Handbook

2024

Economic Evaluation

Health Economics and Policy Innovation Lab
National Taiwan University

PREFACE

This handbook is designed for use in the Economic Evaluation course at the College of Public Health, National Taiwan University. The course introduces key concepts in economic evaluation, including the rationale for conducting these evaluations, methods for valuing health outcomes, approaches to calculating costs, and the role of trials as a vehicle for economic evaluation . It also covers foundational principles of economic evaluation, with a focus on cost-effectiveness analysis (CEA), cost-utility analysis (CUA), cost-benefit analysis (CBA), and their application in decision-making processes.

The course is tailored for heathcare practitioners and is suitable for both Master's and PhD students aiming to specialize in economic evaluation or pursue careers in health technology assessment (HTA).

This handbook provides practical exercises using Excel and TreeAge to build decision tree, Markov models, and Microsimulation Model, three of the most commonly used techniques in economic evaluation. By the end of the course, students will have the essential skills to apply these tools in real-world economic evaluations.

We would like to extend our gratitude to Professor Ming-Chin Yang for his invaluable guidance, which has enriched this year's course significantly with great depth and inspiration.

前言

本手冊專為臺灣大學公共衛生學院經濟評估課程設計使用。該課程介紹經濟評估之關鍵概念，包括進行經濟評估之背景理論與實務、健康結果估算的方法、成本計算的方法，臨床試驗作為經濟評估之平台，經濟評估建模與敏感度分析，醫療科技評估國際比較，特別強調成本效益分析(CEA)、成本效用分析(CUA)、成本效益分析(CBA)，以及其在決策過程中之應用。

本課程專為臺大碩士與博士學生設計，無論是從事經濟評估研究，或是有意從事健康經濟與結果(Health Economics and Outcomes Research, HEOR)或醫療科技評估(Health Technology Assessment, HTA)工作的學生都可以從中受益。

本手冊提供使用Excel和TreeAge進行決策樹模型(Decision Tree)，馬可夫模型(Markov Model)與微觀模擬(Microsimulation Model)模型建構之實用練習，這兩者為經濟評估中最常用之技術。透過活用之練習，學生將具備應用該工具進行實際經濟評估之基礎技能，也能輕鬆地應對較為複雜之模型分析。

誠摯感謝楊銘欽老師的建議，使今年的課程更加深入與具有啓發性！

ACKNOWLEDGEMENT

We acknowledge the valuable resourses provided by TreeAge, including both their general manual and online materials, which have greatly supported the learning experience in this course.

We would also like to express our gratitude to the teaching assistants who have contributed to the continous development of the course. As an evolving, incremental online course, each year bring new insights and impovements to the content.

Disclaimer: All examples used in this course are based on hypothetical data and not real cases.

The teaching assistants in 2024 are:

- Valerie Tzu-Ning Liu / Content Development (CD), Content Verification (CV), Tutor (T)
- Toby Kai-Bo Shen / Content Verification (CV), Tutor (T)
- Rachel Ai-Ting Yang / Content Verification (CV), Tutor (T)
- Melody Hsiao-San Yeh / Content Verification (CV)

授課教師 Instructor
李達宇 副教授
A/P John Tayu Lee

致謝

我們感謝TreeAge所提供之寶貴資源，包括其線上資料與操作手冊，這些對於課程之學習體驗提供莫大的支持。

我們也要向在本課程持續發展與研議，做出貢獻的助教們表達感謝。隨著課程步調與發展逐步穩定，每年都為內容帶來新的見解與改進。

聲明：所有本課程所使用之範例均基於假設數據，並非真實案例。

2024年助教群｜

內容開發(CD)
內容驗證(CV)
教學輔導(T)
劉子寧

內容驗證(CV)
教學輔導(T)
沈楷博

內容驗證(CV)
教學輔導(T)
楊艾庭

內容驗證(CV)
葉曉姍

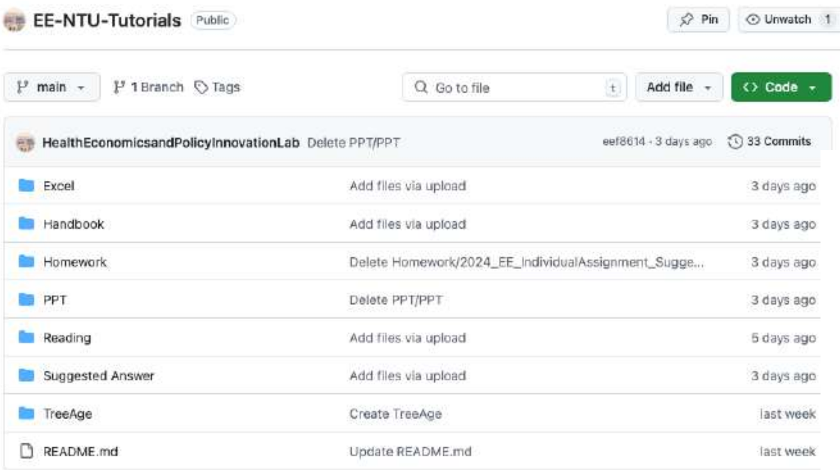
CONTENTS

❑ 內容介紹： Material, GitHub, NTU Cool

Course Material	Quantity	Location
Handbook (Printed)	1	Distributed in class
Handbook (PDF)	1	GitHub / NTU Cool
Slide Deck	1	GitHub/NTU Cool
Reading	4	GitHub/NTU Cool
Excel Template: Decision Tree	1	GitHub
Excel Template: Markov Model	1	GitHub
TreeAge Template: Decision Tree	1	GitHub
TreeAge Template: Markov Model	1	GitHub
TreeAge Microsimulation Template	1	GitHub
Class Participation Exercises	1	NTU Cool
Homework	1	NTU Cool

Source: 柴語錄 Shiba Says

❑ 內容介紹： Material, GitHub, NTU COOL



TreeAge實習課教材與資料皆上傳至NTU COOL與GitHub

❑ 單元一：
模型結構 Visualization of Decision Tree/ Markov/Microsimulation Modelling

我們介紹三個比較常見的模型：
(1) Decision Tree
(2) Markov Model
(3) Patient-level simulation (又稱microsimulation)

Decision Analytic Modeling

- Building mathematical relationships to quantify possible outcomes of interest resulting from different alternative options
- Purpose:
  - Integrate evidence on clinical and economic outcomes into a consistent framework to inform decisions about clinical practices and healthcare resource allocations
  - Allow for variability and uncertainty associated with all decisions

- 建立HTA模型可以幫助我們量化不同治療方案之效果與成本
- 好的模型應該同時考慮不同方案的差異與不確定性因素

Stages in Developing a Decision Model (1)

1. Specifying the decision problem
   - Defining population, interventions, comparators and outcomes
   - Specifying the perspective (payers, healthcare providers, society)
   - Specifying the time span of decision
2. Defining the model boundaries (simplification)
   - Should we model the effect of certain comorbidities on the outcomes?
   - Should we take into account the effect of past events on the outcomes?
   - Should we simulate treatment compliance?

建模一般包含以下五個步驟：
(1) 明確界定決策問題
(2) 定義模型界限與簡化問題範疇
(3) 選擇適當的模型結構
(4) 參數整理與統合分析
(5) 納入不確定性

Stages in Developing a Decision Model (2)

3. Selecting an appropriate modelling paradigm and developing structure

		Cohort level		Individual level	
		Continuous state	Discrete state	Markovian	Non-Markovian
No interaction among objects	Implicit time	-	• **Decision tree**	• Patient-level decision tree	
	Explicit time	-	• **Markov model**	• **Patient-level Markov model**	• Discrete time simulation • Discrete event simulation
Interaction among objects	Discrete or continuous time	System dynamics	• Markov chain model	• Individual event history model	• Discrete event simulation • Individual-based simulation

- 以上是模型類別的大致方法，依照個人/群體；時間特性、健康狀態變化、互動性、考慮個人差異及屬性來區分。
- 我們專注在三個「紅色」的模型，大概涵蓋至少8成以上的研究。

Stages in Developing a Decision Model (3)

4. Identifying and synthesizing evidence, and analysing data
   - Use entirety of existing evidence or representative the entire evidence
   - Search electronic databases (e.g. Medline, Embase, Cochrane Library)
   - Systematic review and meta-analysis
   - In the presence of large data (representative of the target population):
     - Survival analysis or logit models to estimate probabilities
     - Generalized linear models for resource utilization
     - Mixture model for costs and health utility
     - Other regression analysis

關於參數：
1. 可以使用統合分析：透過系統性文獻回顧，或採用關鍵證據或專家意見。
2. 也可進行資料分析，例如：使用存活分析健保資料分析。

Stages in Developing a Decision Model (4)

5. Capturing uncertainty
   - Variability
   - Parameter uncertainty
   - Decision uncertainty
   - Heterogeneity

模型納入不確定性之分析：

- 包括參數不確定性、人群差異性與異質性
- 不確定分析可以提升模型之可靠度與彈性

Two Common Modelling Techniques Used in Health Economic Evaluation

- Decision tree
  - Problem involving chance events that occur over a short time horizon
- Markov modelling
  - Problem involving risk that is on-going over time

兩個常見的模型建立技術：
1. 決策樹(Decision Tree)
2. 馬可夫模型(Markov Model)

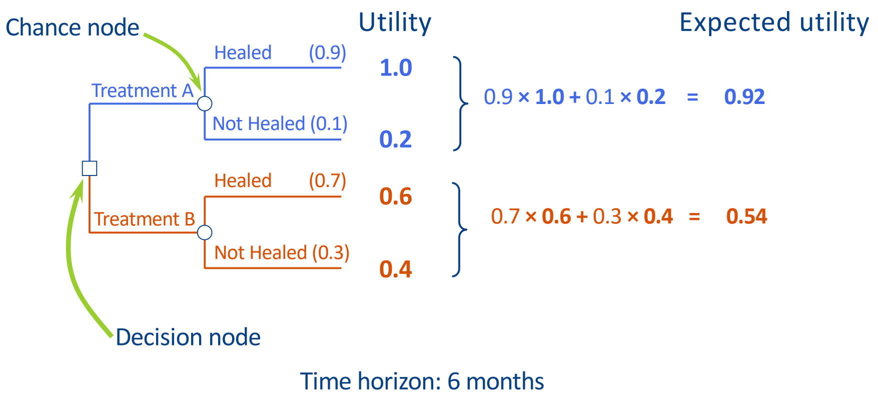
Approach 1- Decision Tree

- A method for estimating the expected payoff of various different options
- Outcomes of a decision are not perfectly known
  - Health of child after mother smoked during pregnancy
- but the probability of each outcome is
  - 80% likely to have a respiratory problem
- Thus decision analysis is a technique for helping decision makers identify the best option

決策樹為幫助決策者辨識最佳決策方案的方法，透過估算不同選項的預期收益和各結果的發生機率，讓決策者在結果不確定的情況下做出最佳決策。例如，孕期吸菸對孩子健康的影響機率。

Key Elements of Decision Analysis

- Probabilities: Likelihood of an event occurring
- Payoffs: Cost and outcomes assigned to each 'state of the world'
- Expected value: The sum of the probability of each possible outcome multiplied by the outcome value (or payoff).



決策分析包含以下重要元素：機率、支付價格、期望值

Common Steps in Building a Decision Tree

1. Define the problem
2. Structure the tree
3. Estimate the costs and the consequences of each stage in the tree (payoffs)
4. Assign probabilities and folding (rolling) back to calculate expected values
5. Calculate the incremental cost-effectiveness ratio
6. Conduct sensitivity analysis
7. Validate

建立決策樹模型包含以上7個步驟

Define the Problem

- Some key questions:
  - What are the major issues?
  - What is the perspective?
  - What are the alternatives/options?
  - What is the analytical horizon?
    - Longer term horizons may require other approaches: Markov models, simulations

界定問題：包含主要探討議題、觀點、替代方案、分析視角

Structuring a Decision Tree

- Decision tree built from left to right in a logical sequence
  1. List decision options (Decision nodes)
  2. Identify the sequences of events (pathways) resulting from the decision options (Chance nodes)
  3. Identify terminal events (Terminal nodes)
- Ensure all pathways are mutually exclusive and exhaustive

決策樹從左至右建立模型，包括決策、機會及終端節點，所有路徑需互斥(各自獨立)且完整，以清楚呈現結果

Case Study of Decision Tree: Communicable Disease

- A communicable disease spreads to Taiwan. There is a risk of mortality from infection with the disease
- Currently no vaccine is available in Taiwan
- A vaccine has been developed, which is effective in reducing risk of infection for the next year
- After that, the disease mutates and the vaccine is no longer effective

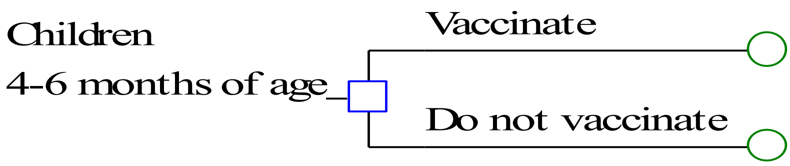
決策樹分析之案例研究：傳染性疾病
若傳染病傳入台灣，需研發疫苗，可減少一年內感染風險，
但一年後因病毒變異將失效

Objective of Case Study

- To estimate the *potential* costs and outcomes associated of the introduction of the vaccine compared to having no vaccine in the Taiwanese setting
- The comparator is *no vaccine*
- The perspective of the analysis is *societal*
- **A short-term (1 year) decision analysis**

該案例研究的目標為評估引入疫苗相較於無疫苗情況下的潛在成本和結果

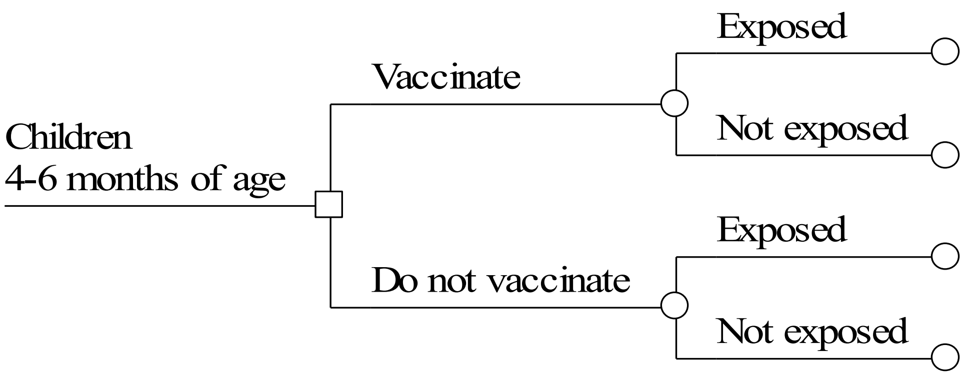
Building the Decision Tree



- Root node summarises patient population.
- Decision node drawn as a square (represents alternative actions under control of decision maker.
- The 2 alternatives - vaccinate and do not vaccinate - are represented as branches.

根據節點描述患者群體，決策節點用方形表示。兩個選項「接種」與「不接種」分別為決策的分支

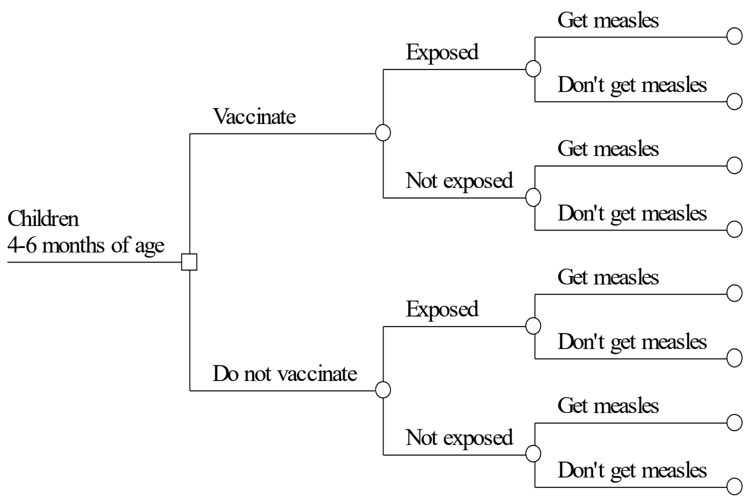
Building the Decision Tree



Chance nodes identify one or more of several possible events that are beyond the control of the decision maker.
Probabilities are associated with events depicted at chance nodes.
At any given chance node, probabilities of events must sum to one - mutually exclusive and exhaustive events.

機會節點表示決策者無法控制的多重可能事件具不同的發生機率。在每個機會節點上，所有事件的機率總和需等於一，確保這些事件互斥(各自獨立)且完整。每個機會節點能完整描述在特定情況下的所有可能結果，讓決策樹能更準確地反映不同選項的潛在風險和效益，幫助決策者評估每種情境的可能性並進行合理的選擇。

Building the Decision Tree



For each branch of exposed/not exposed, chance of getting measles or not is represented by a chance node

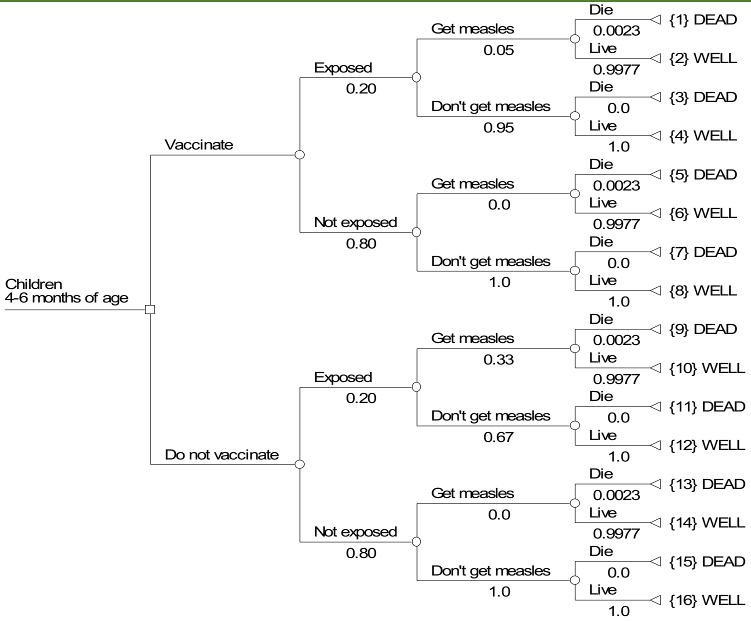
在每個「暴露/未暴露」分支中，感染麻疹的機率用機會節點表示

Estimating probabilities

- **Gathering information to fill the tree**

Event	Probabilities
Vaccinate/do not vaccinate	
Exposed	0.2000
Not exposed	0.8000
Vaccinate	
Exposed	
Get measles	0.0500
Do not get measles	0.0950
Not exposed	
Get measles	0.0000
Do not get measles	1.0000
Do not vaccinate	
Exposed	
Get measles	0.3300
Do not get measles	0.6700
Not exposed	
Get measles	0.0000
Do not get measles	1.0000
Death	
Get measles	
Die	0.0023
Live	0.9977
Do not get measles	
Die	0.0000
Live	1.0000

Estimating probabilities



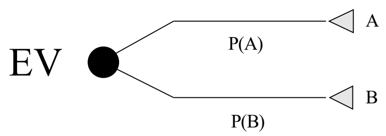
Rolling Back and Expected Values

- Analysing the decision tree
  - for each pathway, all the probabilities are multiplied together (*rolling back the decision tree*)
  - the products of pathway probabilities and outcomes are summed for each decision option *(weighted average)*
  - the weighted average is the *expected value* of that outcome for the specified decision option

在分析決策樹的過程中，需回溯(Roll Back)每條路徑並將相對應的機率相乘，並將每個決策選項的所有路徑機率與其結果相乘後的數值相加，計算出加權平均。此加權平均值即為特定決策選項的期望值，代表在此選擇下可能得到的預期結果。

Rolling Back- Estimating Expected Value

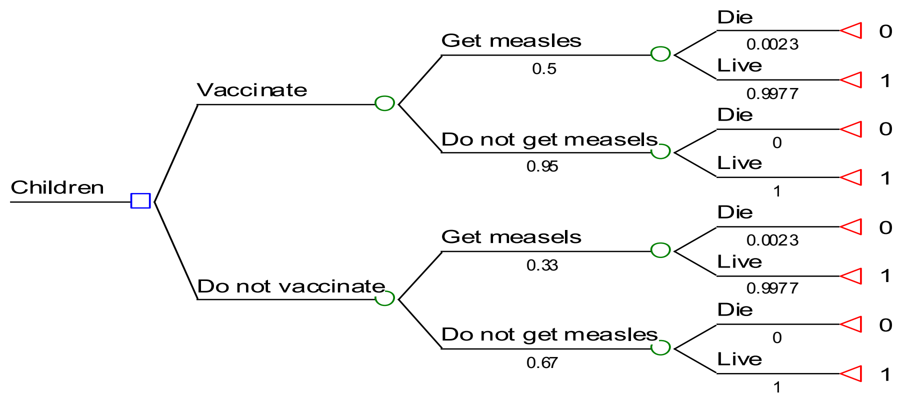
- Calculating the expected value (EV) at a particular chance node: multiply along pathways, then sum across pathways



$$EV = P(A) \times A + P(B) \times B$$

Rolling Back- Estimating Expected Value (Cont'd)

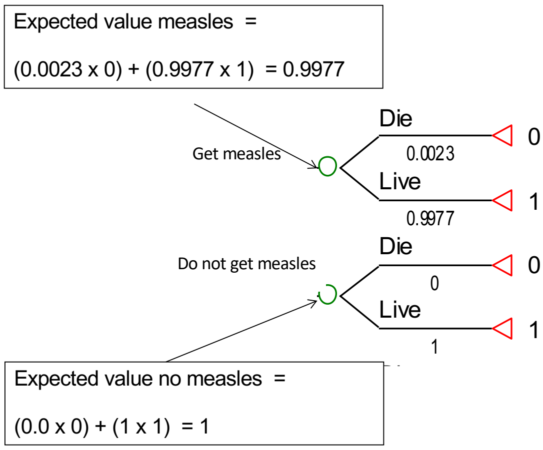
Assume utility of 1 for live and 0 for die



效用值(Utility)：1代表存活；0代表死亡

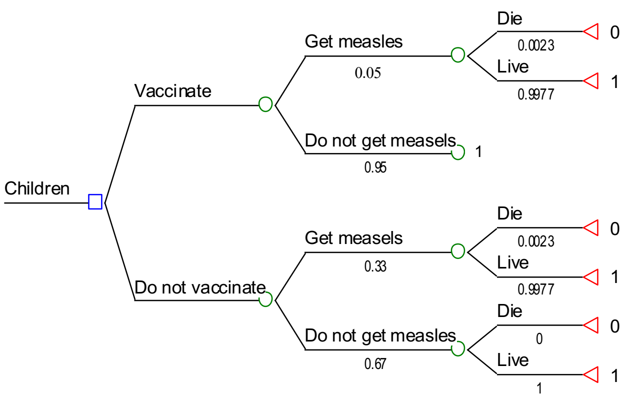
Rolling Back- Estimating Expected Value (Cont'd)

Assume utility of 1 for live and 0 for die



Rolling Back- Estimating Expected Value (Cont'd)

Assume utility of 1 for live and 0 for die



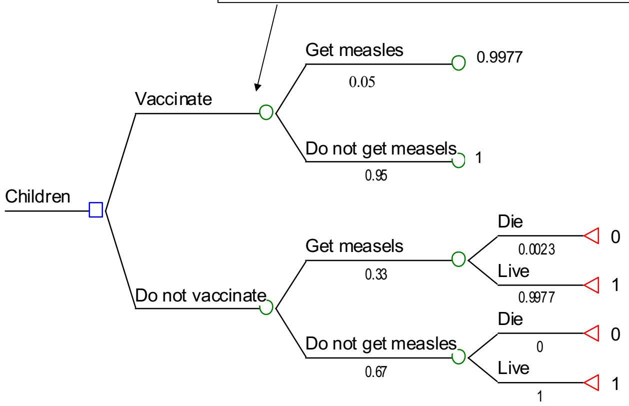
Rolling Back- Estimating Expected Value (Cont'd)

Assume utility of 1 for live and 0 for die

Expected value at this chance node =

(0.05 x 0.9977) + (0.95 x 1) = 0.99989

The expected value of vaccinating is 0.99989



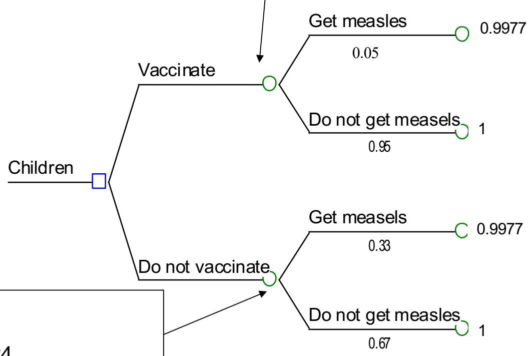
Rolling Back- Estimating Expected Value (Cont'd)

Assume utility of 1 for live and 0 for die

Expected value at this chance node =

(0.05 x 0.9977) + (0.95 x 1) = 0.99989

The expected value of vaccinating is 0.99989



Expected value at chance node:

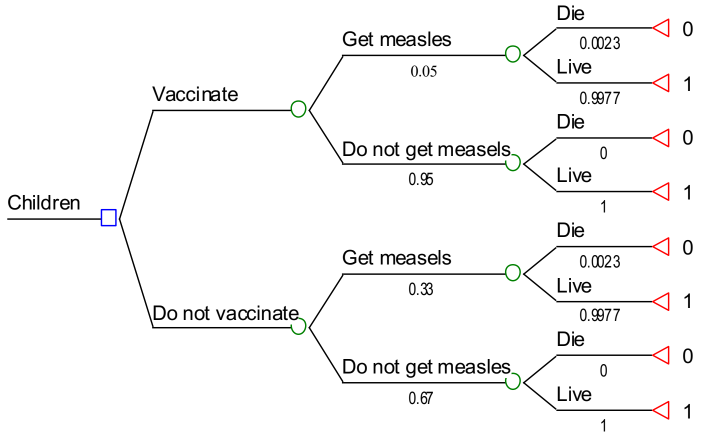
(0.33 x 0.9977) +(0.67 x 1) = 0.99924

The expected value of not vaccinating is 0.99924

Rolling Back- Estimating Expected Value (Cont'd)

