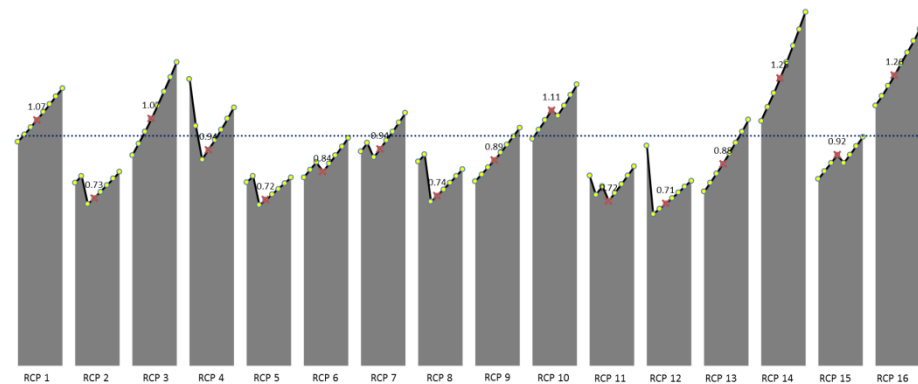
## Optimal Allocation – Using NLIP

Provincial Picture - # of Patients Over or Under Total Provincial Capacity



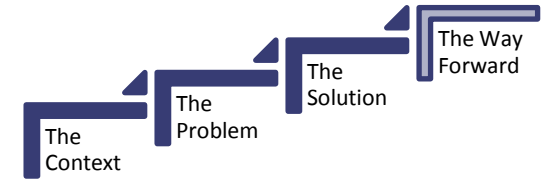
Demand to Capacity Ratio for Each CC - Scaled CMI

— Demand to Capacity Ratio by Year    x Tracer    ..... Demand / Capacity = 1



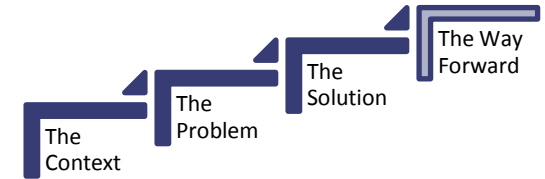
# The Way Forward:

## Benefits of using a mathematical model



1. Objective and defensible approach to radiation machine allocation and capital planning
2. Agile enough to adapt to assumption changes
3. Ability for allocation scenario exploration

# The Way Forward: Lessons Learned



- Complex modelling is an **iterative process**
- Understanding the **limitations** of using complex modeling and the contextual/qualitative factors is critical
  - Using complex modeling is **not the final answer**, but just the beginning of the decision making process
- Potential applicability in answering clinical or administrative problems
  - Resource allocation
  - Scheduling

Thank you!  
Questions?