Assume utility of 1 for live and 0 for die

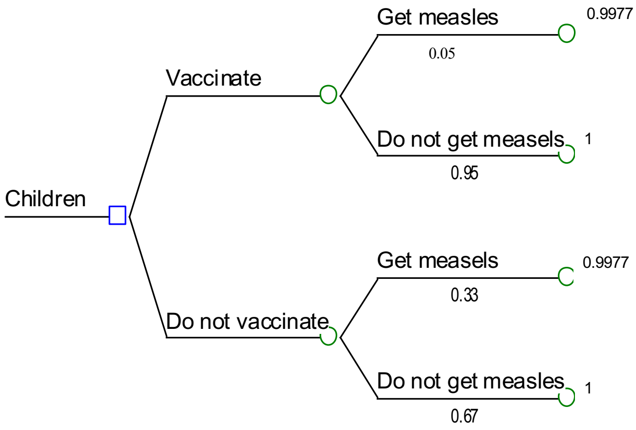
Started with this…



Rolling Back- Estimating Expected Value (Cont'd)

Assume utility of 1 for live and 0 for die

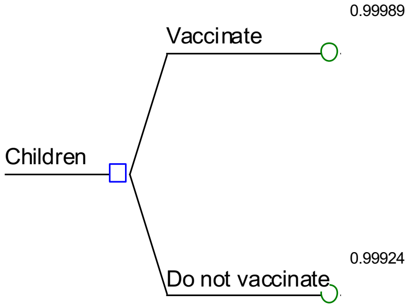
Roll back #1…



Rolling Back- Estimating Expected Value (Cont'd)

Assume utility of 1 for live and 0 for die

Roll back #2…



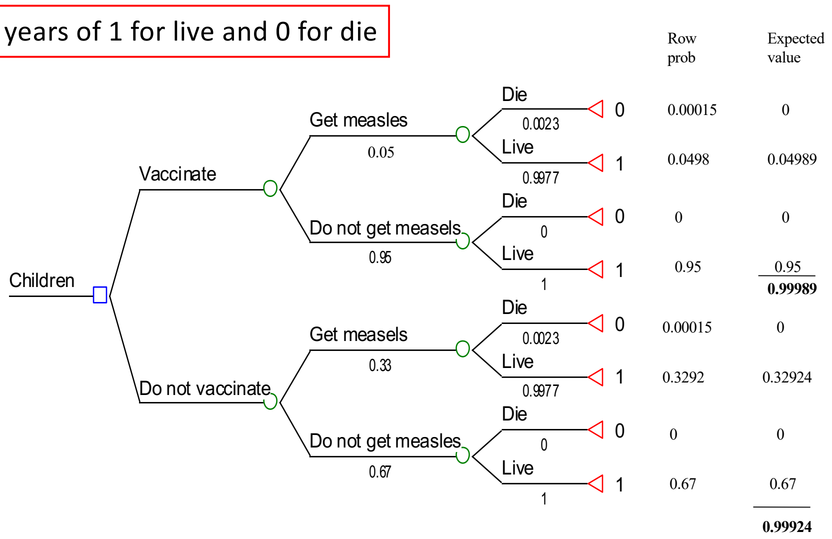
Incremental Outcomes

- Difference in expected probability of getting measles and dying between a strategy of becoming vaccinated or not being vaccinated
  - Deaths avoided = 0.9999 - 0.9992 = 0.0007
    - 7 deaths avoided per 10,000 children vaccinated
  - Measles cases prevented = 0.33- 0.05 = 0.27
    - 27 cases prevented per 100 children vaccinated

增量結果：接種疫苗與未接種疫苗策略在感染麻疹及死亡的機率上有顯著差異，用以評估疫苗效益

Other Method of Estimating Payoffs

Assume life years of 1 for live and 0 for die



這是依照每個分支(branch) 機率的算法

Approach 2- Markov Model

A decision-analytic technique that involves a **Markov process**, a ***modelling*** technique derived from matrix algebra, which describes the ***transitions*** a cohort of patients make among a number of ***health states*** during a series of short intervals or ***cycles.***

- 馬可夫模型(Markov Model)：運用馬可夫過程以描述患者群體健康狀態，會隨著時間而轉變。
- 此模型來自「矩陣代數」。
- 我們在Excel會進行練習，同學就能清楚知道如何做出Markov Model Trace (馬可夫軌跡圖)。

矩陣代數：用於描述系統在不同狀態間的轉移過程，透過「轉移矩陣」表示從一個狀態到另一狀態的轉移概率。每一狀態分佈可由當前狀態向量乘以轉移矩陣得出，經過多步驟的轉移則可使用矩陣的冪次計算。在長期的穩定狀態下，系統的狀態分佈達到不再變動的狀態。馬可夫模型的矩陣代數廣泛應用於醫學和經濟學等領域，用以評估策略在長期下的預期效益，並幫助決策者了解系統隨時間變化的行為。

Key Elements of Markov Models

- Conventional tree describes the ways in which a patient (or cohort) in one health state might end up in other health states over a fixed time period

- Markov model is concerned with health state transitions over time
  - Repeats a series of short intervals or cycles

- Decision tree: 描述患者（或群體）在固定時間內從一種健康狀態轉移到其他健康狀態的可能路徑。
- Markov model: 患者的健康狀態會隨著時間推移而產生變化。

Key Elements of Markov Models

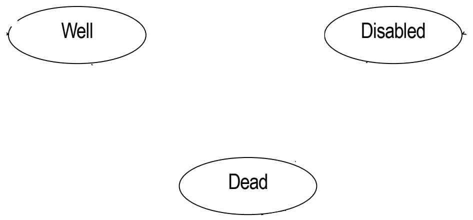
- **Health states**
  - The health state defines how a patient is counted for a given cycle.
  - Health states have to be mutually exclusive and exhaustive
  - This status determines their costs, their risks and any other benefits/ payoffs.
- **Transition probabilities**
  - These are the probabilities that a patient will move from one health state to another in a given cycle.
- **State rewards (no longer called payoffs)**
  - Accumulated for each cycle that a patient resides in a health state
  - Payoffs can also be assigned to specific events in the model (as opposed to just time spent in the health state)
- **Termination condition**
  - The number of Markov cycles that the patient cohort is followed for

Markov Model的關鍵元素：

1. 健康狀態
2. 轉移機率
3. 狀態回饋
4. 終端情況

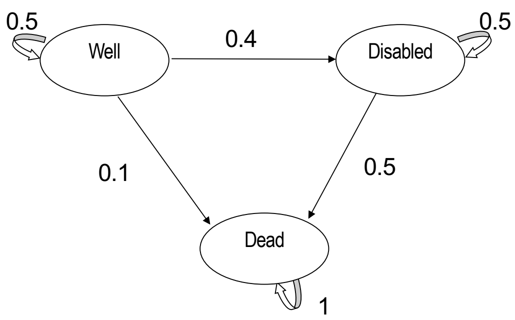
Key Elements of Markov Models

- Health states
  - The health state defines how a patient is counted for a given cycle.
  - Health states have to be mutually exclusive and exhaustive
  - Determines their costs, their risks and any other benefits/ payoffs.



Key Elements of Markov Models

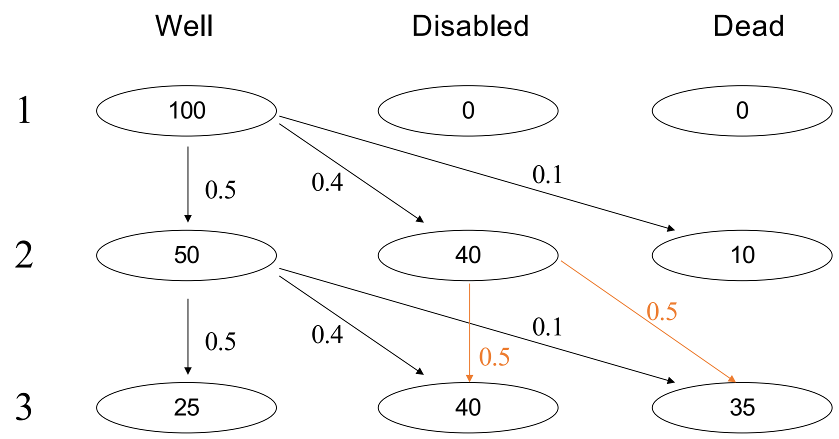
- Transition probabilities
  - These are the probabilities that a patient will move from one health state to another in a given cycle.



This is called a state transition diagram

- State transition diagram: 狀態轉移地圖
- 我們會練習如何用TreeAge畫此圖

Health State Transitions



Key Elements of Markov Models

- Termination condition
  - The number of Markov cycles that the patient cohort is followed for

Cycle	State A	State B	State C	State D	Total
0	1000	0	0	0	1000
	1000×0.721	1000×0.202	1000×0.067	1000×0.01	
1	721	202	67	10	1000
2	520	263	181	36	1000
3	375	258	277	90	1000
4	270	226	338	166	1000
5	195	186	363	256	1000
6	140	147	361	351	1000
7	101	114	340	445	1000
8	73	87	308	532	1000
9	53	65	271	611	1000
10	38	48	234	680	1000
11	27	36	197	739	1000
12	20	26	164	789	1000
13	14	19	135	831	1000
14	10	14	110	865	1000
15	7	10	89	893	1000
16	5	7	72	916	1000
17	4	5	57	934	1000
18	3	4	45	948	1000
19	2	3	36	959	1000
20	1	2	28	968	1000

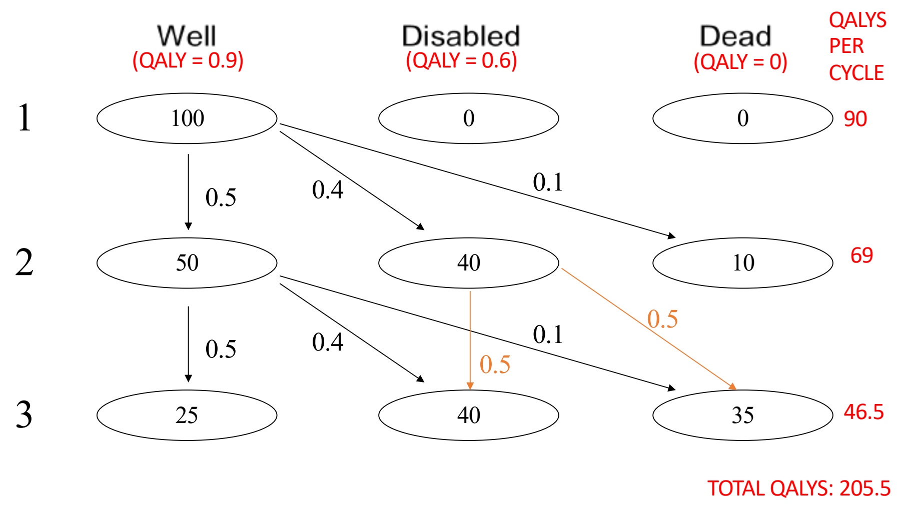
Fig. 9.6 The results of the Markov trace for the monotherapy group in the HIV example. The trace assumes a starting cohort of 1000 beginning in State A.

Analysing a Markov Model

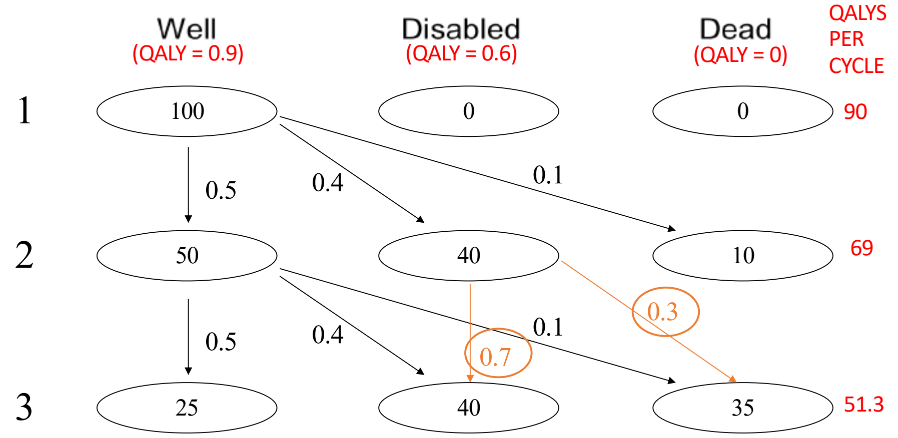
- The Markov trace tells us the proportion of patients in each health state at each time point
- From there, the expected costs and benefits accruing in each cycle can be calculated
- Summing all the costs and benefits across the cycles will provide the total expected cost/benefits
- Compare Markov outcomes for treatment versus control to estimate ICER

馬可夫追蹤圖描述不同時間點處於各健康狀態的患者比例，藉此計算每個週期的預期成本與效益。將各週期的數據相加而得到總預期成本與效益，進而比較治療組與控制組的模型結果，計算增量成本效益比（ICER），協助評估不同治療策略的經濟效益。

Health State Transitions: Control



Health State Transition: Treatment



Treatment reduces mortality for disabled

TOTAL QALYS: 210.3

Key Practical Modeling Message

- **Keep model as simple as possible**
  - What question are you answering?
- **Use a multi-disciplinary team to build model**
  - Can’t simplify if don’t know your issue
- **Good modelling takes time and resources**
  - Iterative – normally don’t get it right first time
- **Don’t overlook your data**
  - Garbage in – garbage out
- **Presentation of results of model as transparent as possible**
  - Back of the Envelope!
- **Use sensitivity analysis to check robustness of results**
- **Validation a process rather than a ‘tick the box’**

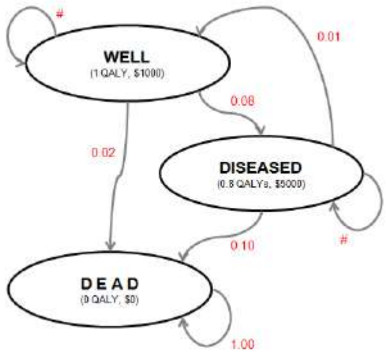
關鍵的實用建模訊息：

1. 模型盡可能簡單化
2. 與跨學科團隊建構模型
3. 良好的建模需要時間和資源
4. 不要忽視數據的重要性
5. 模型結果的呈現應該盡可能透明
6. 使用敏感度分析以檢視結果的穩健性
7. 驗證是一個過程，而非單純的「打勾確認」

Key Elements of Markov Models

- The "Markov property"
  - Memoryless

    The model does not take into account of all previous health states, just the one immediately before.
  - *"The behaviour of the process subsequent to any cycle depends only on its description in that cycle"* (Sonnenberg and Beck, 1993)
  - Not necessarily ideal in all health applications



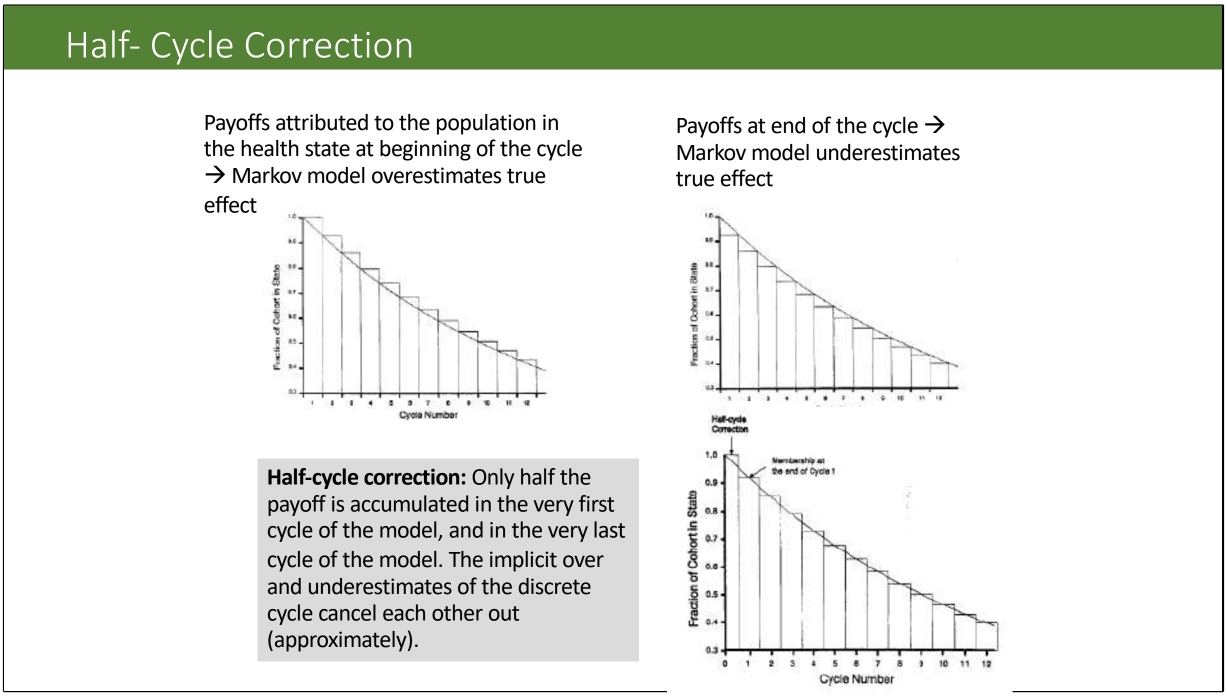
馬可夫模型不具記憶性，僅考慮當前狀態，不會追溯過往健康狀態。每個周期後的行為僅描述當下所造成的影響

Determine Transition Probabilities

- Most available information about transitions between health states expressed as a *rate* and *not a probability*
  - A rate is a number of events per unit time (e.g. infection attack rate per 100 person years)
  - A probability is a quantity that is unitless (time is built into it)
  - A rate *r* can be used to estimate a transition probability *p* of an event occurring over a time interval *t* based on the following formula:

$$p = 1 - e^{-rt}$$
$$r = -\ln(1-p)/t$$

健康狀態轉換多用比率表示，可透過上圖公式將比率轉為機率，並包含時間因素



半週期修正 (Half-cycle Correction)

在馬可夫模型中，若在週期開始時就計算收益，可能會高估真實效果，若在週期結束時計算，則可能低估真實效果。

- 半週期修正的概念為該方案中一半的收益，是在模型的第一個及最後一個週期中所累積的。
- 以此方式減少週期離散化帶來的高估與低估誤差達到近似的校正效果。

COHORT VERSUS MICROSIMULATIONS (1)

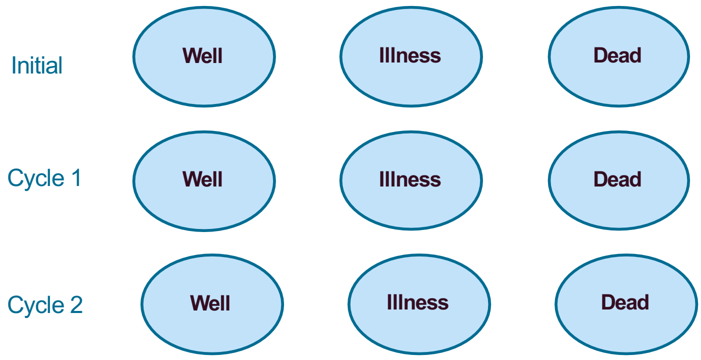
- **Cohort simulation**
  Model a group of hypothetical patients at the same time
  Time horizon is fixed
  Computationally less intensive
- **Individual or microsimulations (Monte Carlo)**
  Individuals are modeled through the Markov models one at a time
  Time for each patient can be short or long
  Computationally intensive

個體或微觀模擬：將個體逐一透過馬可夫模型進行模擬，每位患者的模擬時間可長可短，但計算量較大

COHORT VERSUS MICROSIMULATIONS (1)

Cohort simulation

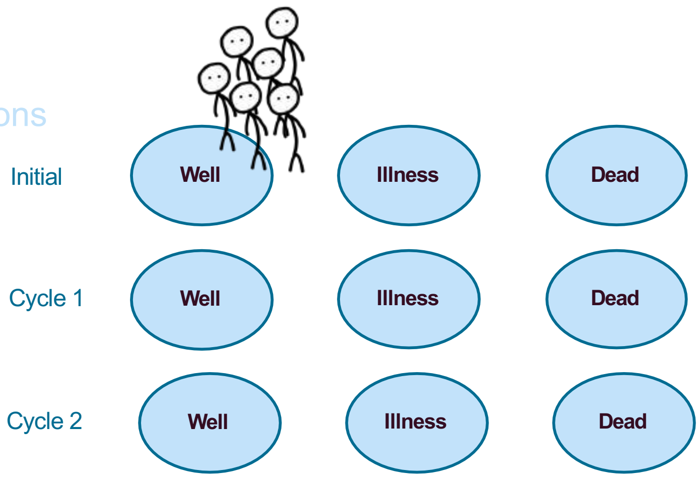
Individual or microsimulations



COHORT VERSUS MICROSIMULATIONS (2)

Cohort simulation

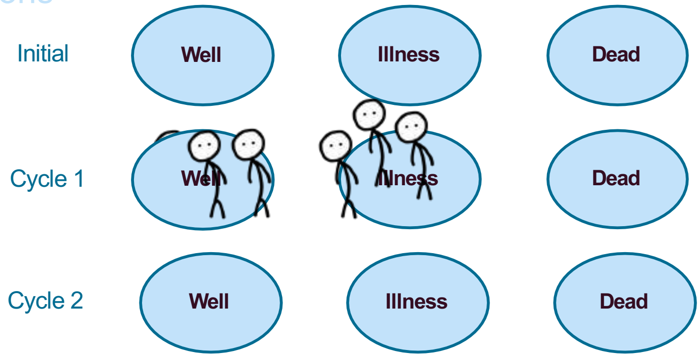
Individual or microsimulations



COHORT VERSUS MICROSIMULATIONS (3)

Cohort simulation

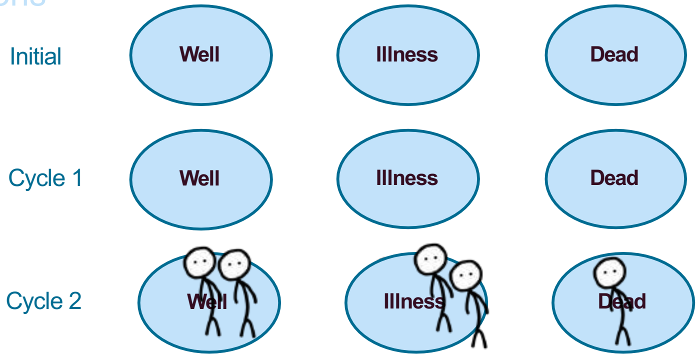
Individual or microsimulations



COHORT VERSUS MICROSIMULATIONS (4)

Cohort simulation

Individual or microsimulations

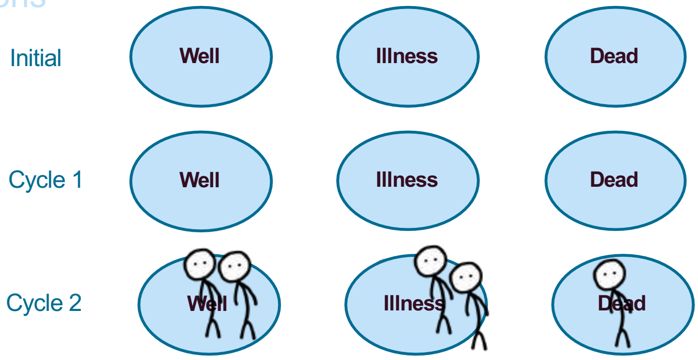


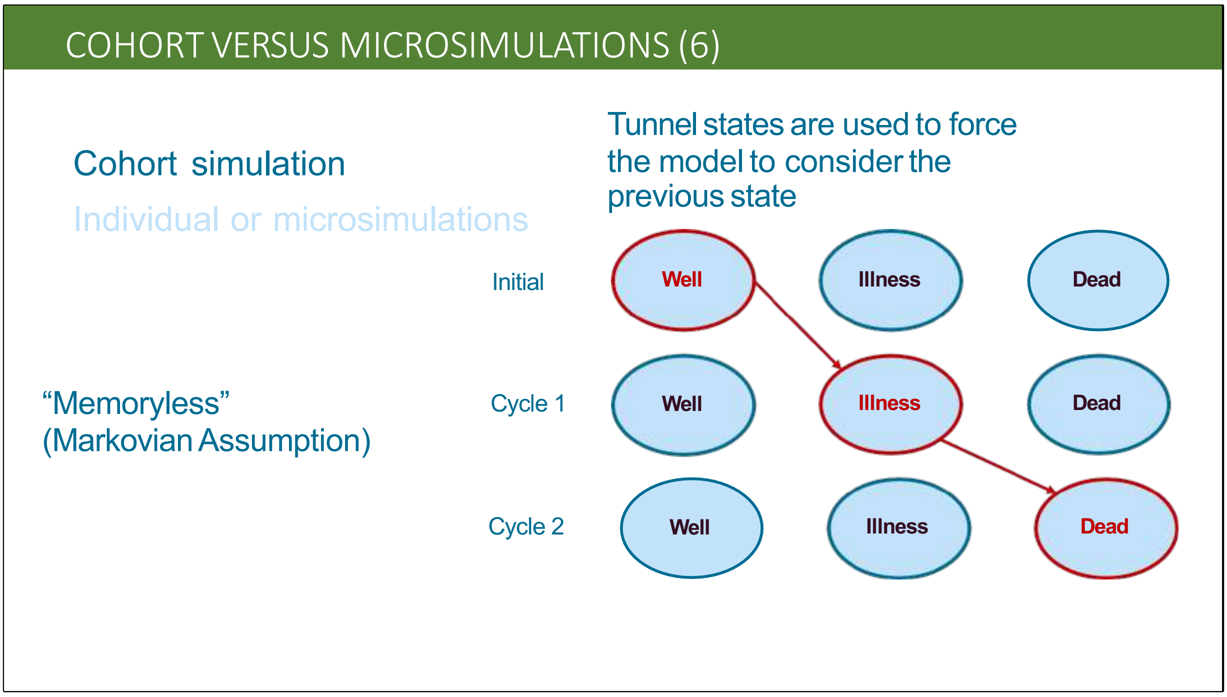
COHORT VERSUS MICROSIMULATIONS (5)

Cohort simulation

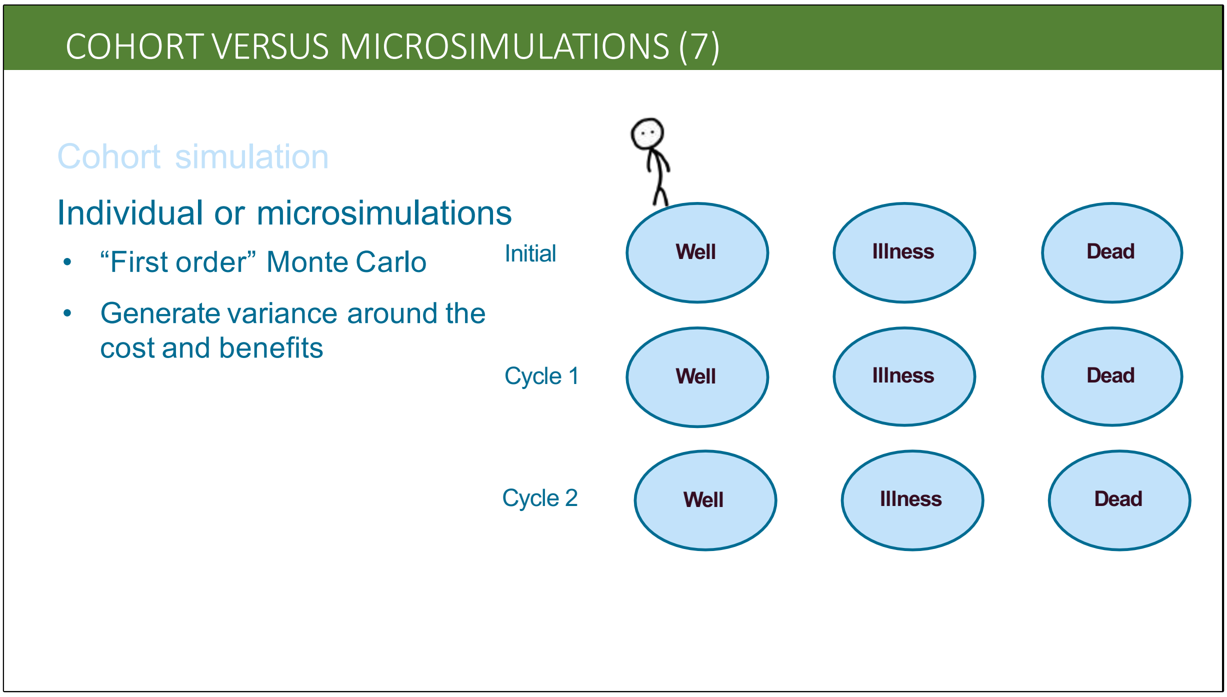
Individual or microsimulations

“Memoryless”
(Markovian Assumption)





Tunnel state(隧道狀態):使馬可夫模型考慮患者之前的健康狀態，以確保過去狀態影響

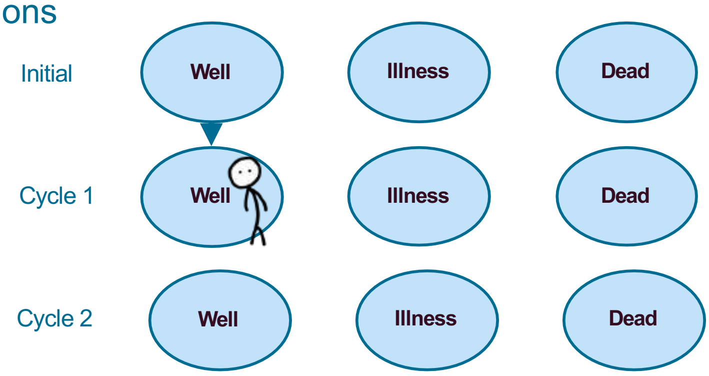


微觀模擬可以將個人因素納入考量，例如：基因
微觀模擬每次跑Markov Model，只會分析一個人，
不像Cohort一次可分析一整群人

COHORT VERSUS MICROSIMULATIONS (8)

Cohort simulation

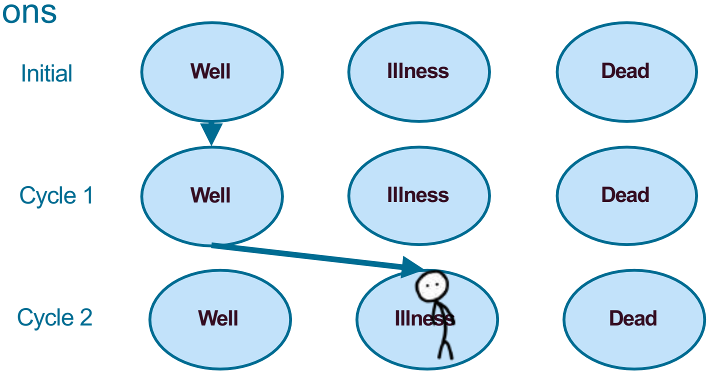
Individual or microsimulations



COHORT VERSUS MICROSIMULATIONS (9)

Cohort simulation

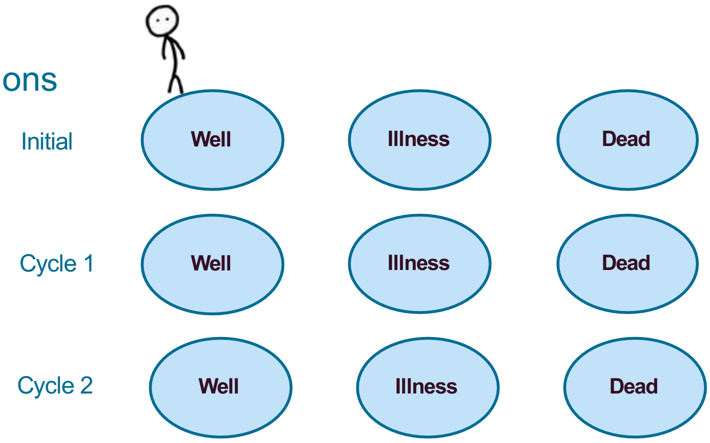
Individual or microsimulations



COHORT VERSUS MICROSIMULATIONS (10)

Cohort simulation

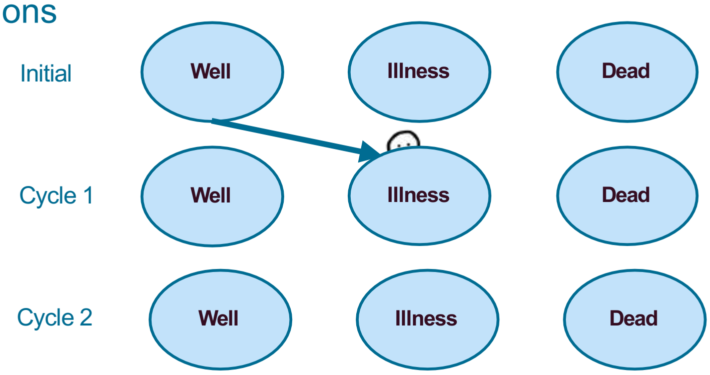
Individual or microsimulations



COHORT VERSUS MICROSIMULATIONS (11)

Cohort simulation

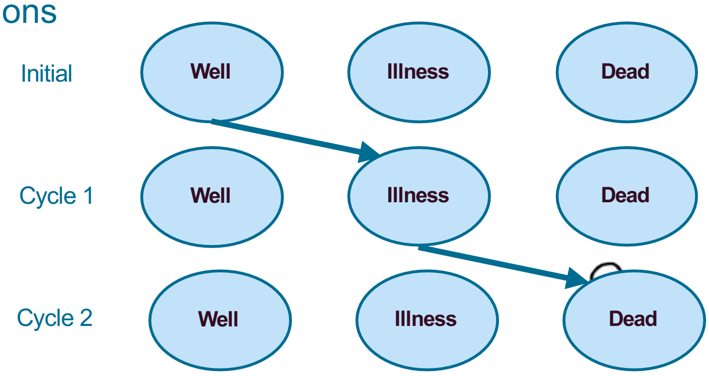
Individual or microsimulations



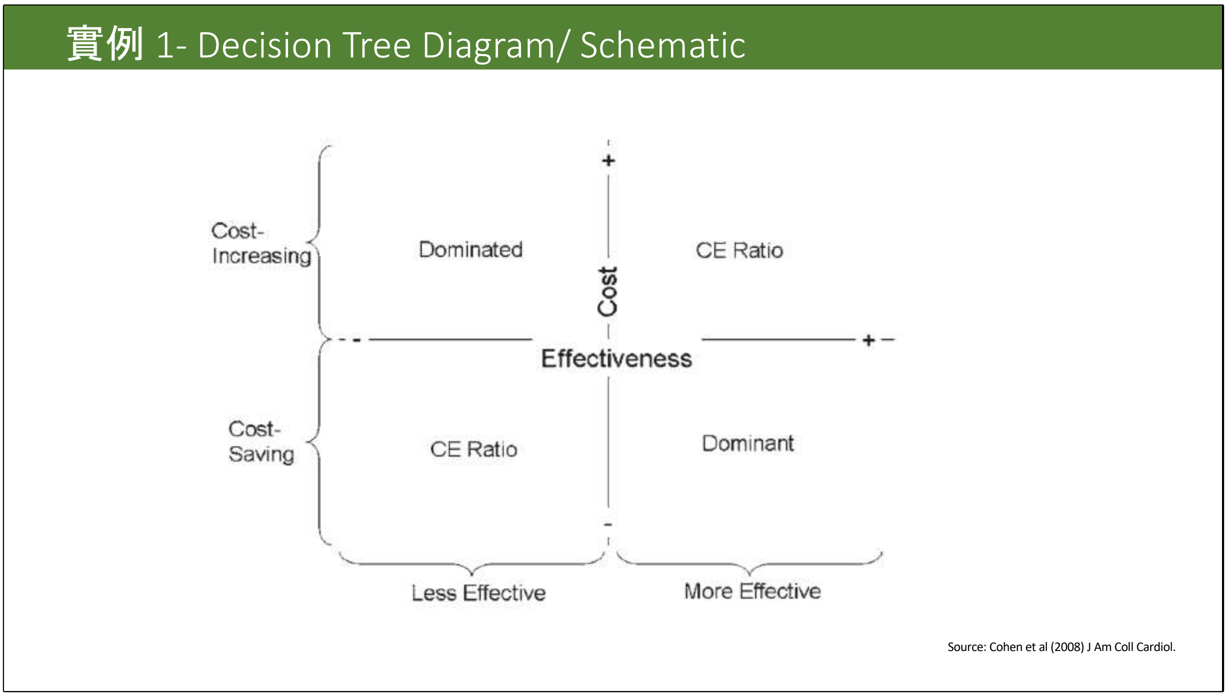
COHORT VERSUS MICROSIMULATIONS (12)

Cohort simulation

Individual or microsimulations



❑ 單元二：
Presentation of Results



我們跑完結果分析之後，要做成圖表以呈現結果。
以下是幫同學整理比較常用的圖表，我們這本手冊都會教如何製作這些圖表

上圖是所謂的Cost-effectiveness Plane 有四個象限 (quadrants)

實例 1- Decision Tree Diagram/ Schematic

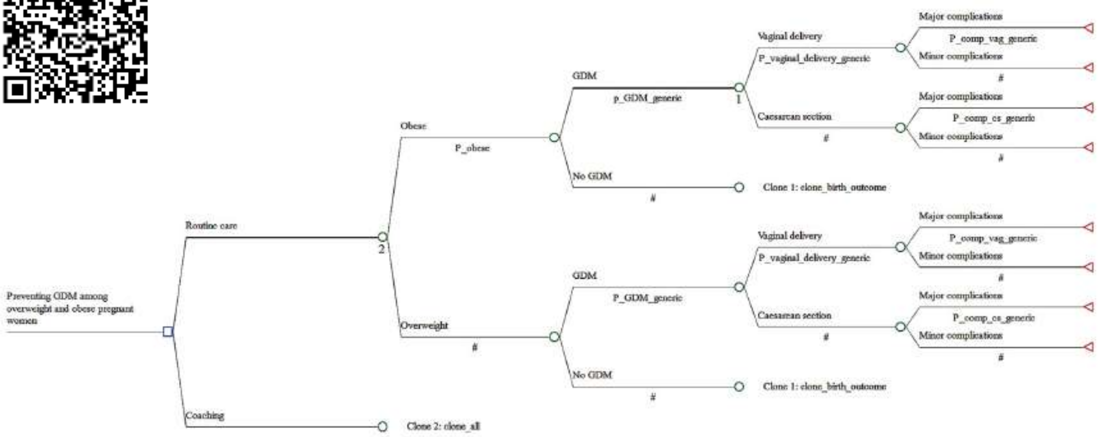


Fig. 1 Simplified diagram of the decision tree model used to analyze the cost-effectiveness of coaching to prevent GDM

Source: de Jersey et al (2024) Cost Effectiveness and Resource Allocation

請同學閱讀文章 (Figure 1): https://resource-allocation.biomedcentral.com/articles/10.1186/s12962-024-00520-9 (可掃描上圖QR code)

上圖為TreeAge所繪製，在這個tree作者給他上下對應，所以下面的coaching branch直接用clone的 (TreeAge有這個功能)
同學請不要擔心TreeAge的價錢，他有試用版，金額不算太高，未來工作公司應該也可以購買

實例 2- Markov Model Diagram/ Schematic

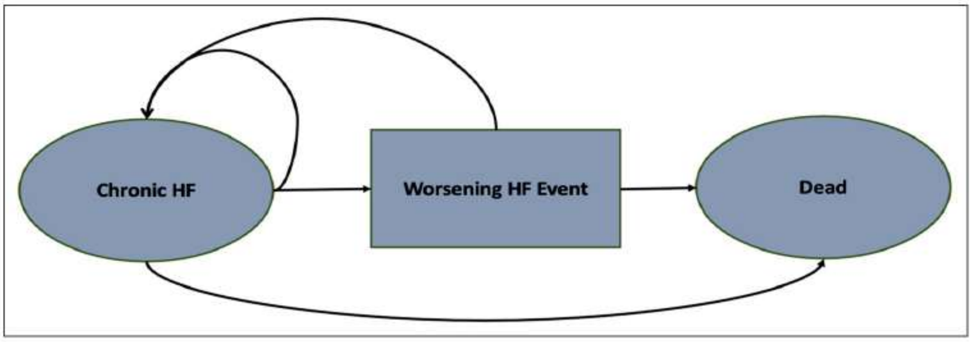


Figure 1. Diagram of the Markov model.
Patients occupy health states, shown in the ovals and boxes. Patients transition from different health states represented as arrows based on transition probabilities derived from participant-level data from DAPA-HF and DELIVER. Worsening HF events include hospitalization for HF and urgent HF visits. DAPA-HF indicates Dapagliflozin and Prevention of Adverse Outcomes in Heart Failure; DELIVER, Dapagliflozin Evaluation to Improve the Lives of Patients With Preserved Ejection Fraction Heart Failure; and HF, heart failure.

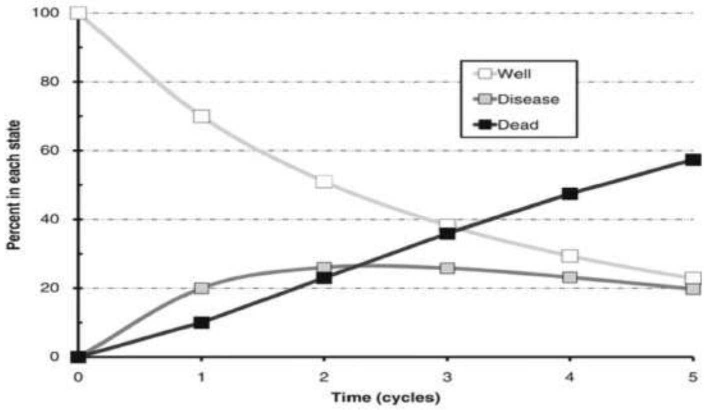
Source: Bhatt et al, (2024) Journal of the American Heart Association

請同學閱讀文章 (Figure 1):
https://www.ahajournals.org/doi/full/10.1161/JAHA.123.032279 (可掃描上圖QR code)

關於 Markov diagram裡面的health state，可以參考之前其他類似的研究，或者是可以跟chatgpt聊一聊
上圖中的state transition其實不難，可能是因為data沒那麼多，所以精簡一點
未來有比較多的data，再用多一點state也不遲！

實例 3- Markov Trace

Fig. 5.3



Graphical depiction of the Markov trace for a simple Markov model

Source: Cost-effectiveness modelling for health technology assessment. Adis publisher (2015)

Markov trace 是很常見的圖表，用以呈現每週期有多少人在哪個健康狀態
在上圖中，本來有100個人，經過五個週期後，剩下20人健康、20人生病、60人死亡

我們會說明如何在Excel做這個圖，重點是每一週期都要加起來要同樣人數

實例 4- ICER

Table 3 Within-trial cost-effectiveness analysis

Cost-effectiveness	Costs (95% CI) [P(most costly)]	QALYs (95% CI) [P(most effective)]	Inc Costs (95% CI)	Inc QALY (95% CI)	ICER
Dyad					
Services as usual	£1,988.61 (146.79, 2615.43) [0.037]	2.58680 (2.54927, 2.62129) [0.06]			
E-SEE Steps	£2,609.46 (2312.07, 2951.04) [0.963]	2.61775 (2.60252, 2.6342) [0.94]	£620.85 (-103.32, 1288.70)	0.03095 (-0.00830, 0.07094)	£20,061.02
Primary carer					
Services as usual	£942.44 (604.51, 1461.11) [0.052]	1.31392 (1.27465, 1.35166) [0.044]			
E-SEE Steps	£1,388.26 (1142.31, 1639.19) [0.948]	1.34818 (1.33322, 1.36373) [0.956]	£445.82 (-136.90, 890.20)	0.03427 (-0.00643, 0.07679)	£13,010.68
Child					
Services as usual	£1,000.28 (746.07, 1322.25) [0.143]	1.27420 (1.26722, 1.28191) [0.868]			
E-SEE Steps	£1,177.33 (1034.65, 1340.39) [0.856]	1.26957 (1.26629, 1.27261) [0.132]	£177.05 (-175.88 484.85)	-0.00463 (-0.01333, 0.00331)	Dominated

Source: Cox et al, (2022) BMC Health Service Research

請同學閱讀文章 (Table 3): https://bmchealthservres.biomedcentral.com/articles/10.1186/s12913-022-08220-x (可掃描上圖QR code)

這就是很常見的COST, QALY, Incremental Cost, Incremental QALY, ICER的 Table
Excel裡面就每個都寫一下公式（這些公式大家應該在國中小就學習過囉）
TreeAge都有內建好了，只要知道按哪個鈕就好 （跟 Outlook, SPSS一樣）

複習： ICER = (differences in costs)/(differences in QALY)

實例 5- Net Monetary Benefit

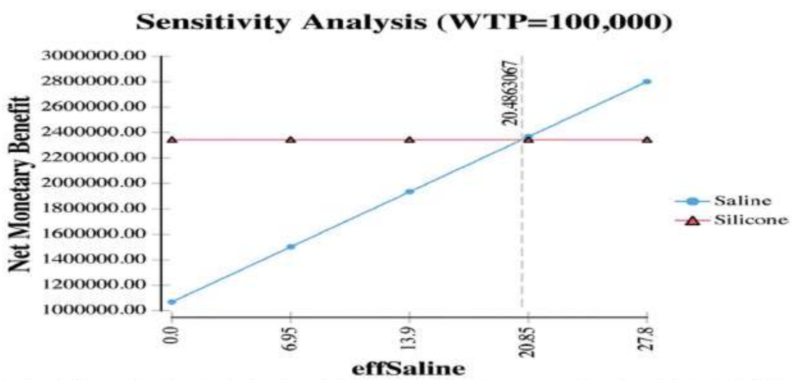


Fig. 2. Sensitivity analysis by differential effectiveness showing the BREAST-Q–adjusted life-year threshold (20.5) at which saline yields a greater net monetary benefit. The net monetary benefit calculation combines cost, effectiveness (*eff*), and willingness-to-pay (*WTP*) (set at $100,000) into a single measurement (created using TreeAge Pro 2017).

Source: Siotos et al, (2019) Plastic and Reconstructive Surgery

這個我們上課還沒教 *NMB = (Incremental Benefit x Threshold) – Incremental Cost*
NMB在成本利益 (cost-benefit analysis) 分析中常見
白話文來說 淨貨幣效益 (Net Monetary Benefit, NMB) 是一種統計方法，用於將一項干預措施的價值轉化為貨幣形式，當已知單位效益（例如健康結果或生活質量調整年數，QALY）的支付意願閾值時使用。以下是簡易的解釋：
- 簡單定義：淨貨幣效益表示一項干預措施的貨幣價值，當我們知道每單位效益（例如 QALY）的支付意願閾值時，NMB 將健康效益和資源使用轉換為貨幣來比較，不需使用比例（例如增量成本效益比 ICER）。
- 計算公式: NMB= (增量效益) * (支付意願閾值) – (增量成本)
- 解釋：
  - 增量淨貨幣效益：比較不同干預措施時，計算它們的 NMB 差異。
  - 若增量 NMB 為正值，表示在給定支付意願閾值下，干預措施是具有成本效益的，意即所獲效益的成本低於決策者願意支付的最高金額。

請同學閱讀文章 (Figure 2):
https://journals.lww.com/plasreconsurg/fulltext/2019/02000/cost_effectiveness_analysis_of_silicone_versus.7.aspx (可掃描上圖QR code)

上圖是一種 sensitivity analysis：隨著effectiveness的差別（X軸）, NMB的變化
請記得：NMB = (E × WTP) – C.
直觀上來說 隨著Saline 的 effectiveness 增加 NMB也會上升 ---藍色線
但Silicone的effectiveness並沒有變化（這是one-way sensitivity analysis)所以 NMB就 silicone是固定的 ---紅色線
我們上課會教如何在one-way PSA後 用TreeAge做這個圖

實例 6- Tornado Diagram

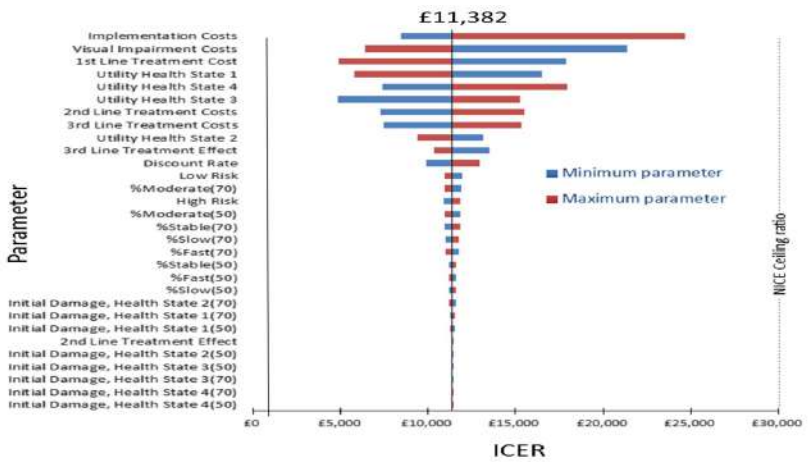


Fig. 4 Tornado Diagram measuring the impact in variation in parameters for the health economic model with included visual impairment costs (ICER = £11,382). Maximum and minimum limits for parameters were identified. ICERs were derived and ordered in terms of impact (greatest to lowest ICER variation)

Source: Boodhna et al (2016) BMC Health Service Research

請同學閱讀文章 (Figure 4):
https://bmchealthservres.biomedcentral.com/articles/10.1186/s12913-016-1849-9 (可掃描上圖QR code)

Tornado 主要是可以知道哪些變數會影響結果
這裡可以看得出來 Implementation Costs 是很重要的參數

在TreeAge軟體分析後呈現的pattern： 藍色是Positive的，紅色是Negative的
這篇文章中：比較組是頻率較密集的眼睛檢查，對照組是現在正常的頻率。（請看paper的Figure 1)
所以說如果檢查眼睛很貴，成本變貴了，ICER就會比較高
不過呢，有點意外的是，就算檢查費很貴，在這篇文章中ICER也低於NICE的30,000英鎊threshold （例如一條bar，implementation costs到最高，ICER也是差不多25,000)
所以作者的結論是，很符合成本效益！

實例 7- Cost-Effectiveness Scatterplot

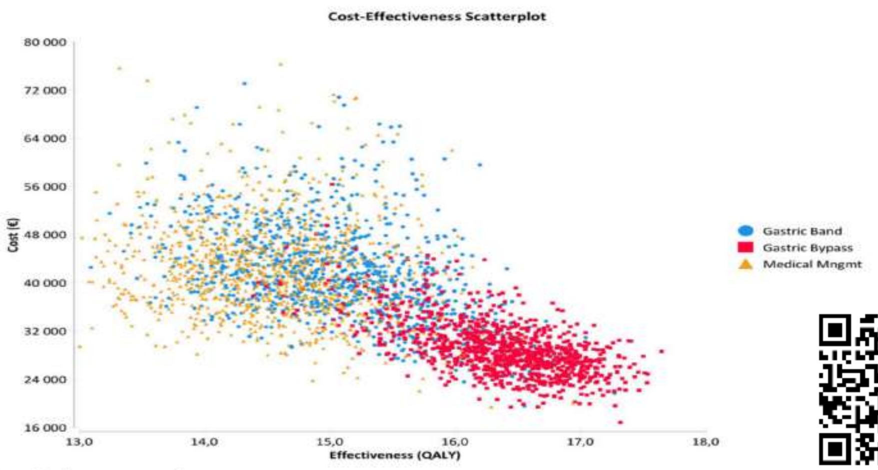
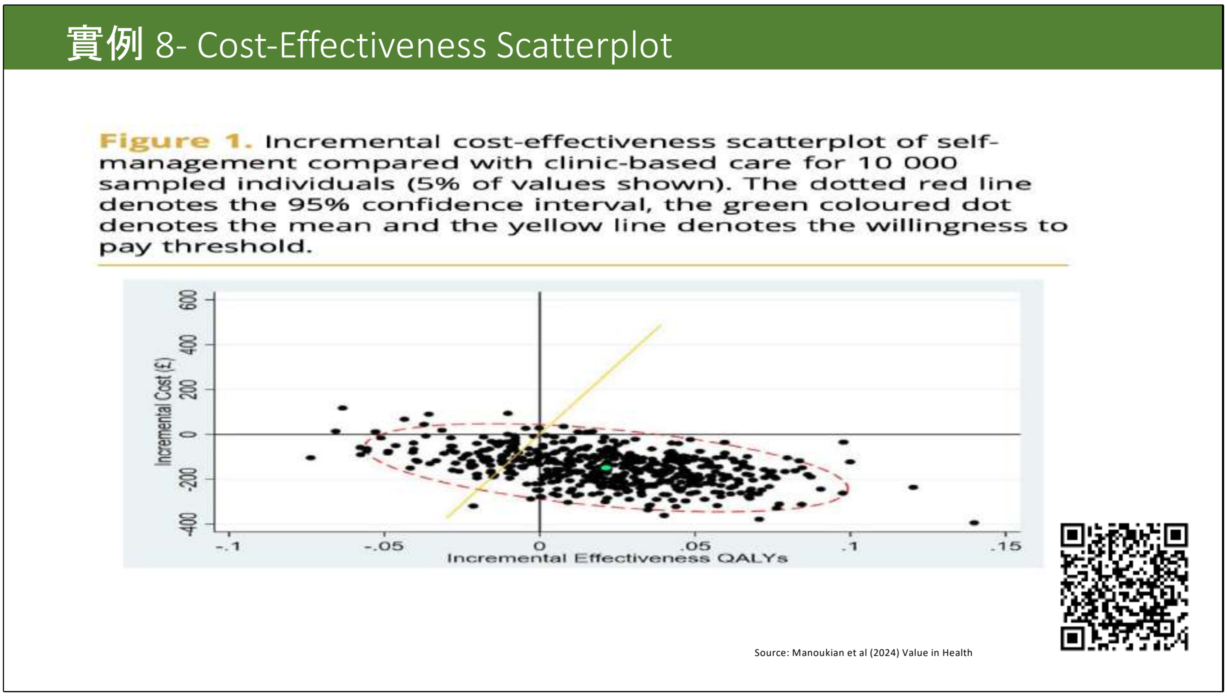


Fig. 2 Cost-effectiveness scatter plot

Source: Faria et al (2013) Obesity Surgery

請同學閱讀文章 (Figure 2):
https://link.springer.com/article/10.1007/s11695-012-0816-8
(可掃描上圖QR code)

上圖很容易理解，即很簡單明瞭地把治療方案的成本和效益標示出來
這裡每個方案的點都很多，這是這裡呈現每個simulation之後的結果
此圖很清楚的呈現Gastric Bypass效用較高 成本較低



上一頁的scatterplot是用各個治療方案的成本和效益做outcome

請同學閱讀文章 (Figure 1):
https://www.valueinhealthjournal.com/article/S1098-3015(24)00118-9/fulltext (可掃描上圖QR code)

這一頁的scatterplot是用直接用ICER 做outcome (e.g.比較兩個方案)
以上圖表顯示兩個方案之比較：比較組 (self-management programme) 成本較低，效果兩個方案沒有顯著差異
大部分的ICER點都在右下象限，所以相比起來符合成本效益機會比較大

實例 9- Monte Carlo Simulation of Incremental Cost-Effectiveness

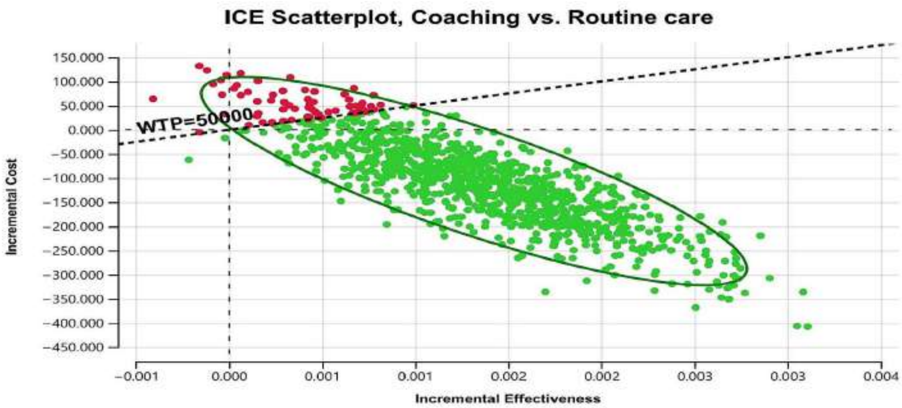


Fig. 4 Monte Carlo simulations scatter plot of incremental cost-effectiveness of coaching compared with routine care with a willingness to pay (WTP) of AUD50, 000

Source: de Jersey et al (2024) Cost Effectiveness and Resource Allocation

請同學閱讀文章 (Figure 4): https://resource-allocation.biomedcentral.com/articles/10.1186/s12962-024-00520-9 (可掃描上圖QR code)

這裡比較營養師 coaching vs routine care 對產婦預防妊娠糖尿病
畫橢圓型的部分表示：95%模擬出來的結果對應圖上在哪裡
這個 scatter plot 顯示出 coaching 比較有效、也比較便宜，在大約93%的模擬結果中
以上模擬結果是依照Willingness-to-pay(WTP) 閾值澳幣50,000 (請同學看WTP斜率)
這個圖是可以在TreeAge中是可以在敏感性分析後，直接叫用軟體繪圖，同學不用擔心
如果是用Excel那就要先算出個別點，在用excel中寫一下指令

實例 10- Cost-Effectiveness Acceptance Curve(s)

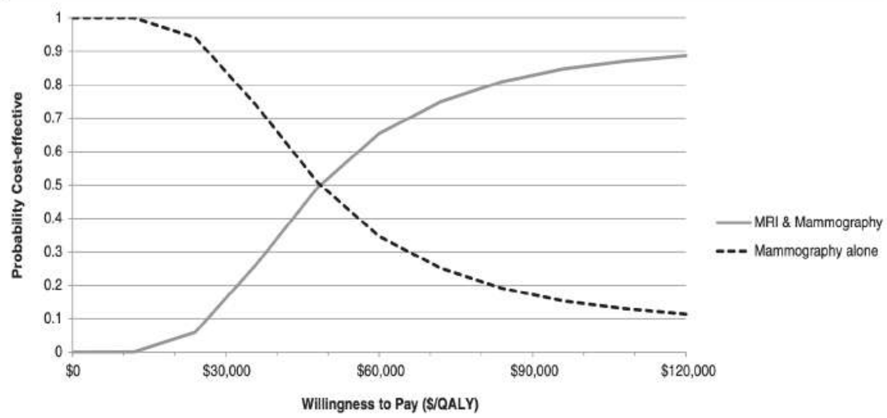


Figure 3 Cost effectiveness acceptability curve. Abbreviations: MRI, magnetic resonance imaging; QALY, quality-adjusted life-year.

Source: Pataky et al (2013) BMC Cancer

請同學閱讀文章 (Figure 3): https://link.springer.com/article/10.1186/1471-2407-13-339 (可掃描上圖QR code)

Cost-effectiveness acceptance curve (CEAC)大概是現在最常見的圖了 所以這裡我們用兩個例子
第一個例子是在說如果兩個方案符合成本效益的可能性
第二個例子（在下一頁）是在說新方案符合成本效益的可能性
其實這兩個是幾乎一樣的 只是第一個例子把對照組也畫出來了

這裡的 X 座標是Willingness-to-pay
直觀上來說就是如果願意多付一點錢換到一QALY，比較有效的治療方案就會較可能被選擇

實例 11- Cost-Effectiveness Acceptance Curve(s)

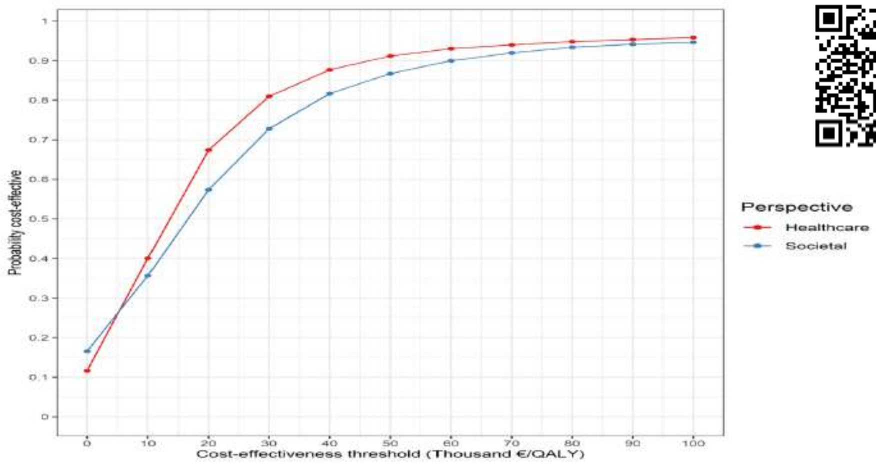


Figure 3. Cost-effectiveness acceptability curve. At a cost-effectiveness threshold of €50,000/QALY, EVT was cost-effective in 87% of replications from a societal perspective, and in 91% of replications from a healthcare perspective.

Source : Pinckaers et al (2024) European Stroke Journal

請同學閱讀文章 (Figure 3):
https://pmc.ncbi.nlm.nih.gov/articles/PMC11318439/pdf/10.1177_23969873231220464.pdf (可掃描上圖QR code)

上圖顯示出對照組 endovascular treatment (EVT) 符合成本效益的機會
這個研究使用了兩個觀點（健康照護觀點與社會觀點）
所以有兩條曲線是這個原因
上面的圖中顯示 如果以健康照護觀點 （其實在這個例子，社會觀點結果也差不多）套用歐洲閾值 €50,000 threshold, EVT 大概9成以上的模擬結果會是符合成本效益的

實例 12- Cost-Effectiveness Acceptance Curve(s)

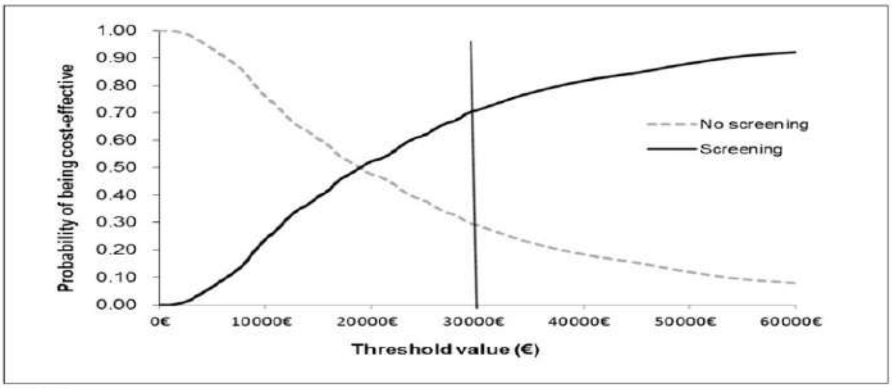


FIGURE 2
Cost-effectiveness acceptability curves. Note: Threshold value of €30 000 = US$40 000.

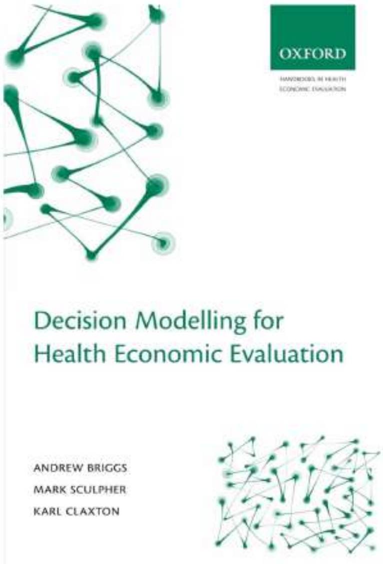
Source : Vallejo-Torres et al (2015) Pediatrics

請同學閱讀文章 (Figure 2):
https://publications.aap.org/pediatrics/article/136/2/e424/33779/Cost-Effectiveness-Analysis-of-a-National-Newborn (可掃描上圖QR code)

這是一樣的，除了加上一條willingness-to-pay的直線並標記閾值，就能知道新治療方案符合成本效益的機會

❑ 單元三：
Decision Tree Modelling in Excel

Decision Tree Modelling in Excel (1)



接下來這個單元，將使用excel來做決策模型，市面上教科書也有相關內容；其中比較好的是以上這兩本 (Authors: Andrew Briggs 和 Peter Muenning)
同學們有興趣可以自學，大概一本三至四天左右可以讀完。

我們講義安排Excel和TreeAge兩者都會進行 Decision Tree 和 Markov modelling 說明與練習，
需要做圖的部分只在TreeAge教授，TreeAge也會教到microsimulation，但會比較難在excel做執行。

Decision Tree Modelling in Excel (2)

ORIGINAL RESEARCH ARTICLE

Pharmacoeconomics 1997 Nov; 12 (5): 565-577
1170-7690/97/0011-0565/$06.50/0

© Adis International Limited. All rights reserved.

Economic Evaluation of Oral Sumatriptan Compared with Oral Caffeine/Ergotamine for Migraine

Kenneth W. Evans,[1] *John A. Boan,*[2] *John L. Evans*[3] and *Ashfaq Shuaib*[4]

1 Saskatchewan Health, Regina, Saskatchewan, Canada
2 Department of Economics, University of Regina, Regina, Saskatchewan, Canada
3 Department of Health, Government of Canada, Vancouver, British Columbia, Canada
4 Department of Neurology, University of Saskatchewan, Saskatoon, Saskatchewan, Canada

Summary

We conducted an economic comparison of oral sumatriptan with oral caffeine/ergotamine in the treatment of patients with migraine. Cost-effectiveness, cost-utility and cost-benefit analyses were conducted from societal and health-departmental perspectives. A decision tree was used. Utilities were assigned to health states using the Quality of Well-Being Scale. Simple and probabilistic sensitivity analyses were also carried out.

From a societal perspective, using sumatriptan instead of caffeine/ergotamine resulted in an incremental cost-effectiveness ratio of –25 Canadian dollars ($Can) per attack aborted, an incremental cost-utility ratio of –$Can7507 per quality-adjusted life-year (QALY), and a net economic benefit of $Can42 per patient per year (1995 values). From the perspective of the health department, the incremental cost-effectiveness ratio was $Can98 per attack aborted, the incremental cost-utility ratio was $Can29 366 per QALY; the grade of recommendation based on past decisions regarding health technology for adoption into health insurance plans was 'moderate'. Sensitivity analysis showed that the results were robust to relatively large changes in the input variables.

The incremental health benefits obtained from using oral sumatriptan rather than oral caffeine/ergotamine were achieved at moderately acceptable incremental costs, if past decisions on the adoption of other health technologies are used as a guide.

Source: Evans et al (1997) Pharmacoeconomics

第一個練習相對簡單，同學們可以不用自己做，但要看懂並理解。

請同學們下載並仔細讀完以上文章(Evans et al 1997)，可至GitHub下載Excel_decisiontree_reverengineeringEvans(1997)檔案

Decision Tree Modelling in Excel (3)

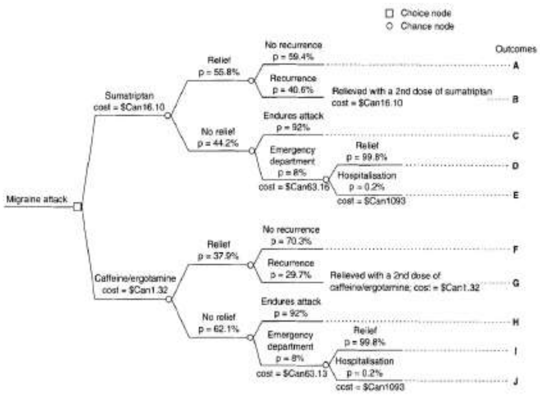


Fig. 1. Decision tree used in the model.

Table VI. Outcome values of the decision tree (outcomes are shown in figure 1) (all costs are expressed in 1995 Canadian dollars ($Can))

Outcome	Probability (%)	Cost ($Can)	Expected cost ($Can)	Utility	Expected utility
Sumatriptan					
A	33.1	16.10	5.34	1.00	0.33
B	22.7	32.20	7.28	0.90	0.20
C	40.7	16.10	6.55	−0.30	−0.12
D	3.5	79.26	2.80	0.10	0.0035
E	0.007	1172	0.06	−0.30	−0.000021
Total	**100**		$\boxed{22.06}$		$\boxed{0.42}$
Caffeine/ergotamine					
F	26.6	1.32	0.35	1.00	0.27
G	11.3	2.64	0.30	0.90	0.10
H	57.1	1.32	0.75	−0.30	−0.17
I	5.0	64.45	3.20	0.10	0.0050
J	0.010	1157	0.11	−0.30	−0.000030
Total	**100**		$\boxed{4.71}$		$\boxed{0.20}$

Results

Base-Case Evaluation

The outcome values of the decision tree are shown in table VI. Assuming an incremental effect with the use of sumatriptan of (55.8 − 37.9%) = 17.9%, the incremental cost was $Can17.34, and the incremental utility was 0.22.

Table VII shows the incremental cost-effectiveness and cost-utility ratios, and the net economic benefit, associated with using sumatriptan in place of caffeine/ergotamine.

From the societal perspective, the use of oral sumatriptan resulted in net savings as well as improved health outcomes, as evidenced by the negative cost-effectiveness and cost-utility ratios and the positive net economic benefit.

From the health-departmental perspective, the use of oral sumatriptan resulted in net costs for improved health outcomes. The cost-effectiveness ratio was $Can98 per attack aborted, and the cost-utility ratio was $Can29 366 per QALY. This cost-utility ratio translates into a 'moderate' recommendation for adoption according to Laupacis et al.[34] (table IV).

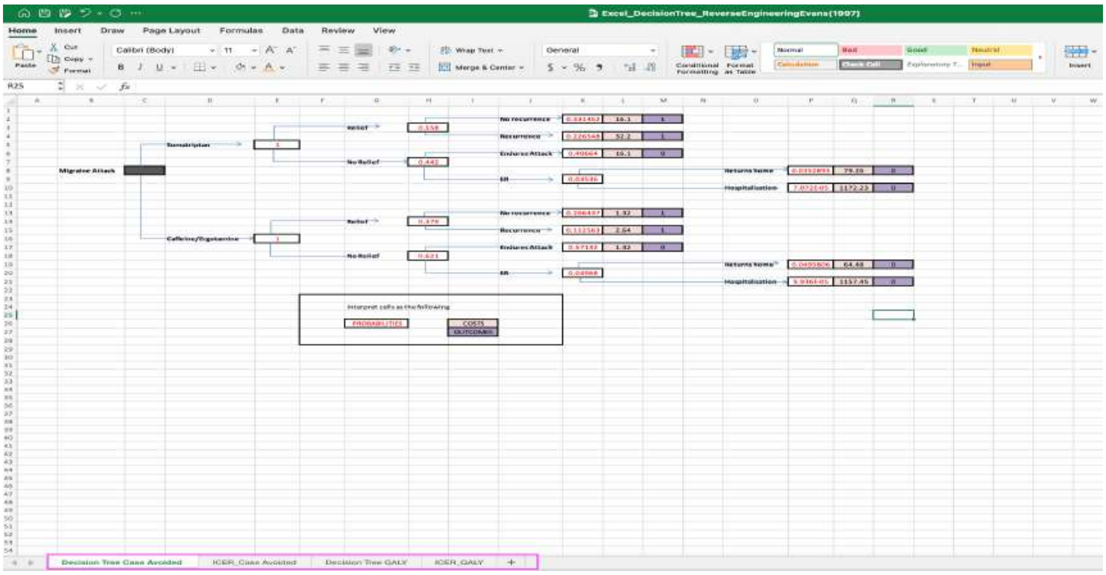
Sensitivity Analyses

The simple sensitivity analysis (table VIII) showed that from the health-departmental perspective, the results are not sensitive to changes in the various input variables. However, from the societal perspective, the results were sensitive to large changes in relative effectiveness. A threshold analysis indicated that the net economic benefit

以上是該decision tree 研究主要的參數
有兩個偏頭痛治療方式 成效很不同 請看Figure 1

這研究有CEA和CUA 比較兩種治療
在CEA 要算出 incremental cost per migrant attack aborted (是個比較臨床的outcome)
在CUA要算出 incremental cost per QALY

Decision Tree Modelling in Excel (4)



上圖Excel中做出4個tabs，前兩個是用來計算CEA (cost per migraine cases avoided)，後兩個是用來計算 CUA (cost per QALY)。
同學們可以先看一下 Tab 1和3，其實幾乎是一樣的，因為tree的結構都一樣 ，唯一的差別是 payoff不一樣；
在第一個tab是用case avoided，在第三個tab則是用utility value
Probability和成本，在兩個tabs都是一樣的。

Decision Tree Modelling in Excel (5)

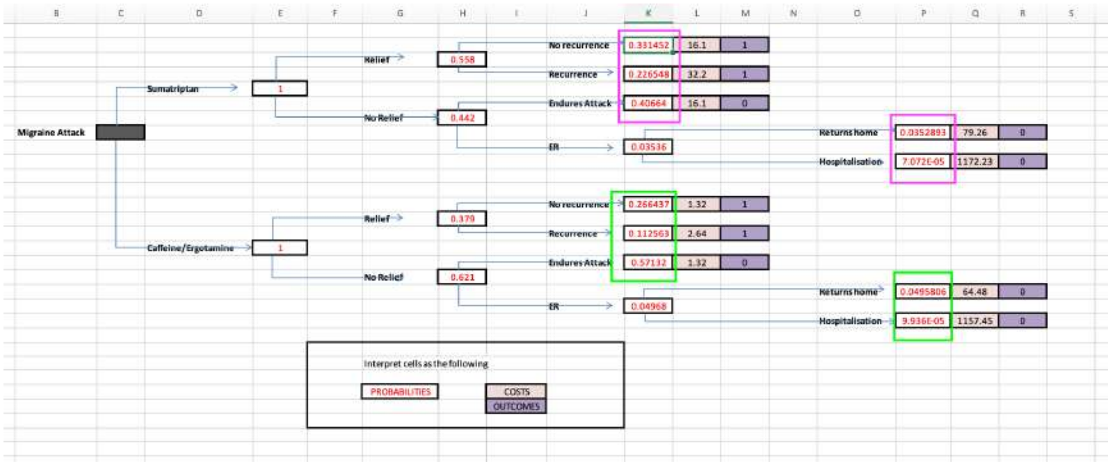
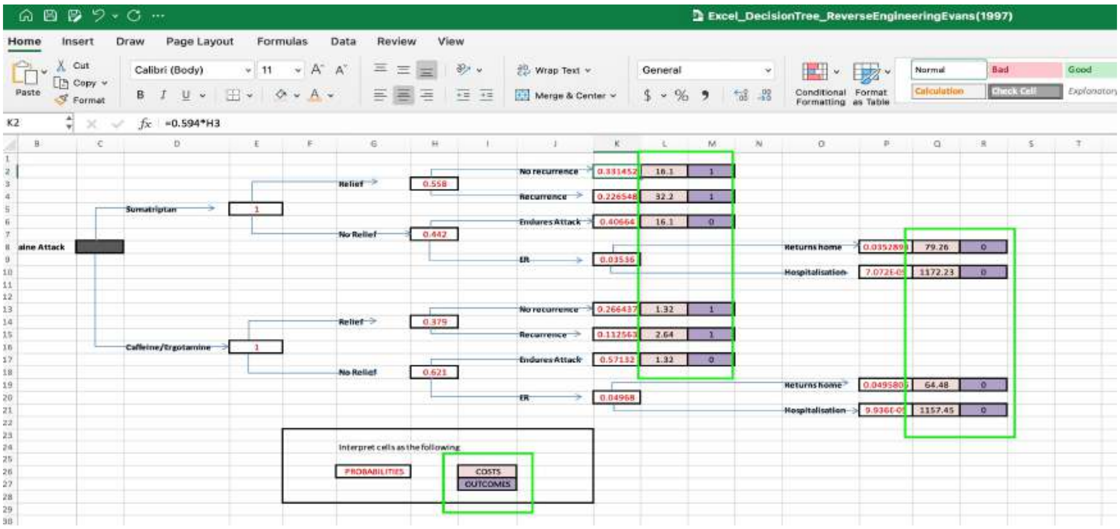


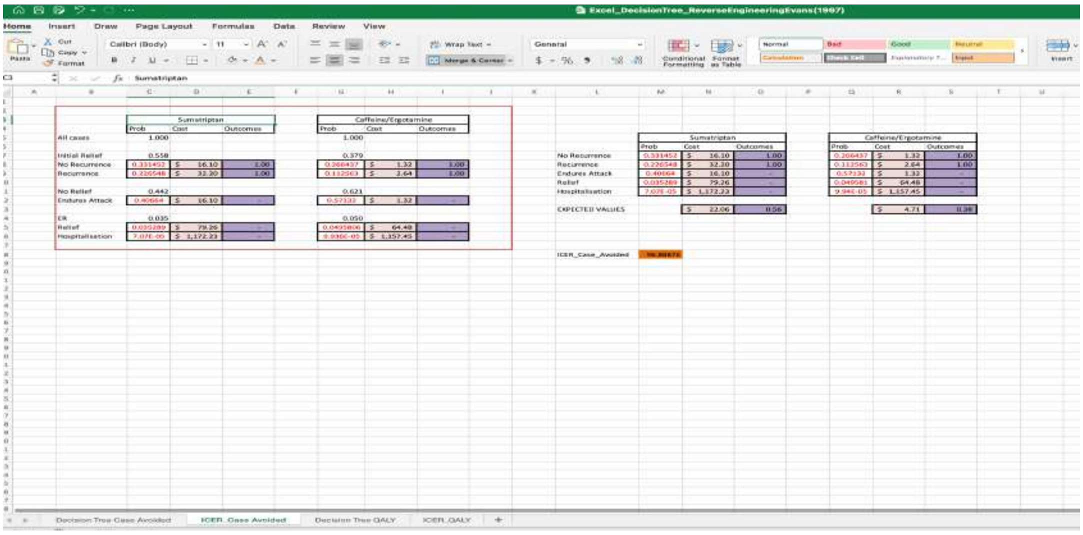
Table 3 應該滿容易理解，關於decision tree 要注意的就上方的branches probabilities 和下方的branches probabilities，相加起來要各自等於一
同學們可以看一下column K 和 P的 formula (同學們或許有些 excel 實務操作的經驗)
舉例來說 K 2= 0.556 *0.594 (也就是說 Probabilities of relief * probability of no recurrence)
0.556 和 0.594的數值在Figure 1可以看到
這裡我們標註粉紅色的部分，相加起來要等於1　綠色的部分相加起來也要等於1

Decision Tree Modelling in Excel (6)



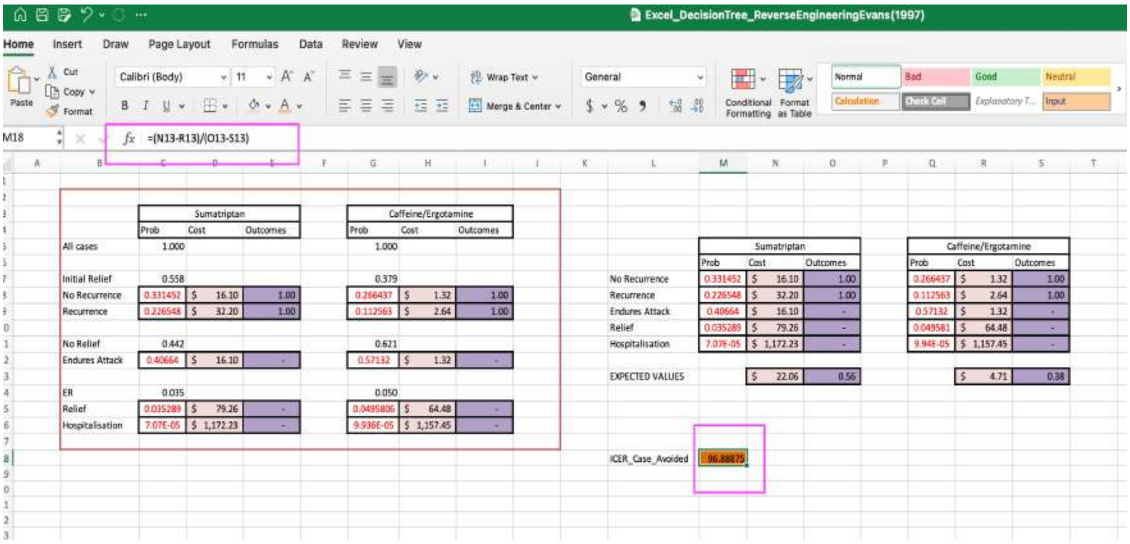
先輸入每個路徑可能的成本和結果 - 對照Figure 1
成本在後面的branch要加上之前的所有成本，舉例來說Q10 = 16.1+63.13+1093 就是藥的價錢 + 急診室 + 住院費，這才是整個branch之總成本

Decision Tree Modelling in Excel (7)



第二個Tab 要計算ICER，這裡以方框標示出來的部分，其實就是上一頁的數值，只是把他讀出來而已

Decision Tree Modelling in Excel (8)



這裡就可以開始計算ICER，比較兩個方案的cost的差別(e.g. N13- R13) 除上outcome的差別 (e.g. O13-S13)

把所有的branch相加後，就可以算出在兩個方案都算出expected costs and outcomes (N13, O13, R13, S13)

答案ICER=96.888 和 paper 裡面的 98有點差別，但沒關係那是因為有小數
如果到目前大家都還跟得上，第一個ICER就算結束囉☺

Decision Tree Modelling in Excel (9)

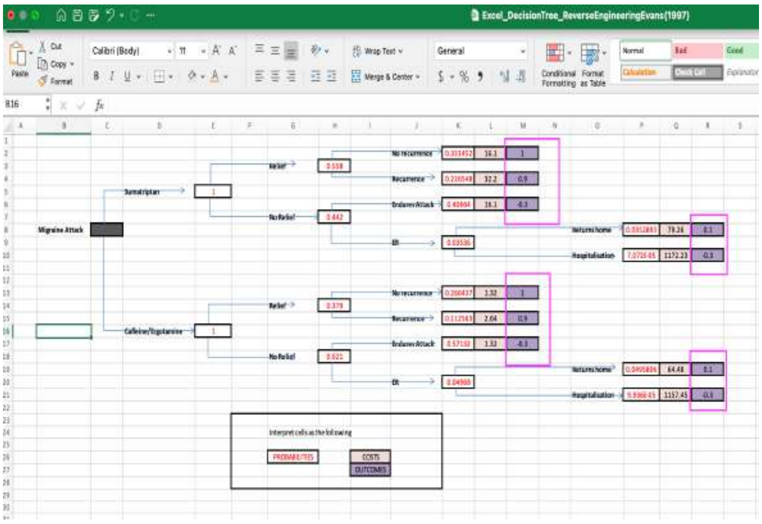
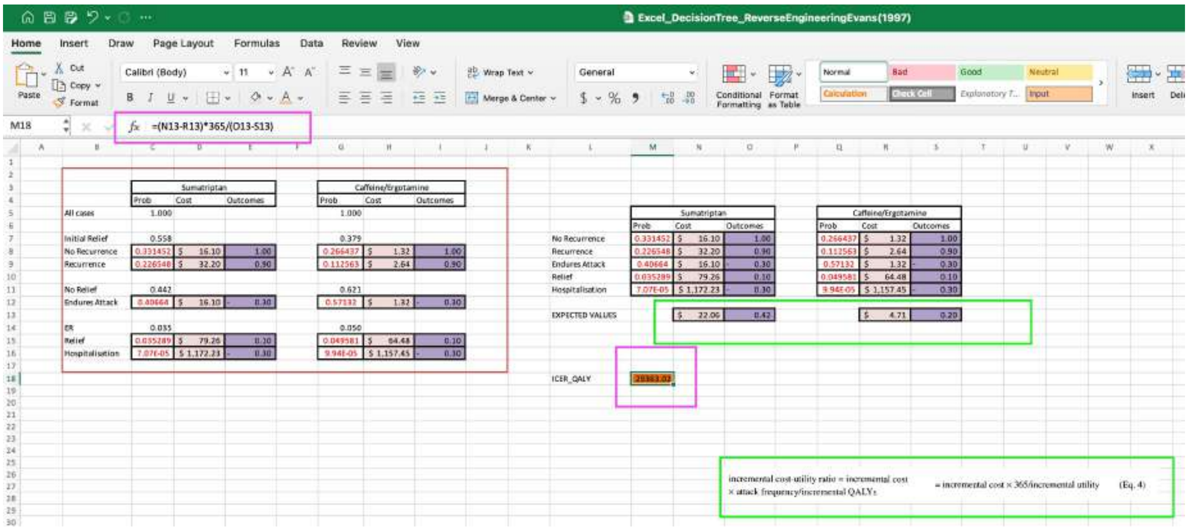


Table II. Table of utilities (outcomes are shown in figure 1)

Outcome	Mean utility	Standard deviation
A	1.0	0.00
B	0.9	0.01
C	−0.3	0.10
D	0.1	0.10
E	−0.3	0.10
F	1.0	0.00
G	0.9	0.01
H	−0.3	0.10
I	0.1	0.10
J	−0.3	0.10

接下來我們來計算CUA= Cost per QALY，所以做一個新的tree，其實和前一個幾乎一樣，只是outcome變成utility（上面slide紫色框列的地方）。
關於這些utility怎麼來的，可以查看該篇paper的Table 2，這裡我們所看到utility呈現負值，可推論 migraine 主觀感覺非常痛苦。

Decision Tree Modelling in Excel (10)



那我們建立一個新的tab，再來計算ICER只是這次用的是 cost per QALY，ICER公式標示在紫色方框 ，請同學們特別注意，因為這裡的公式考慮到一年migrant發生次數 (請看equation 4) ，
所以做了個很巧妙的轉化，在分子乘上365，這裡我們答案29365和paper中的29366就很接近了。

❑ 單元四：
Building Markov Model in Excel

❑ 單元四：
Markov Model in Excel

情境：
小李想用Markov Model 了解2007年~2015年
iPhone、Samsung或他牌，各個品牌市佔率的變化。

請開啟一個空白的Excel檔案 ，並輸入以下的值建立表格：

	A	B	C	D	E
1			To		
2			Iphone	Samsung	Others
3	From	Iphone	90%	10%	0%
4		Samsung	60%	20%	20%
5		Others	40%	10%	50%

轉移機率（Transition Probability）總和應為1

品牌忠誠度

馬可夫模型可用以分析品牌市場佔有率的變化。

解釋轉移矩陣(Transition Probability)中每一列代表的意義，即從當前品牌轉移到其他品牌的機率總和應為 1。
如果品牌沒有轉換，即「品牌忠誠度」之意，例如：上圖excel表格中之橘色網底方格(iPhone-iPhone)。

Markov Model in Excel (2)

【概念說明】
建立另一個表格（I~L），如右圖
假設第一年有1000人使用Samsung，
且設定一個Cycle是一年，一直到2015年
針對不同品牌將數量乘以轉移機率。

	A	B	C	D	E
1			To		
2			Iphone	Samsung	Others
3	From	Iphone	90%	10%	0%
4		Samsung	60%	20%	20%
5		Others	40%	10%	50%

以2008年iPhone為例：
0*90%+1000*60%+0*40%=600
（1000人中有600人拿iPhone）

	I	J	K	L
1	Cycle	Iphone	Samsung	Others
2	2007	0.0	1000.0	0.0
3	2008	600.0	200.0	200.0
4	2009	740.0	120.0	140.0
5	2010	794.0	112.0	94.0
6	2011	819.4	111.2	69.4
7	2012	831.9	111.1	56.9
8	2013	838.2	111.1	50.7
9	2014	841.3	111.1	47.6
10	2015	842.9	111.1	46.0

先說明怎麼運算，後面會教你如何使用EXEL的函數。
開啟Excel建立表格，假設一開始是1000個人都使用三星手機
而每個品牌之間都有不同的轉移機率
計算這1000人每一年使用的手機廠牌的變化是怎麼樣？
先從2008年開始算。

Markov Model in Excel (3)

【概念說明】
接下來看看2009年要怎麼算？

	A	B	C	D	E
1			To		
2			Iphone	Samsung	Others
3	From	Iphone	90%	10%	0%
4		Samsung	60%	20%	20%
5		Others	40%	10%	50%

以2009年iPhone為例：
600*90%+200*60%+200*40%=740
（1000人中有740人拿iPhone）

	I	J	K	L
1	Cycle	Iphone	Samsung	Others
2	2007	0.0	1000.0	0.0
3	2008	600.0	200.0	200.0
4	2009	740.0	120.0	140.0
5	2010	794.0	112.0	94.0
6	2011	819.4	111.2	69.4
7	2012	831.9	111.1	56.9
8	2013	838.2	111.1	50.7
9	2014	841.3	111.1	47.6
10	2015	842.9	111.1	46.0

再來看看2009年怎麼算，就是用2008年算出來的各品牌人數，分別乘上轉移機率，就會得到2009年的人數。

Markov Model in Excel (4)

不過一個一個算太複雜了！
可以使用Excel內建的Function，
公式長這樣：
=MMULT(J2:L2,$C$3:$E$5)

加入金錢符號鎖定欄位

	A	B	C	D	E
1			To		
2			Iphone	Samsung	Others
3	From	Iphone	90%	10%	0%
4		Samsung	60%	20%	20%
5		Others	40%	10%	50%

	I	J	K	L
1	Cycle	Iphone	Samsung	Others
2	2007	0.0	1000.0	0.0
3	2008			
4	2009			
5	2010			
6	2011			
7	2012			
8	2013			
9	2014			
10	2015			

在J3年這格輸入
=MMULT(J2:L2,$C$3:$E$5)
按enter

鎖定欄位快捷鍵：Mac 是Fn+F4 / Windows是 F4

可以使用Excel的函數公式計算會更有效率 =MMULT()

Markov Model in Excel (5)

不過一個一個算太複雜了！
可以使用Excel內建的Function，
公式長這樣：

=MMULT(J2:L2,$C$3:$E$5)

加入金錢符號鎖定欄位

	A	B	C	D	E
1			To		
2			Iphone	Samsung	Others
3	From	Iphone	90%	10%	0%
4		Samsung	60%	20%	20%
5		Others	40%	10%	50%

	I	J	K	L
1	Cycle	Iphone	Samsung	Others
2	2007	0.0	1000.0	0.0
3	2008	600.0	200.0	200.0
4	2009			
5	2010			
6	2011			
7	2012			
8	2013			
9	2014			
10	2015			

輸入好公式之後
並框下J3~L3，
游標移到右下角出現＋
長按複製下拉到2015年

鎖定欄位快捷鍵：Mac 是Fn+F4 / Windows是 F4

可以使用Excel的函數公式計算會更有效率 =MMULT()

Markov Model in Excel (6)

不過一個一個算太複雜了！
可以使用Excel內建的Function，
公式長這樣：

=MMULT(J2:L2,$C$3:$E$5)

加入金錢符號鎖定欄位

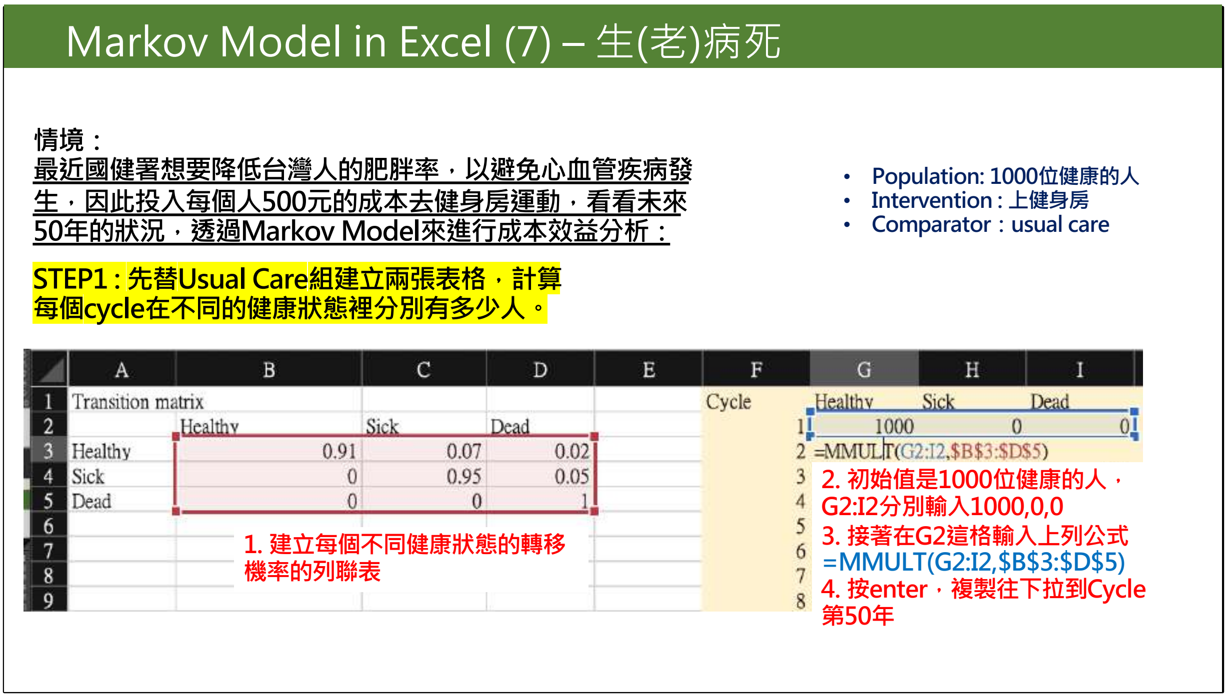
	A	B	C	D	E
1			To		
2			Iphone	Samsung	Others
3	From	Iphone	90%	10%	0%
4		Samsung	60%	20%	20%
5		Others	40%	10%	50%

結果就出來拉！

	I	J	K	L
1	Cycle	Iphone	Samsung	Others
2	2007	0.0	1000.0	0.0
3	2008	600.0	200.0	200.0
4	2009	740.0	120.0	140.0
5	2010	794.0	112.0	94.0
6	2011	819.4	111.2	69.4
7	2012	831.9	111.1	56.9
8	2013	838.2	111.1	50.7
9	2014	841.3	111.1	47.6
10	2015	842.9	111.1	46.0

鎖定欄位快捷鍵：Mac 是Fn+F4 / Windows是 F4

可以使用Excel的函數公式計算會更有效率 =MMULT()



請另外在Excel上建立新Sheet，可取名為「生老病死」

<u>衛生福利部國民健康署（下稱國健署）想要降低國人的肥胖率，以避免心血管疾病發生，因此投入每個人500元的成本去健身房運動</u>
透過Markov Model來進行成本效益分析
假設有1000位原本是身體健康的人，在常規的照護之下，各自有不同的機率從健康到死亡。
要注意的是，生病的人變回完全健康的機率是0
而死亡的人也不可能起死回生。
另外也要注意 每一橫列的機率加起來要等於1
同樣使用MMULT()的函數公式進行計算

Markov Model in Excel (8) – 生(老)病死

情境：
<u>最近國健署想要降低台灣人的肥胖率，以避免心血管疾病發生，因此投入每個人500元的成本去健身房運動，看看未來50年的狀況，透過Markov Model來進行成本效益分析：</u>

- Population: 1000位健康的人
- Intervention : 上健身房
- Comparator : usual care

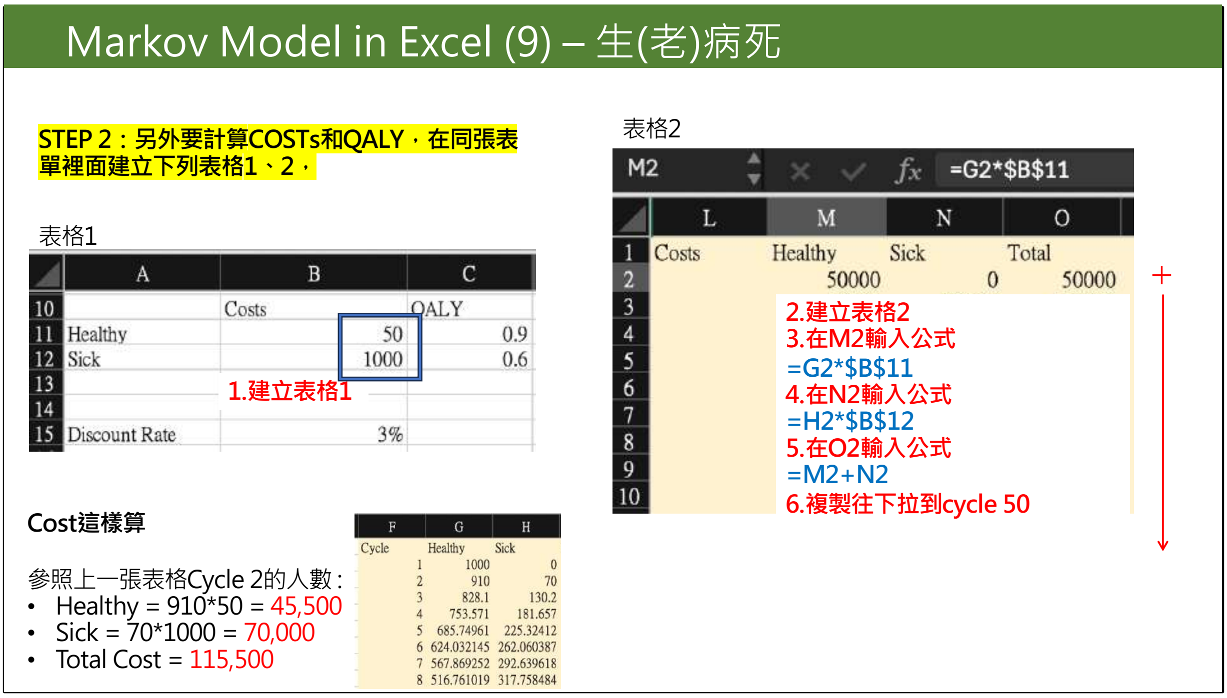
STEP1 : 先替Usual Care組建立兩張表格，計算每個cycle在不同的健康狀態裡分別有多少人。

數值結果如下，供參照

	A	B	C	D	E	F	G	H	I
1	Transition matrix					Cycle	Healthy	Sick	Dead
2		Healthy	Sick	Dead		1	1000	0	0
3	Healthy	0.91	0.07	0.02		2	910	70	20
4	Sick	0	0.95	0.05		3	828.1	130.2	41.7
5	Dead	0	0	1		4	753.571	181.657	64.772
6						5	685.74961	225.32412	88.92627
7						6	624.032145	262.060387	113.907468
8						7	567.869252	292.639618	139.49113
9						8	516.761019	317.758484	165.480496

請另外在Excel上建立新Sheet，可取名為「生老病死」

<u>衛生福利部國民健康署（下稱國健署）想要降低國人的肥胖率，以避免心血管疾病發生，因此投入每個人500元的成本去健身房運動</u>
透過Markov Model來進行成本效益分析
假設有1000位原本是身體健康的人，在常規的照護之下，各自有不同的機率從健康到死亡。
要注意的是，生病的人變回完全健康的機率是0
而死亡的人也不可能起死回生。
另外也要注意 每一橫列的機率加起來要等於1
同樣使用MMULT()的函數公式進行計算



要做成本效益分析，要先計算COSTs和QALY。
以第二年為例，就是以第二年人數，分別乘上健康和生病的所花費的單價，再加起來，就是該年的總成本。
死亡是沒有所謂的成本跟QALY的！

Markov Model in Excel (10) – 生(老)病死

STEP 2：另外要計算COSTs和QALY，在同張表單裡面建立下列表格1、2。

表格1

	A	B	C
10		Costs	QALY
11	Healthy	50	0.9
12	Sick	1000	0.6
13			
14			
15	Discount Rate	3%	

Cost這樣算

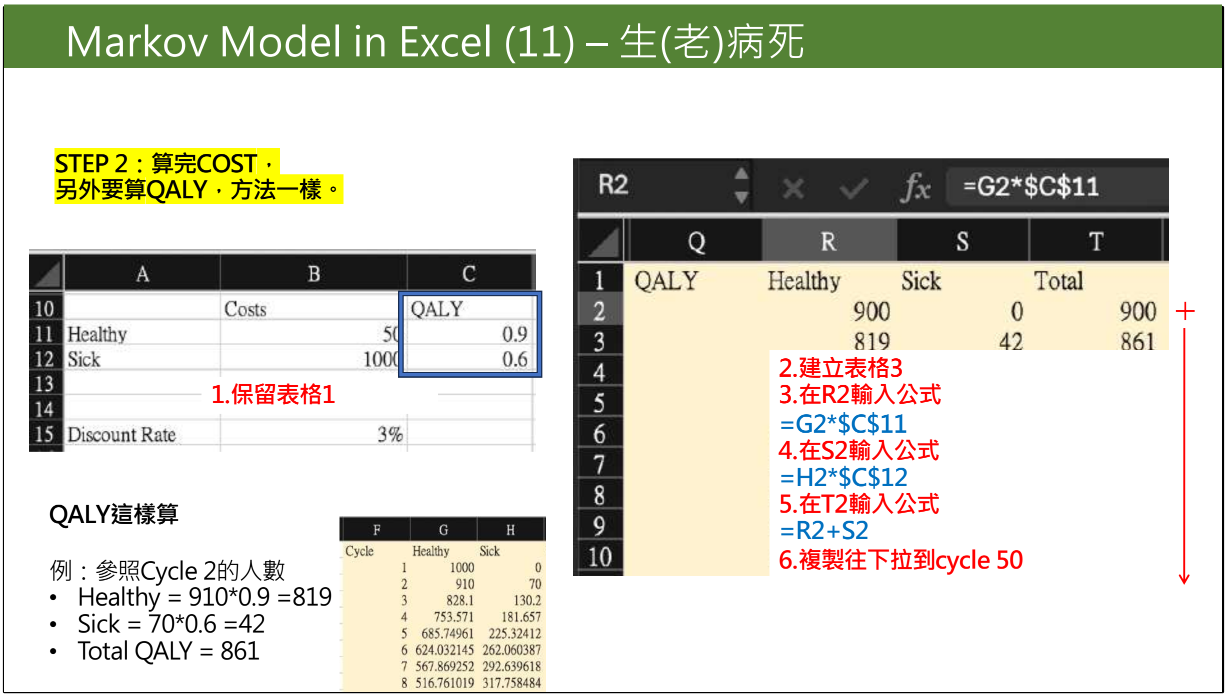
F	G	H
Cycle	Healthy	Sick
1	1000	0
2	910	70
3	828.1	130.2
4	753.571	181.657
5	685.74961	225.32412
6	624.032145	262.060387
7	567.869252	292.639618
8	516.761019	317.758484

參照上一張表格Cycle 2的人數：
- Healthy = 910*50 = 45,500
- Sick = 70*1000 = 70,000
- Total Cost = 115,500

表格2 **結果如下，數字供參照**

	L	M	N	O
1	Costs	Healthy	Sick	Total
2		50000	0	50000
3		45500	70000	115500
4		41405	130200	171605
5		37678.55	181657	219335.55
6		34287.4805	225324.12	259611.601
7		31201.6073	262060.387	293261.994
8		28393.4626	292639.618	321033.08
9		25838.051	317758.484	343596.535
10		23512.6264	338043.831	361556.458
11		21396.49	354059.317	375455.807
12		19470.8059	366311.437	385782.243
13		17718.4334	375254.993	392973.427
14		16123.7744	381298.05	397421.825
15		14672.6347	384806.432	399479.067
16		13352.0976	386107.799	399459.897
17		12150.4088	385495.346	397645.754
18		11056.872	383231.151	394288.023
19		10061.7535	379549.214	389610.967
20		9156.19569	374658.208	383814.404

要做成本效益分析，要先計算COSTs和QALY。
以第二年為例，就是以第二年人數，分別乘上健康和生病的所花費的單價，再加起來，就是該年的總成本。
死亡是沒有所謂的成本跟QALY的！



QALY亦同，以第二年為例，就是以第二年人數，分別乘上健康和生病的QALY，再加起來，就是該年的總QALY。
死亡是沒有所謂的成本跟QALY的。

Markov Model in Excel (12) – 生(老)病死

STEP 2：算完COST，
另外要算QALY，方法一樣。

	A	B	C
10		Costs	QALY
11	Healthy	50	0.9
12	Sick	1000	0.6
13			
14			
15	Discount Rate	3%	

1.保留表格1

QALY這樣算

例：參照Cycle 2的人數
- Healthy = 910*0.9 =819
- Sick = 70*0.6 =42
- Total QALY = 861

F	G	H
Cycle	Healthy	Sick
1	1000	0
2	910	70
3	828.1	130.2
4	753.571	181.657
5	685.74961	225.32412
6	624.032145	262.060387
7	567.869252	292.639618
8	516.761019	317.758484

結果如下，數字供參照

R2 =G2*$C$11

	Q	R	S	T
1	QALY	Healthy	Sick	Total
2		900	0	900
3		819	42	861
4		745.29	78.12	823.41
5		678.2139	108.9942	787.2081
6		617.174649	135.194472	752.369121
7		561.628931	157.236232	718.865163
8		511.082327	175.583771	686.666097
9		465.084917	190.655091	655.740008
10		423.227275	202.826299	626.053574

死亡是沒有所謂的成本跟QALY

Markov Model in Excel (13) – 生(老)病死

STEP 3：計算成本和QALY折現

	A	B	C
10		Costs	QALY
11	Healthy	50	0.9
12	Sick	1000	0.6
13			
14			
15	Discount Rate	3%	

Discount factor 這樣算
Excel的Function:

=POWER(1/(1+$B$15),$F2-1)

	F	G	H	I
1	Cycle	Healthy	Sick	Dead
2	1	1000	0	0
3	2	910	70	20
4	3	828.1	130.2	41.7
5	4	753.571	181.657	64.772
6	5	685.74961	225.32412	88.92627
7	6	624.032145	262.060387	113.907468
8	7	567.869252	292.639618	139.49113
9	8	516.761019	317.758484	165.480496
10	9	470.252528	338.043831	191.703641

	V	W	X	Y	Z
1	Discount factor		Discounted Costs		Discounted QALY
2	1		50000		900
3					835.9223301
4					776.1428975
5					720.4069269
6	0.888487048				668.4702193
7	0.862608784		252970.3721		620.0994041
8	0.837484257		268860.1505		
9	0.813091511		279375.4261		
10	0.789409234		285416.0065		

1.在V2輸入
=POWER(1/(1+$B$15),$F2-1)

2.在X2輸入
Cycle 1的Total cost* V 2
(=O2*V2)

3.在Z2輸入
=Cycle 1 的Total QALY*V2
(=T2*V2)

4. V2:Z2框起來往下複製拉到cycle 第50年

接下來要考慮折現率3%，首先要先計算每一年的折現因子是多少？
可以直接使用excel的函數公式，再接著再把每一年算出的COSTs或QALY分別乘上每一年的折現因子，就可以囉~

Markov Model in Excel (14) – 生(老)病死

STEP 3：計算成本和QALY折現

	A	B	C
10		Costs	QALY
11	Healthy	50	0.9
12	Sick	1000	0.6
13			
14			
15	Discount Rate	3%	

Discount factor 這樣算

Excel的Function:

=POWER(1/(1+$B$15),$F2-1)

	F	G	H	I
1	Cycle	Healthy	Sick	Dead
2	1	1000	0	0
3	2	910	70	20
4	3	828.1	130.2	41.7
5	4	753.571	181.657	64.772
6	5	685.74961	225.32412	88.92627
7	6	624.032145	262.060387	113.907468
8	7	567.869252	292.639618	139.49113
9	8	516.761019	317.758484	165.480496
10	9	470.252528	338.043831	191.703641

結果如下請參考

	V	W	X	Y	Z
1	Discount factor		Discounted Costs		Discounted QALY
2	1		50000		900
3	0.970873786		112135.9223		835.9223301
4	0.942595909		161754.171		776.1428975
5	0.915141659		200723.0992		720.4069269
6	0.888487048		230661.5445		668.4702193
7	0.862608784		252970.3721		620.0994041
8	0.837484257		268860.1505		575.0720461
9	0.813091511		279375.4261		533.1766341
10	0.789409234		285416.0065		494.2124723

接下來要考慮折現率3%，首先要先計算每一年的折現因子是多少？
可以直接使用excel的函數公式，再接著再把每一年算出的COSTs或QALY分別乘上每一年的折現因子，就可以囉～

Markov Model in Excel (15) – 生(老)病死

STEP 4：計算Usual Care的Total、平均 COST、QALY

	V	W	X	Y	Z
1	Discount factor		Discounted Costs		Discounted QALY
2	1		50000		900
3	0.970873786		112135.9223		835.9223301
4	0.942595909		161754.171		776.1428975
5	0.915141659		200723.0992		720.4069269
6	0.888487048		230661.5445		668.4702193
7	0.862608784		252970.3721		620.0994041
8	0.837484257		268860.1505		575.0720461
9	0.813091511		279375.4261		533.1766341
10	0.789409234		285416.0065		494.2124723

Total Discounted	=SUM(X2:X51)	=SUM(Z2:Z51)
Average Discounted	=X52/G2	=Z52/G2

結果如右

Total Discounted	7573928.394	11996.60304
Average Discounted	7573.928394	11.99660304

將新方案和比較品50個cycle的總成本、總QALY算出來後除以1000人（第7的G2）（用公式去帶比較方便）。
再計算出ICER值，就可以知道是否具有成本效益。

Markov Model in Excel (16) – 生(老)病死

試試看用同樣的方法，接著計算Intervention組，Costs變成多了500元。

Transition matrix (Intervention)			
	Healthy	**Sick**	**Dead**
Healthy	0.95	0.03	0.02
Sick	0	0.95	0.05
Dead	0	0	1
	Costs	**QALY**	
Healthy	**550**	0.9	
Sick	1000	0.6	
Discount Rate	3%		

新方案的做法和原本Usual care的方法一樣，只是新方案多投入了500元的成本進去

Markov Model in Excel (17) – 生(老)病死

情境：
最近國健署想要降低台灣人的肥胖率，以避免心血管疾病發生，因此投入每個人500元的成本去健身房運動，看看未來50年的狀況，透過Markov Model來進行成本效益分析：

- Population: 1000位健康的人
- Intervention : 上健身房
- Comparator : usual care

STEP1 : 先替Intervention組建立兩張表格，計算每個cycle在不同的健康狀態裡分別有多少人。

	AE	AF	AG	AH	AI	AJ	AK	AL	AM
1	Transition matrix					Cycle	Healthy	Sick	Dead
2		Healthy	Sick	Dead		1	1000	0	0
3	Healthy	0.95	0.03	0.02		2	=MMULT(AK2:AM2,$AF$3:$AH$5)		
4	Sick	0	0.95	0.05		3			
5	Dead	0	0	1		4			
6						5			
7						6			
8						7			

1. 建立每個不同健康狀態的轉移機率的列聯表
2. 初始值是1000位健康的人，AK2:AM2分別輸入1000,0,0
3. 接著在AK3這格輸入上列公式 =MMULT(AK2:AM2,$AF$3:$AH$5)
4. 按enter，複製往下拉到Cycle第50年

衛生福利部國民健康署(下稱國健署)想要降低台灣國人的肥胖率，以避免心血管疾病發生，因此投入每個人500元的成本去健身房運動。
透過Markov Model來進行成本效益分析，假設有1000位原本是身體健康的人，在常規的照護之下，各自有不同的機率從健康到死亡。
要注意的是...生病的人變回完全健康的機率是 0，而死亡的人也不可能起死回生；另外也要注意 每一列 (From) 的機率加起來要等於 1。
同樣使用MMULT() 函數公式進行計算。

STEP1 : 先替Intervention組建立兩張表格，計算每個cycle在不同的健康狀態裡分別有多少人。

Markov Model in Excel (18) – 生(老)病死

情境：
最近國健署想要降低台灣人的肥胖率，以避免心血管疾病發生，因此投入每個人500元的成本去健身房運動，看看未來50年的狀況，透過Markov Model來進行成本效益分析：

- Population: 1000位健康的人
- Intervention：上健身房
- Comparator：usual care

STEP1：先替Intervention組建立兩張表格，計算每個cycle在不同的健康狀態裡分別有多少人。

數值結果如下，供參照

	AE	AF	AG	AH	AI	AJ	AK	AL	AM
1	Transition matrix					Cycle	Healthy	Sick	Dead
2		Healthy	Sick	Dead		1	1000	0	0
3	Healthy	0.95	0.03	0.02		2	950	30	20
4	Sick	0	0.95	0.05		3	902.5	57	40.5
5	Dead	0	0	1		4	857.375	81.225	61.4
6						5	814.50625	102.885	82.60875
7						6	773.780938	122.175938	104.043125
8						7	735.091891	139.280569	125.627541
9						8	698.337296	154.369297	147.293407

衛生福利部國民健康署(下稱國健署)想要降低台灣國人的肥胖率，以避免心血管疾病發生，因此投入每個人500元的成本去健身房運動。
透過Markov Model來進行成本效益分析，假設有1000位原本是身體健康的人，在常規的照護之下，各自有不同的機率從健康到死亡。
要注意的是...生病的人變回完全健康的機率是 0，而死亡的人也不可能起死回生；另外也要注意 每一列 (From) 的機率加起來要等於 1。
同樣使用MMULT() 函數公式進行計算。

STEP1：先替Intervention組建立兩張表格，計算每個cycle在不同的健康狀態裡分別有多少人。

Markov Model in Excel (19) – 生(老)病死

STEP 2：另外要計算COSTs和QALY，在同張表單裡面建立下列表格1、2

表格1

	AE	AF	AG
10		Costs	QALY
11	Healthy	550	0.9
12	Sick	1000	0.6
13			
14			
15	Discount Rat	3%	

1.建立表格1

Cost這樣算

參照上一張表格Cycle 2的人數：
- Healthy = 950*550 =522,500
- Sick = 30*1000 = 30,000
- Total Cost = 552,500

AJ	AK	AL
Cycle	Healthy	Sick
1	1000	0
2	950	30
3	902.5	57
4	857.375	81.225
5	814.50625	102.885
6	773.780938	122.175938
7	735.091891	139.280569
8	698.337296	154.369297

表格2

	AP	AQ	AR	AS
1	Costs	Healthy	Sick	Total
2		550000	0	550000
3				
4				
5				
6				
7				
8				
9				
10				

2.建立表格2
3.在AQ2輸入公式
=AK2*$AF$11
4.在AR2輸入公式
=AL2*$AF$12
5.在AS2輸入公式
=AQ2+AR2
6.複製往下拉到cycle 50

要做成本效益分析，要先計算COSTs和QALY
以第二年為例，就是以第二年人數，分別乘上健康和生病的所花費的單價，再加起來，就是該年的總成本
死亡是沒有所謂的成本跟QALY

STEP 2：另外要計算COSTs和QALY，在同張表單裡面建立下列表格1、2

Markov Model in Excel (20) – 生(老)病死

STEP 2：另外要計算COSTs和QALY，在同張表單裡面建立下列表格1、2

表格1

	AE	AF	AG
10		Costs	QALY
11	Healthy	550	0.9
12	Sick	1000	0.6
13			
14			
15	Discount Rat	3%	

Cost這樣算

參照上一張表格Cycle 2的人數：
- Healthy = 950*550 =522,500
- Sick = 30*1000 = 30,000
- Total Cost = 552,500

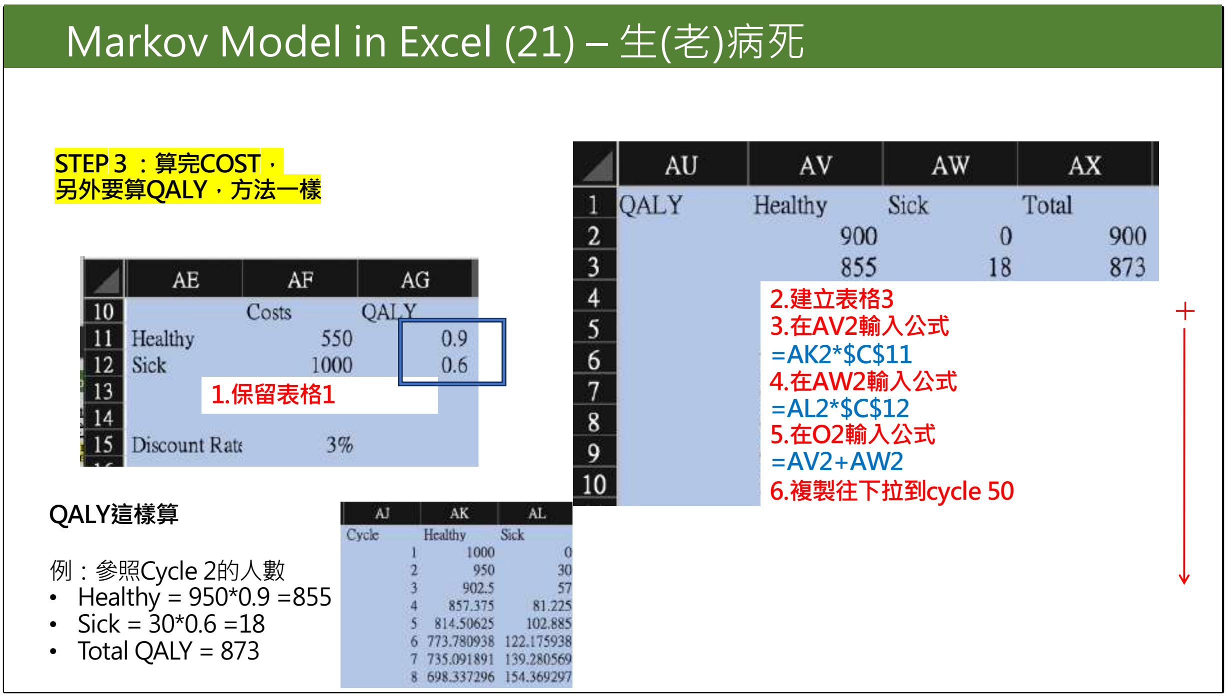
AJ	AK	AL
Cycle	Healthy	Sick
1	1000	0
2	950	30
3	902.5	57
4	857.375	81.225
5	814.50625	102.885
6	773.780938	122.175938
7	735.091891	139.280569
8	698.337296	154.369297

表格2 **結果如下，數字供參照**

	AP	AQ	AR	AS
1	Costs	Healthy	Sick	Total
2		550000	0	550000
3		522500	30000	552500
4		496375	57000	553375
5		471556.25	81225	552781.25
6		447978.438	102885	550863.438
7		425579.516	122175.938	547755.453
8		404300.54	139280.569	543581.109
9		384085.513	154369.297	538454.81
10		364881.237	167600.951	532482.188

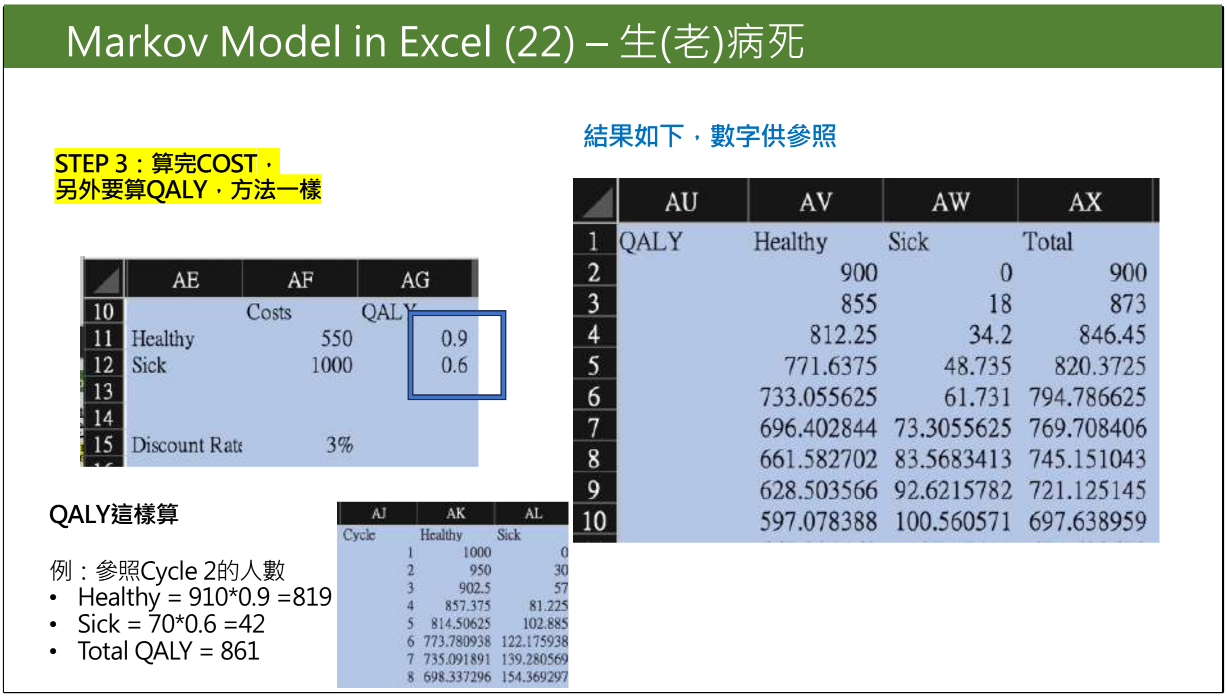
要做成本效益分析，要先計算COSTs和QALY
以第二年為例，就是以第二年人數，分別乘上健康和生病的所花費的單價，再加起來，就是該年的總成本
死亡是沒有所謂的成本跟QALY

STEP 2：另外要計算COSTs和QALY，在同張表單裡面建立下列表格1、2



QALY亦同，以第二年為例，就是以第二年人數，分別乘上健康和生病的QALY，再加起來，就是該年的總QALY
死亡是沒有所謂的成本跟QALY

STEP 3 ：算完COSTs，另外要算QALY，方法一樣。



Markov Model in Excel (22) – 生(老)病死

STEP 3：算完COST，
另外要算QALY，方法一樣

	AE	AF	AG
10		Costs	QALY
11	Healthy	550	0.9
12	Sick	1000	0.6
13			
14			
15	Discount Rate	3%	

結果如下，數字供參照

	AU	AV	AW	AX
1	QALY	Healthy	Sick	Total
2		900	0	900
3		855	18	873
4		812.25	34.2	846.45
5		771.6375	48.735	820.3725
6		733.055625	61.731	794.786625
7		696.402844	73.3055625	769.708406
8		661.582702	83.5683413	745.151043
9		628.503566	92.6215782	721.125145
10		597.078388	100.560571	697.638959

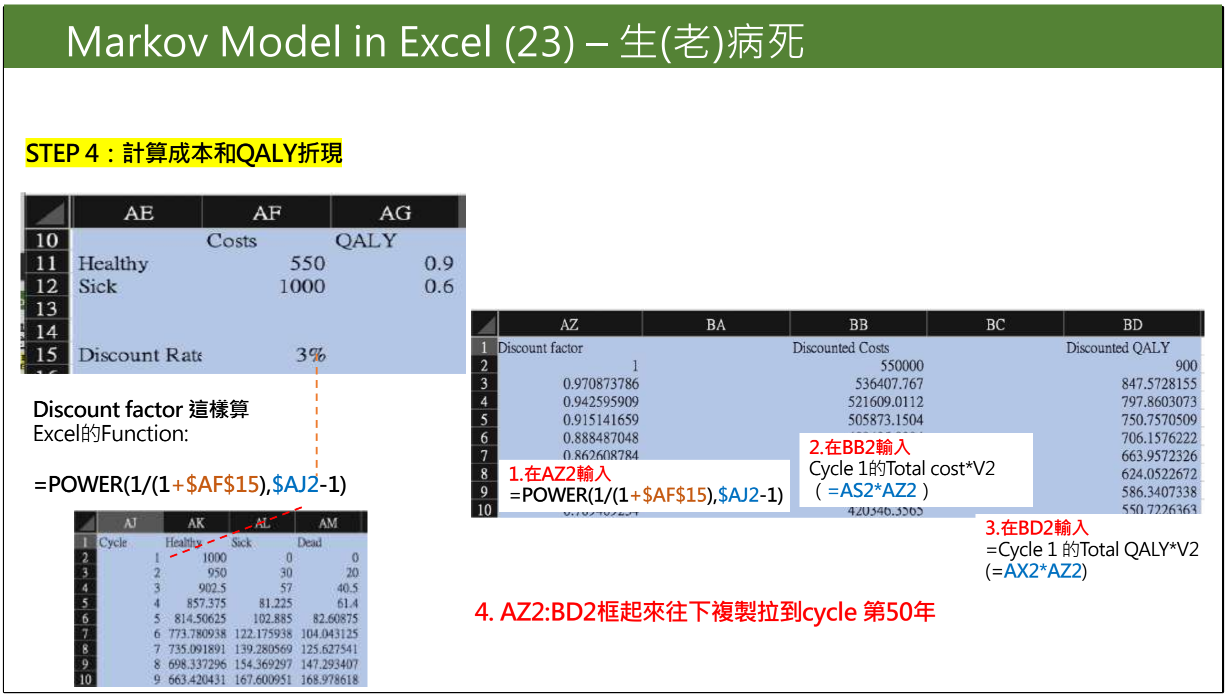
QALY這樣算

例：參照Cycle 2的人數
- Healthy = 910*0.9 =819
- Sick = 70*0.6 =42
- Total QALY = 861

AJ	AK	AL
Cycle	Healthy	Sick
1	1000	0
2	950	30
3	902.5	57
4	857.375	81.225
5	814.50625	102.885
6	773.780938	122.175938
7	735.091891	139.280569
8	698.337296	154.369297

QALY亦同，以第二年為例，就是以第二年人數，分別乘上健康和生病的QALY，再加起來，就是該年的總QALY。
死亡是沒有所謂的成本跟QALY

STEP 3 ：算完COSTs，另外要算QALY，方法一樣。



接下來要考慮折現率3%，首先要先計算每一年的折現因子是多少？可以直接使用excel的函數公式，再接著再把每一年算出的COSTs或QALY分別乘上每一年的折現因子，就可以囉～

STEP 4：計算成本和QALY折現

Markov Model in Excel (24) – 生(老)病死

STEP 4：計算成本和QALY折現

	AE	AF	AG
10		Costs	QALY
11	Healthy	550	0.9
12	Sick	1000	0.6
13			
14			
15	Discount Rat	3%	

Discount factor **這樣算**
Excel的Function:

=POWER(1/(1+$AF$15),$AJ2-1)

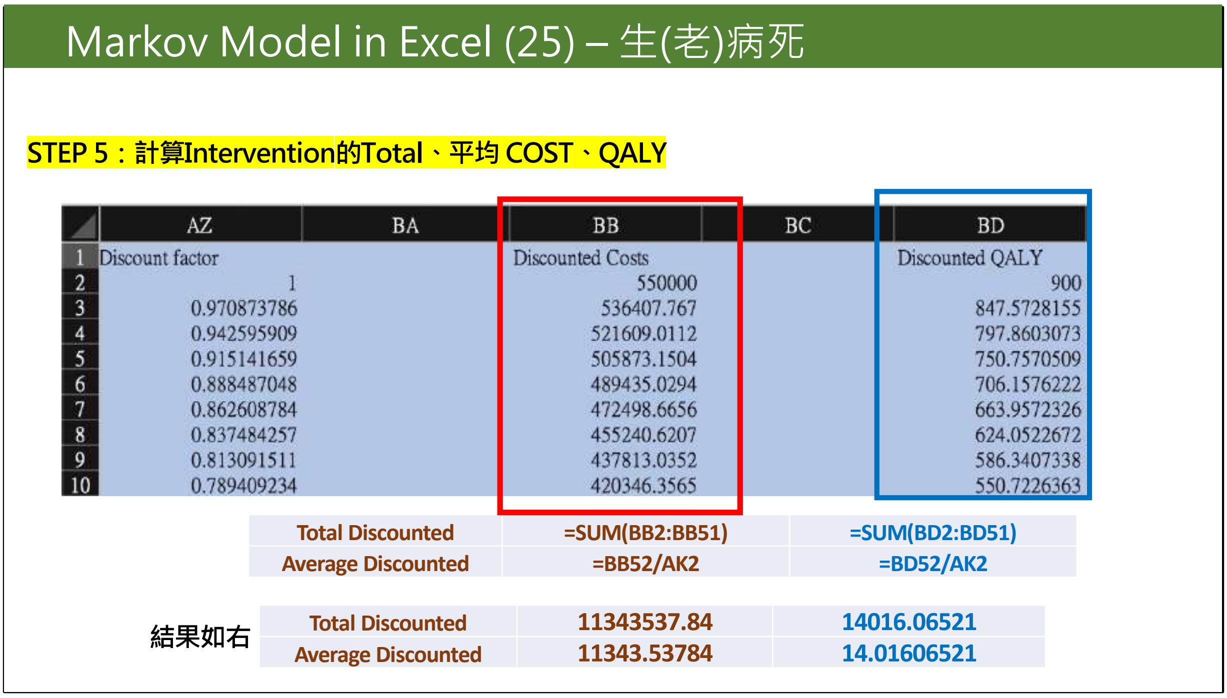
	AJ	AK	AL	AM
1	Cycle	Healthy	Sick	Dead
2	1	1000	0	0
3	2	950	30	20
4	3	902.5	57	40.5
5	4	857.375	81.225	61.4
6	5	814.50625	102.885	82.60875
7	6	773.780938	122.175938	104.043125
8	7	735.091891	139.280569	125.627541
9	8	698.337296	154.369297	147.293407
10	9	663.420431	167.600951	168.978618

結果如下請參考

	AZ	BA	BB	BC	BD
1	Discount factor		Discounted Costs		Discounted QALY
2	1		550000		900
3	0.970873786		536407.767		847.5728155
4	0.942595909		521609.0112		797.8603073
5	0.915141659		505873.1504		750.7570509
6	0.888487048		489435.0294		706.1576222
7	0.862608784		472498.6656		663.9572326
8	0.837484257		455240.6207		624.0522672
9	0.813091511		437813.0352		586.3407338
10	0.789409234		420346.3565		550.7226363

接下來要考慮折現率3%，首先要先計算每一年的折現因子是多少？可以直接使用excel的函數公式，再接著再把每一年算出的COSTs或QALY分別乘上每一年的折現因子，就可以囉～

STEP 4：計算成本和QALY折現



Markov Model in Excel (25) – 生(老)病死

STEP 5：計算Intervention的Total、平均 COST、QALY

	AZ	BA	BB	BC	BD
1	Discount factor		Discounted Costs		Discounted QALY
2	1		550000		900
3	0.970873786		536407.767		847.5728155
4	0.942595909		521609.0112		797.8603073
5	0.915141659		505873.1504		750.7570509
6	0.888487048		489435.0294		706.1576222
7	0.862608784		472498.6656		663.9572326
8	0.837484257		455240.6207		624.0522672
9	0.813091511		437813.0352		586.3407338
10	0.789409234		420346.3565		550.7226363

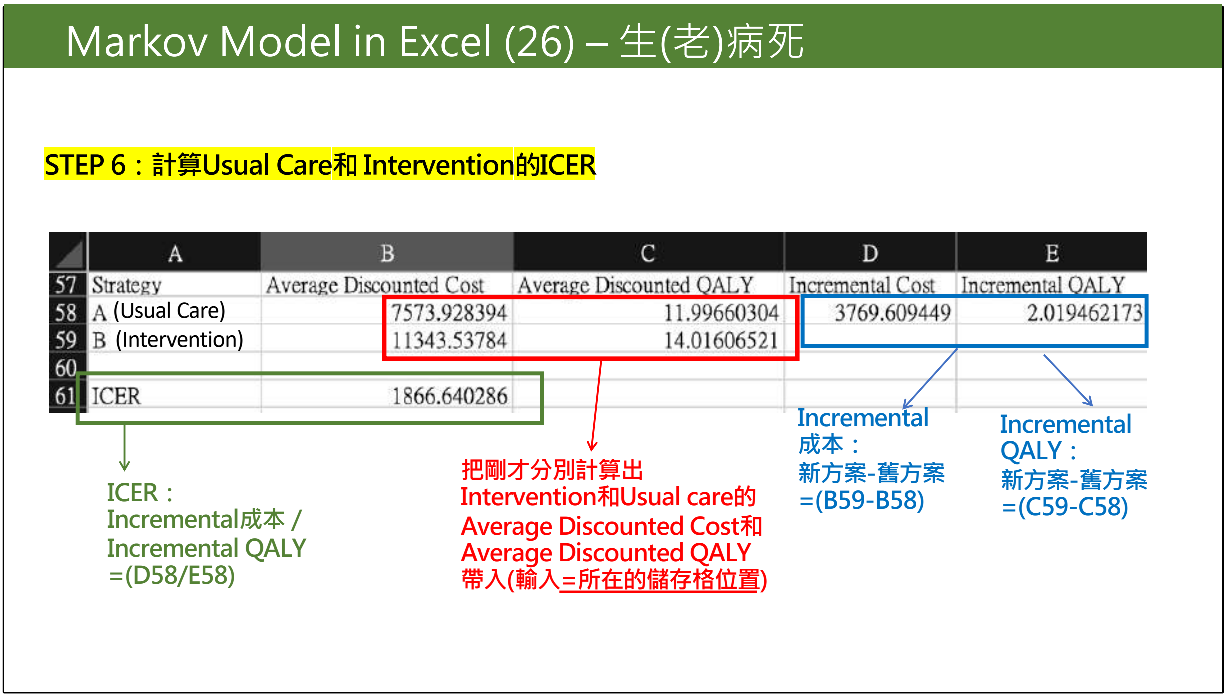
Total Discounted	=SUM(BB2:BB51)	=SUM(BD2:BD51)
Average Discounted	=BB52/AK2	=BD52/AK2

結果如右

Total Discounted	11343537.84	14016.06521
Average Discounted	11343.53784	14.01606521

將新方案和比較品50個cycle的總成本、總QALY算出來後除以1000人用公式去帶比較方便。
再計算出ICER值，就可以知道是否具有成本效益。

STEP 5：計算Intervention的Total、平均 COST、QALY



將新方案和比較品50個cycle的總成本、總QALY算出來後除以1000人（用公式去帶比較方便）。
再計算出ICER值，就可以知道是否具有成本效益。

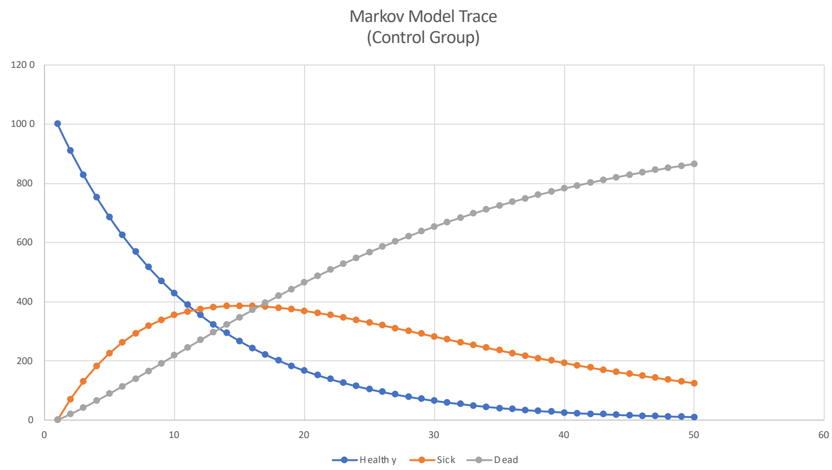
STEP 6：計算Usual Care和 Intervention的ICER

Markov Model in Excel (27) – 生(老)病死

很多研究都會附上Markov trace圖，比較新舊方案的差異。

Markov Model in Excel (28) – 生(老)病死

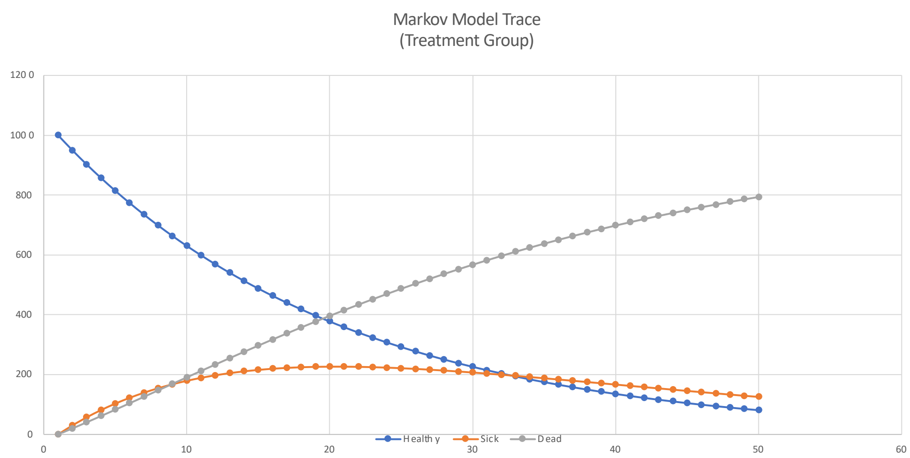
可以分別做出Comparator跟Intervention的Markov Trace圖：



三條線的人數加總一定會等於1000人

Markov Model in Excel (29) – 生(老)病死

可以分別做出Comparator跟Intervention的Markov Trace圖：



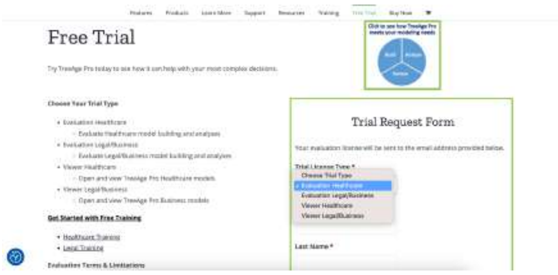
三條線的人數加總一定會等於1000人

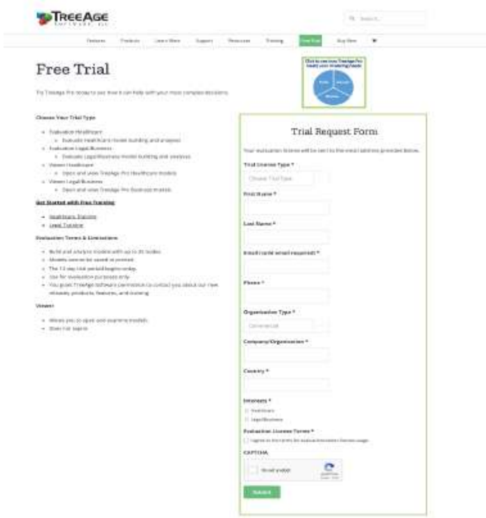
❑ 單元五:
TreeAge Workbench

TreeAge 下載

1. 至TreeAge(以下網址)填寫資料申請試用版

https://www.treeage.com/trial-download/





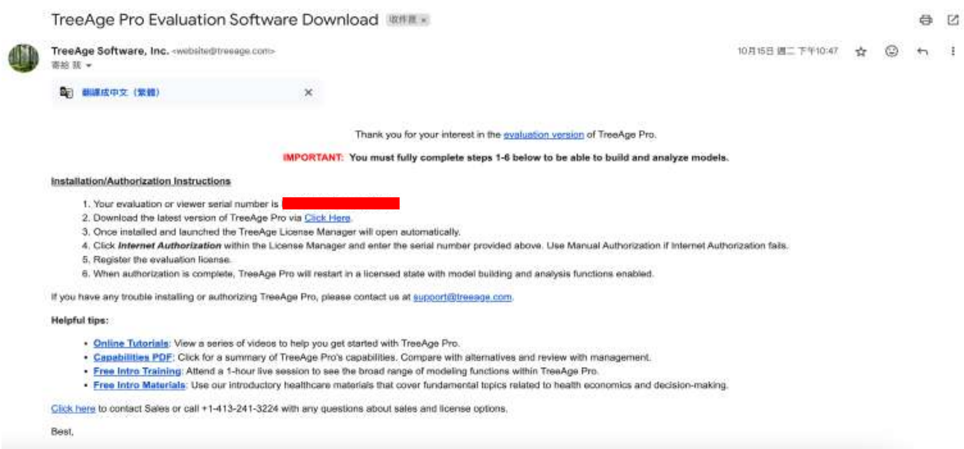
到TreeAge網站點選上方「Free Trial」進入申請免費試用

第一個下拉選單請選 Evaluation Healthcare

每個帳號只能使用一次Free Trial，可以透過註冊不同帳號延長Free Trial時限。

TreeAge 下載

2. 至信箱收信,依指示下載軟體安裝，點Click Here



TreeAge Pro Evaluation Software Download

TreeAge Software, Inc. <website@treeage.com>

10月15日 週二 下午10:47

Thank you for your interest in the evaluation version of TreeAge Pro.

IMPORTANT: You must fully complete steps 1-6 below to be able to build and analyze models.

Installation/Authorization Instructions

1. Your evaluation or viewer serial number is [redacted]
2. Download the latest version of TreeAge Pro via Click Here.
3. Once installed and launched the TreeAge License Manager will open automatically.
4. Click ***Internet Authorization*** within the License Manager and enter the serial number provided above. Use Manual Authorization if Internet Authorization fails.
5. Register the evaluation license.
6. When authorization is complete, TreeAge Pro will restart in a licensed state with model building and analysis functions enabled.

If you have any trouble installing or authorizing TreeAge Pro, please contact us at support@treeage.com.

Helpful tips:

- **Online Tutorials**: View a series of videos to help you get started with TreeAge Pro.
- **Capabilities PDF**: Click for a summary of TreeAge Pro's capabilities. Compare with alternatives and review with management.
- **Free Intro Training**: Attend a 1-hour live session to see the broad range of modeling functions within TreeAge Pro.
- **Free Intro Materials**: Use our introductory healthcare materials that cover fundamental topics related to health economics and decision-making.

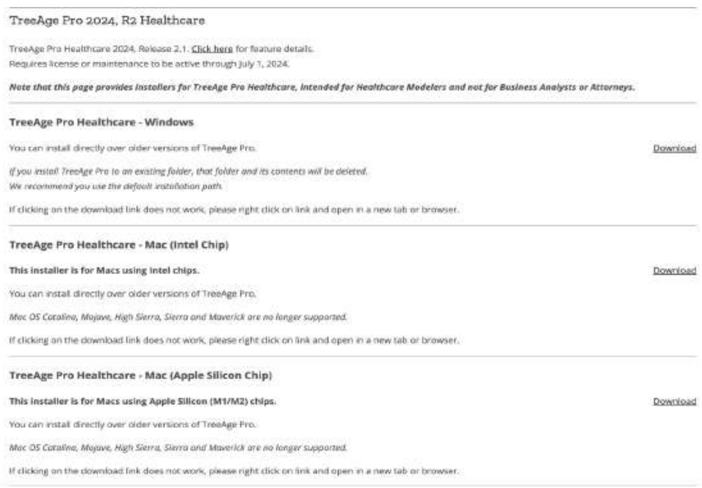
Click here to contact Sales or call +1-413-241-3224 with any questions about sales and license options.

Best,

填寫完資料後，便可到所填信箱收信，依照指示進行安裝

TreeAge 下載

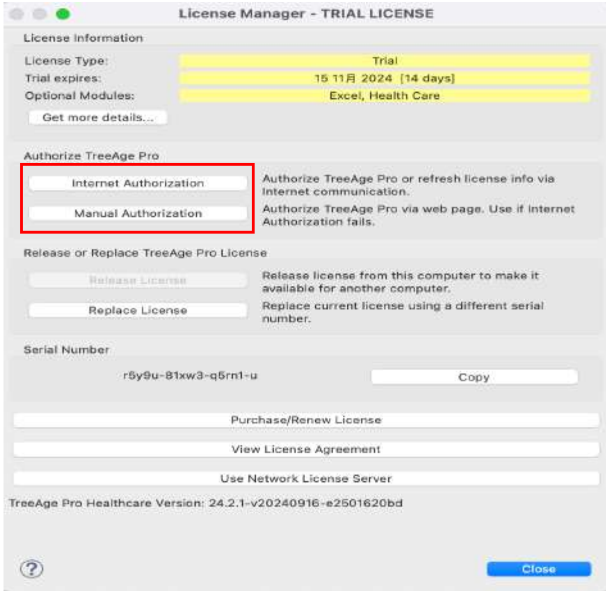
3. Download 符合您電腦的版本



依照你的電腦型號與規格下載相對應軟體版本

TreeAge 下載

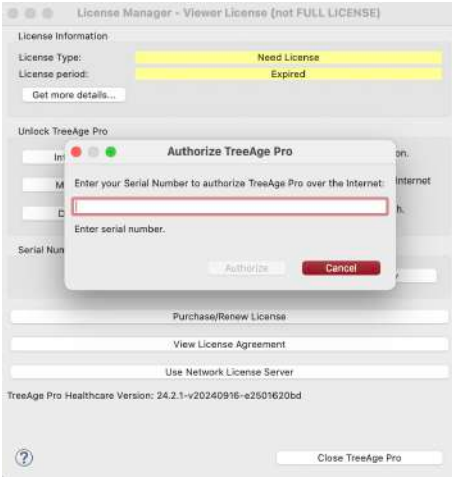
4.手動授權
Internet Authorization或
Manual Authorization都可以,
但Internet容易遭防火牆擋下,
建議點選Manual Authorization



授權：點選Internet Authorization或Manual Authorization(若遇到防火牆問題)

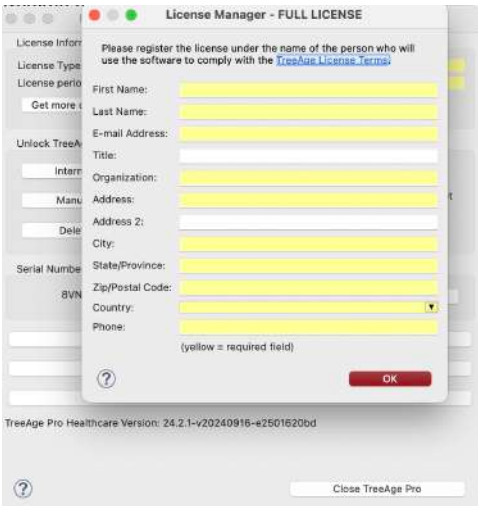
TreeAge 下載

5. 複製Serial Number並貼上

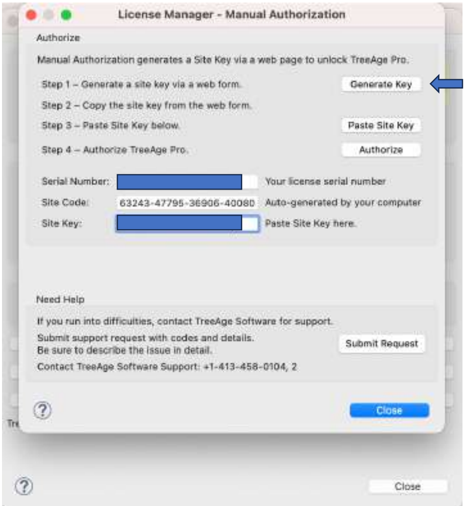


TreeAge 下載

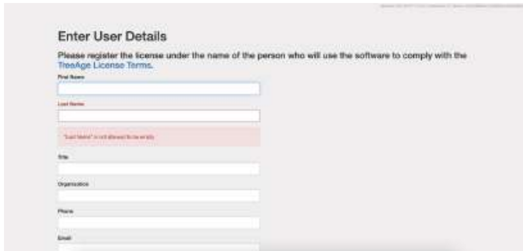
6.填寫黃色網底必填欄位之資料後
按OK(Save)



TreeAge 下載

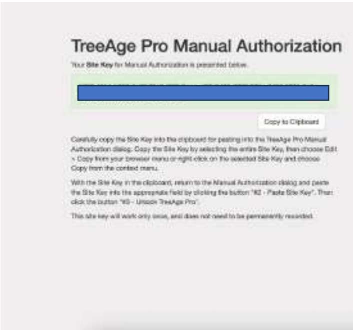


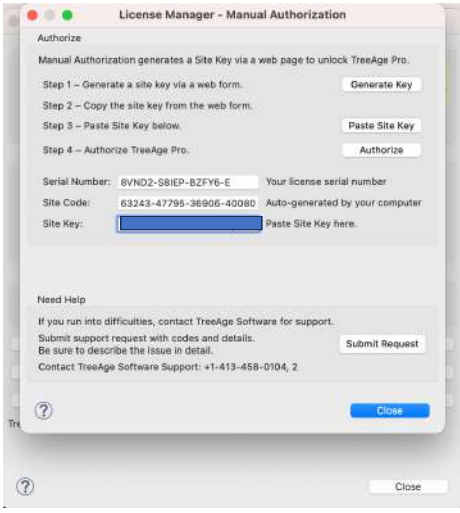
7.Generate Key ,跳到下面網站把資料填完



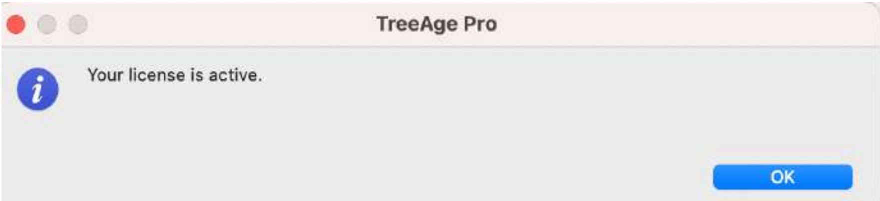
TreeAge 下載

8.複製綠色底的全部號碼,
回到TreeAge,貼上到Site Key
按Authorize

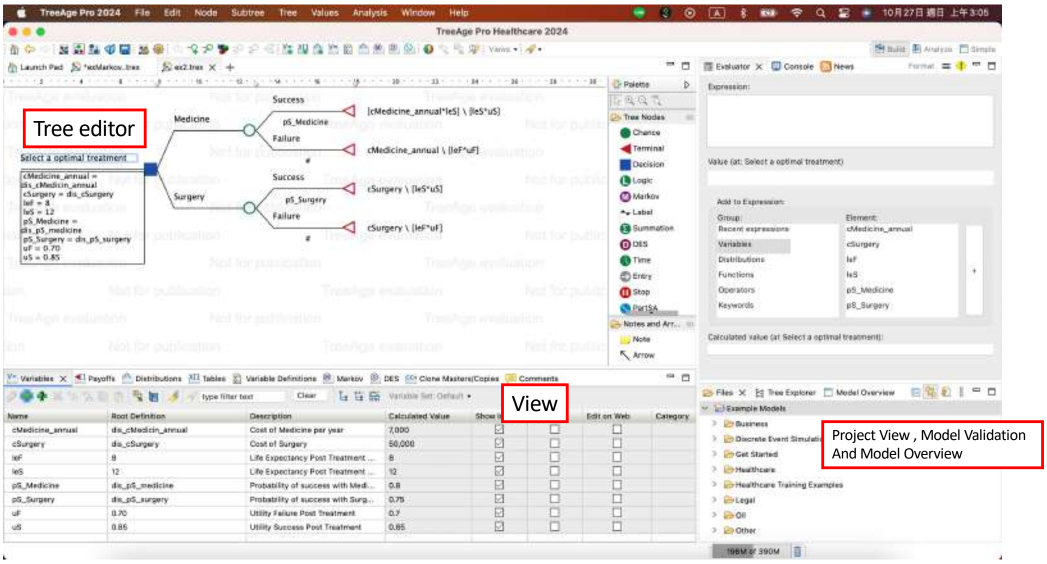




TreeAge 下載

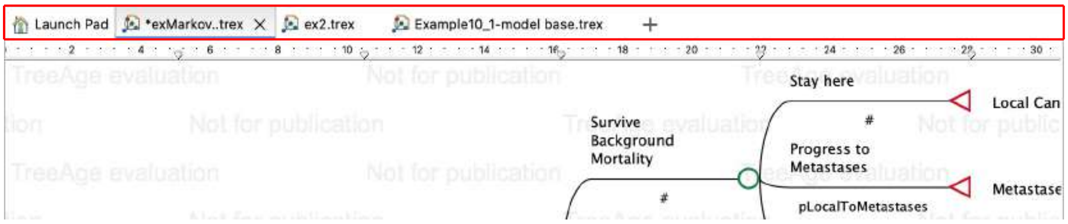


Workbench



左方的工作區域為決策樹編輯區域，右方為分析評估變項，
下方區域為變項名稱/定義描述與量化數值。

Workbench-Tree Diagram Editor

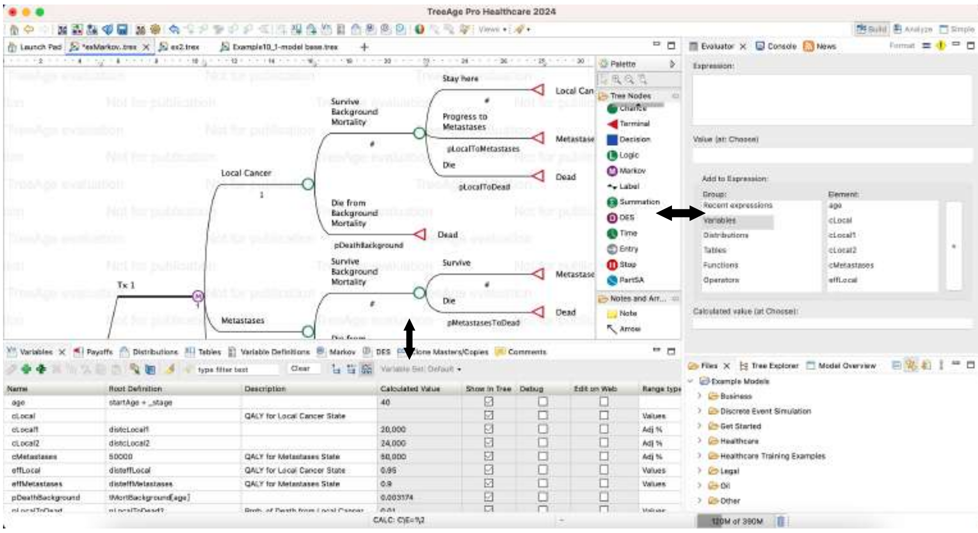


You can open multiple Tree Diagram Editors to edit multiple models. You can also open multiple synchronized editors for the same model. When multiple editor windows are open, the inactive windows will appear as tabs at the top of the active window.

上圖為工作區域編輯視窗

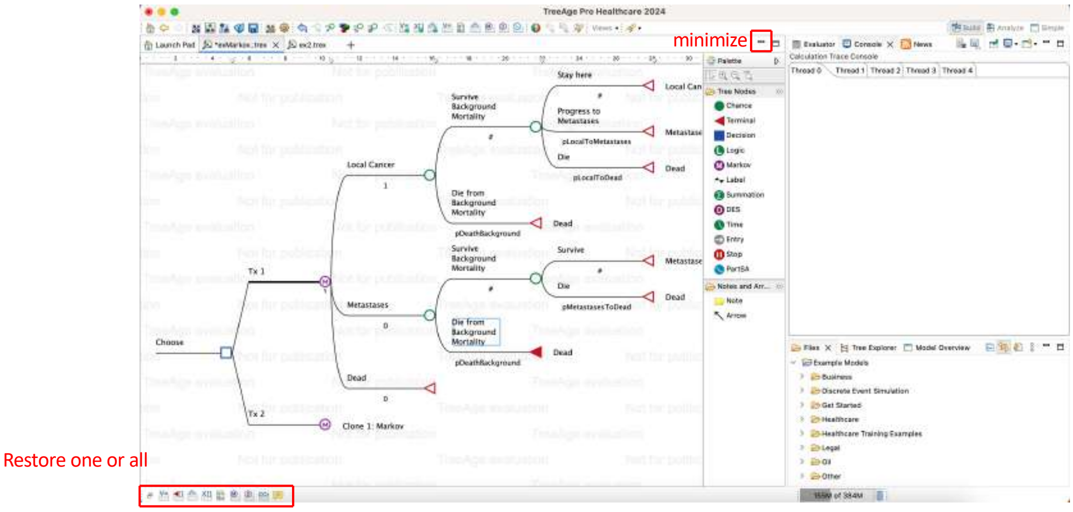
Workbench

Use the arrows between panes to re-size editors and views.

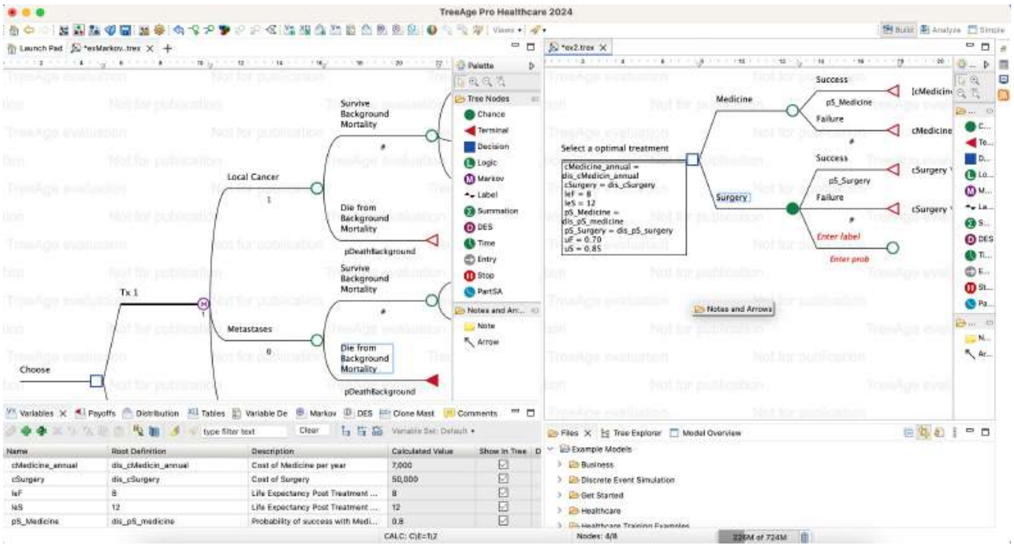


可使用視窗之間的箭頭來調整編輯器的大小

Workbench



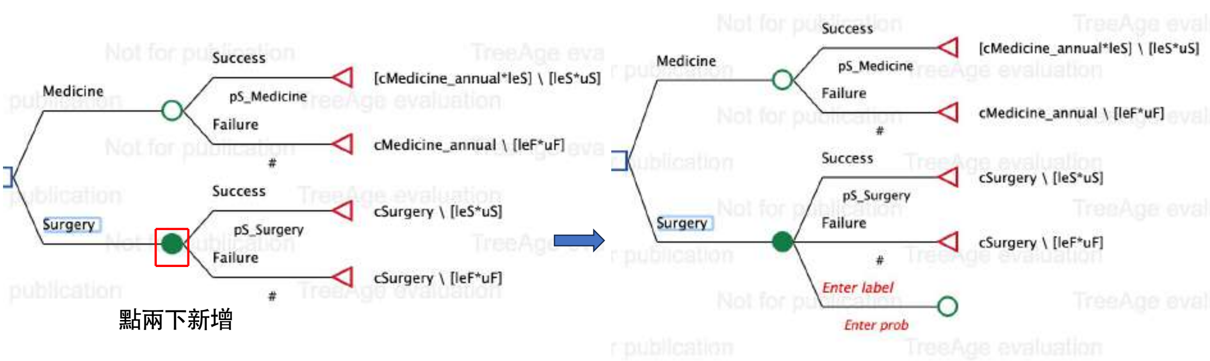
Workbench



Split the Tree Editor to look at two models (or outputs) side by side.
- Click on a Tree Editor pane tab and hold down the mouse button.
- Drag the tab to the left, right, top, or bottom of the Tree Editor pane.
- A bold line will appear down the center of the Tree Editor. Release the mouse button and the moved tab will appear in a separate section or the Tree Editor pane.
- To move back, click and drag the tab back to its original location.

- 將樹狀編輯器視窗分割，以並排檢視兩個模型（或輸出）。
- 點擊樹狀編輯器視窗，並按住滑鼠左鍵。
- 將標籤拖動到樹狀編輯器視窗的左側、右側、頂部或底部。
- 當中央出現粗線時，鬆開滑鼠按鍵，該標籤將顯示在樹狀編輯器視窗獨立區域。
- 若要移回原位，點擊並將視窗拖回其原始位置。

Workbench



點擊節點兩次即可新增branch

Node Types

Decision

- Point where a choice must be made from the options available

Chance

- Point where there are two or more possible event outcomes

Terminal

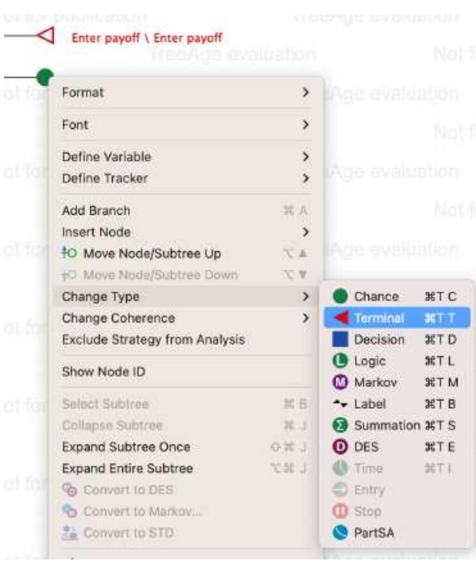
- non-Markov: End point for a scenario within the model
-Markov: End point for a cycle

Markov

- Indicates the start of Markov model

Change Node Types

按住Node/右鍵/Change Type

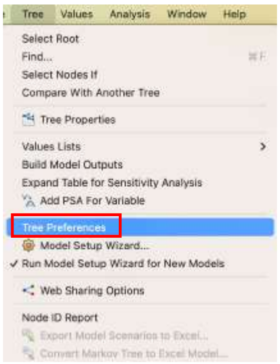


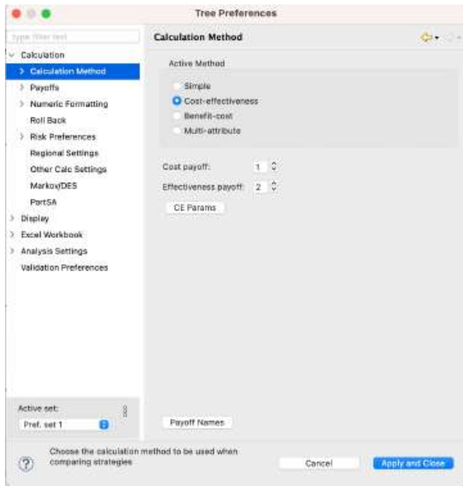
更改決策節點類型，例如：機會節點 (Chance)、終端節點 (Terminal)等

Tree Preferences

- To compare strategies on the basis of cost-effectiveness

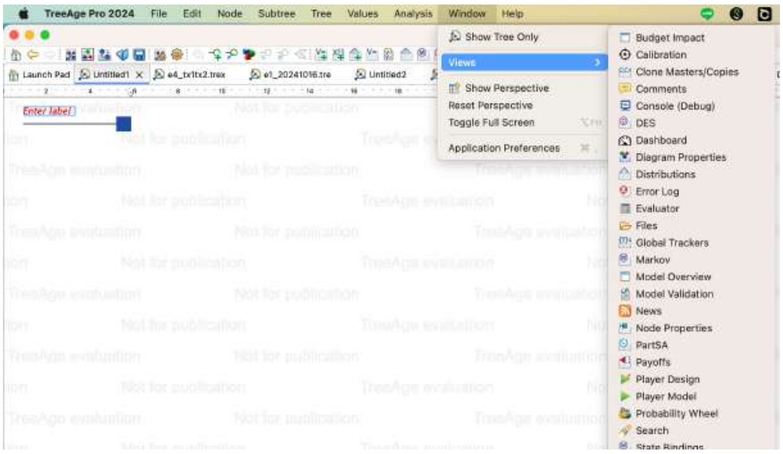
- Calculation Method: Cost-effectiveness
- Two active payoffs (cost and effectiveness)
- Willingness-to-Pay (WTP)





在Tree Preferences (決策樹偏好設定)中可調整計算方法、成本與效益值、支付意願價格等

Views



Views 為展示、分析和解釋模型結果的工具，提供不同的報表、圖表來閱覽模型的輸出結果，包括成本效益分析、敏感度分析等之視覺化圖表呈現

Variable Properties View

- most numeric values should be entered as variables
- variables assign a name to a numeric value (parameter) or a formula within the model variables
- variables can then be referenced throughout the model to return the appropriate value

Variables ✕ | Payoffs | Distributions | Tables | Variable Definitions | Markov | DES | Clone Masters/Copies | Cc

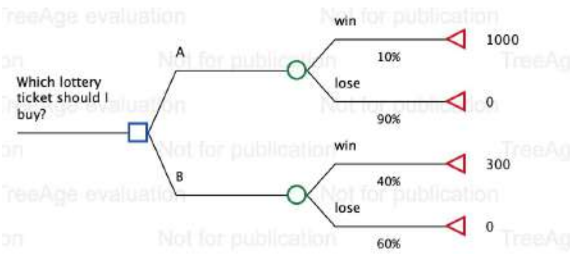
type filter text | Clear | Variable Set: Default ▾

Name	Root Definition	Description	Calculated Value	Show In Tree
age	startAge + _stage		17.5	☑
cLocal	cLocal2	QALY for Local Cancer State	24,333.33333333...	☑
cLocal1	distcLocal1		20,000	☑
cLocal2	distcLocal2		24,333.33333333...	☑
cMetastases	50000	QALY for Metastases State	50,000	☑
effLocal	disteffLocal	QALY for Local Cancer State	0.96	☑
effMetastases	disteffMetastases	QALY for Metastases State	0.88	☑

❑ 單元六：
Decision Tree in TreeAge

Example 1: A decision about playing a lottery

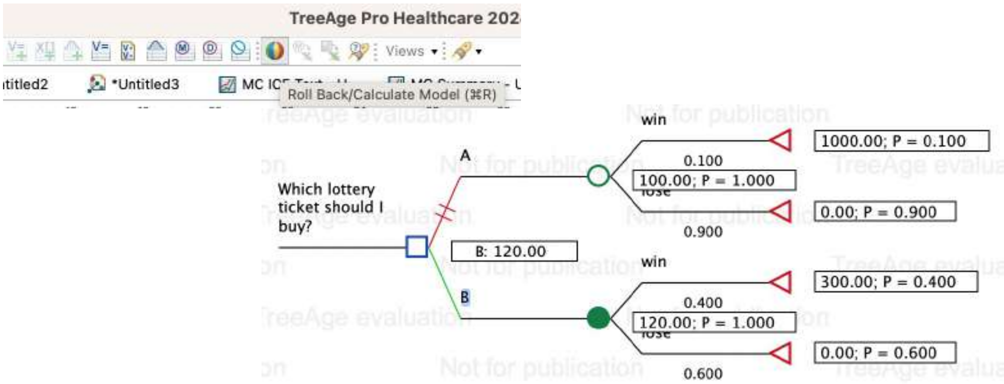
STEP		EX1
Decision Problem		Which lottery ticket should I buy?
Structure the tree	Decision alternatives	Lottery A Lottery B
	Outcomes of each Alternatives	Lottery A Win/Lose Lottery B Win/Lose
Estimate probabilities for each outcome		Lottery A Win(10%)/Lose(90%) Lottery B Win(40%)/Lose(60%)
Assign a value to each outcome		Lottery A Win($1000)/Lose($0) Lottery B Win($300) /Lose($0)



表格將以樂透是否中獎進行舉例說明

Example 1: A decision about playing a lottery

- Analyze the tree to get the expected value for each strategy and to choose the optimal strategy.



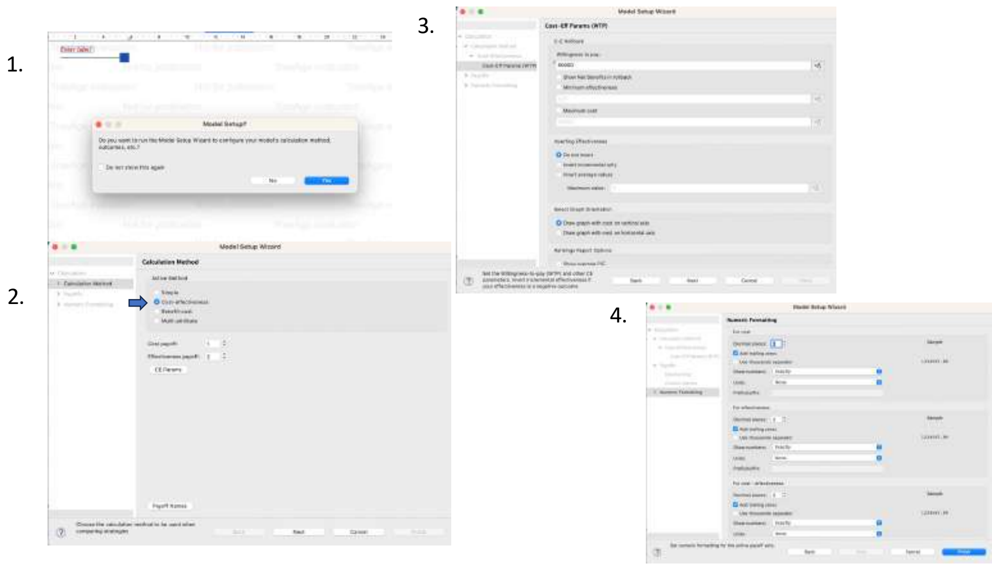
Example 2:Select a optimal treatment

- Before you build any model, you need to have a firm understanding of the goals and measurable outcomes within the model.
- To establish this understanding, answer the following 3 questions

Question	Answer for this example
What is the underlying problem?	Patients with disease X have historically only had one treatment option. A new treatment has become available. We want to identify the most cost-effective treatment for patients with disease X.
What are our strategies/options?	1. Medicine (new treatment) 2. Surgery (standard of care)
How do we measure the outcomes associated with these strategies?	Cost is measured in NT$ Effectiveness is measured in QALYs

在建立模型之前，應充分考量：問題、策略與選擇以及如何測量結果

Example 2-Model Setup



此決策樹使用成本效益分析來比較手術和藥物治療，兩種治療都可能無法根除腫瘤

1.從啟動面板創建一個新的決策樹，系統會跳出我們通過模型設置向導來設置計算偏好，按下Yes

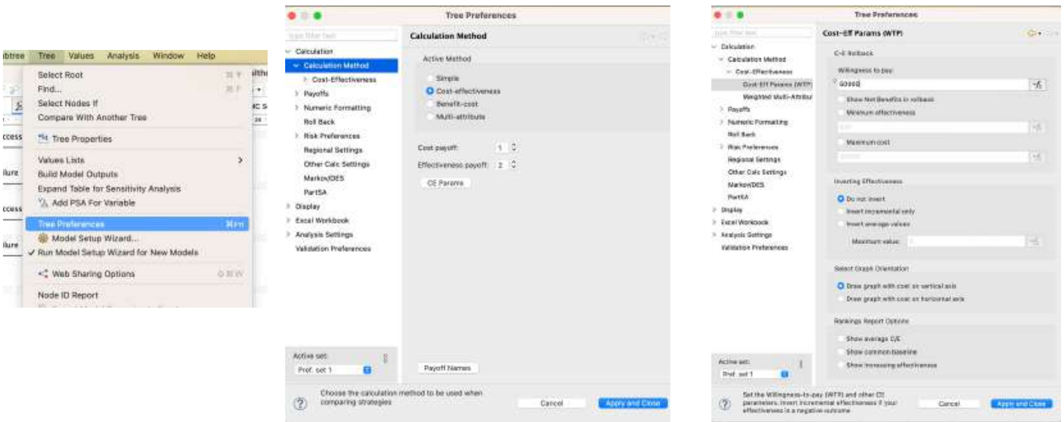
2.在這個模型中，我們將計算方法設為成本效益分析

3.將願付價格（Willingness to Pay, WTP）設為50,000，其他設定按Next跳過即可

4.最後按下 Finish

Example 2-Model Setup

- Set Calculation Method as "Cost-effectiveness"
- Set the Willingness to pay

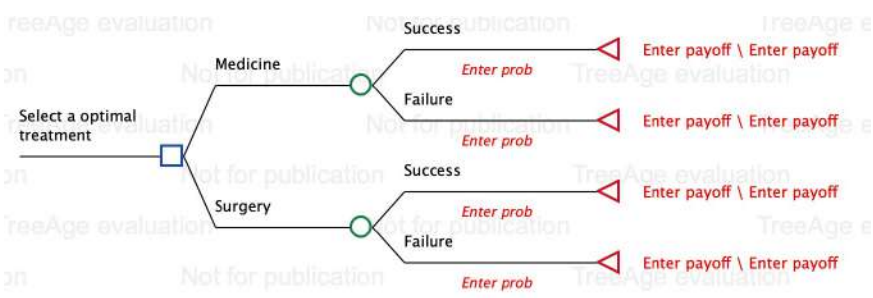


如果前面設定錯誤，可以上述說明進行修改

1. 點Tree / Tree Preference
2. 點左邊 Calculate Method / 選Cost-Effectiveness
3. Cost-Effectiveness點開/選下面WTP / 設置為50000
4. 最後點下面 Apply and Close 就完成了

Example 2-Model Setup

• Develop the model
- define patient pathways for each strategy



在任何模型中，我們需要將策略添加為決策節點的分支，點兩下節點或使用工具欄添加分支，然後標標記命名這些策略；
每個策略接著會展開成不同的患者路徑，機會節點代表著在某些點上，患者可能經歷兩種或多種事件的情況。

Example 2-Parameter definition and estimation

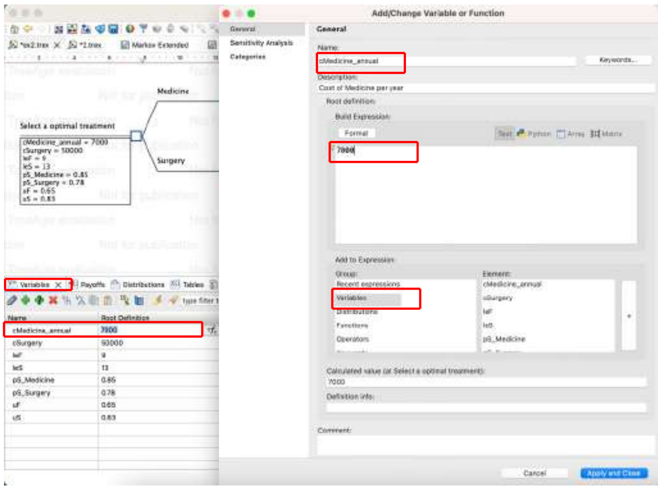
Parameter	Variable Name	
Probability of success with Surgery	pS_Surgery	0.78
Probability of success with Medicine	pS_ Medicine	0.85
Cost of Surgery	cSurgery	50,000
Cost of Medicine per year*	cMedicine_annual	7,000
Life Expectancy Post Treatment Success	leS	13
Life Expectancy Post Treatment Failure	leF	9
Utility Success Post Treatment	uS	0.83
Utility Failure Post Treatment	uF	0.65

* Medicine costs 7,000 per year for the treatment over the course of a patient's lifetime. But if a patient fails on Medicine, treatment is stopped after Year 1.

Parameter 係指模型中的變數或常數，用於定義和量化模型中的不同輸入數據。參數可以代表各種數值，例如：轉換機率、成本、效益等，並在模型計算時被引用。
使用參數可以使模型更加靈活，以利進行敏感度分析，了解不同參數對結果的影響，進而改善決策分析的結果。

Example 2-Add variables at the root node

- these variable definitions will be used throughout the model

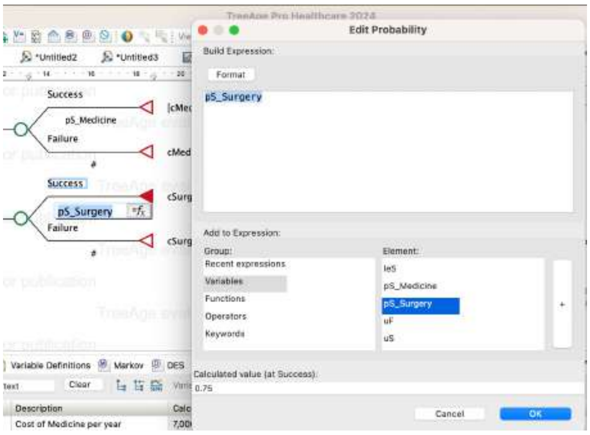


點選位在工作區域下方的Variables，建立變數以輸入數值模型，請同學們對應上一頁的表格，輸入8個數值

1. 選擇Variables，點擊綠色加號來創建新變數
2. 並為新變數命名，然後在根據定義輸入其值
3. 點選Variables
4. Apply and Close
5. 完成8項數值

Example 2-Add probabilities at each chance node branch

For each chance node, probabilities must sum to 1. In TreeAge, the complement to each known is represented by a "#"



定義模型中分支的機率，例如：手術成功的機率

1. 點2下設定機率的地方
2. 點選Variables，選擇對應的機率（這是我們前面設定的）
3. 在另一個分支下方（手術失敗的機率），我們輸入井字號（#），表示互補機率，系統會自動計算1減去該概率的值
4. 設定完4個機率

Example 2- Define outcome measures

Treatment	Consequence	Costs*	Effectiveness (QALYs)
Medicine	success	cMedicine_ annual*leS =7,000*13	leS*uS =13*0.83
	failure	cMedicine_annual =7,000	leF*uF =9*0.65
Surgery	success	cSurgery=50,000	leS*uS =13*0.83
	failure	cSurgery=50,000	leF*uF =9*0.65

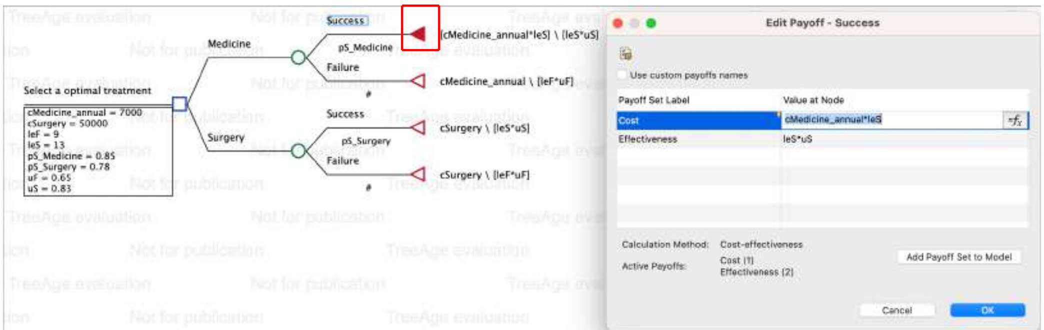
* Medicine costs 7,000 per year for the treatment over the course of a patient's lifetime. But if a patient fails on Medicine, treatment is stopped after Year 1.

在TreeAge 中定義 outcome measures的步驟如下：

1. 設定結果變數：在模型中定義關鍵的結果變數，例如：成本、效益（QALY或其他健康結果指標）。
2. 分配結果數值：在終端節點（terminal nodes）中，為每個可能結果輸入相對應之成本和效益數值，確保所建立的模型可以針對不同情境來計算結果。
3. 設置總和或期望值公式：在模型中，定義計算整體結果（例如：總成本或總效益）的公式，能從根節點分析並獲得期望值。
4. 設定敏感度分析和視覺化圖表**：使用 TreeAge 提供的視覺話圖表和敏感度分析工具，可以針對我們所設定的 outcome measures 進行評估，判斷不同策略的效果並改進策略。

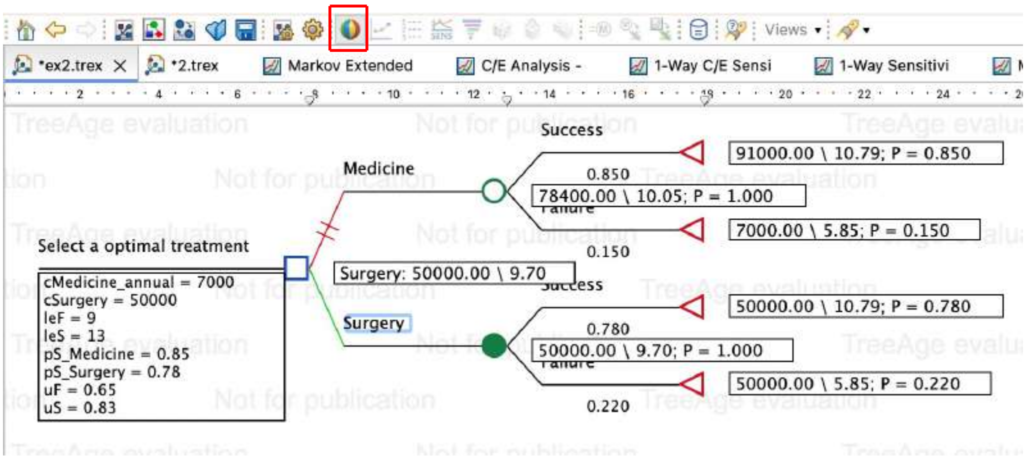
上方表格為說明該藥物的治療費用每年為 7,000 元，患者在整個生命週期中持續接受治療；但如果患者在使用該藥物的第一年治療失敗，則會停止治療。

Example 2- Add outcome measures



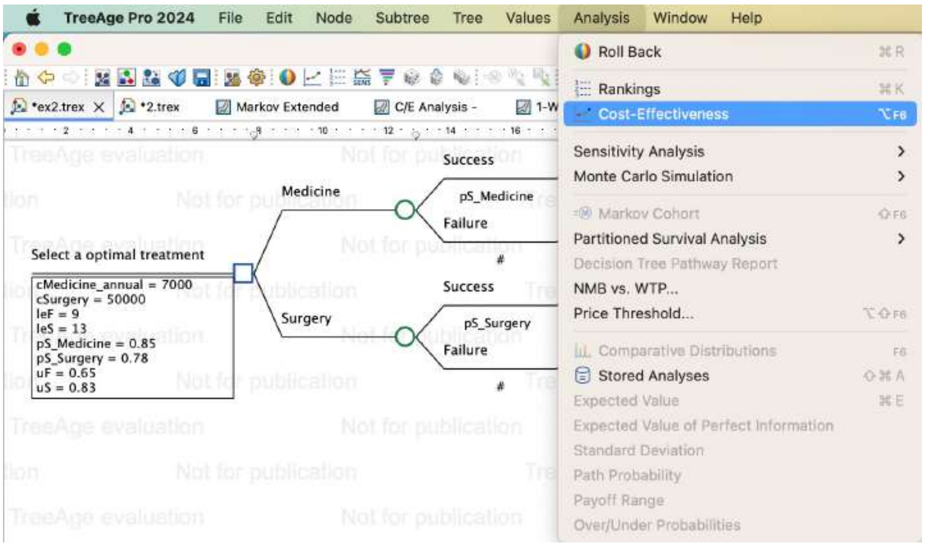
要結束一個情境，只需將機會節點更改為「終端節點 (Terminal)」。當我們在建立並設定模型參數時，已經在初始設定的偏好中選擇了計算成本效用，因此我們只需要將上表的數值對應後填入。

Example 2- Analyze the tree (run Roll Back)



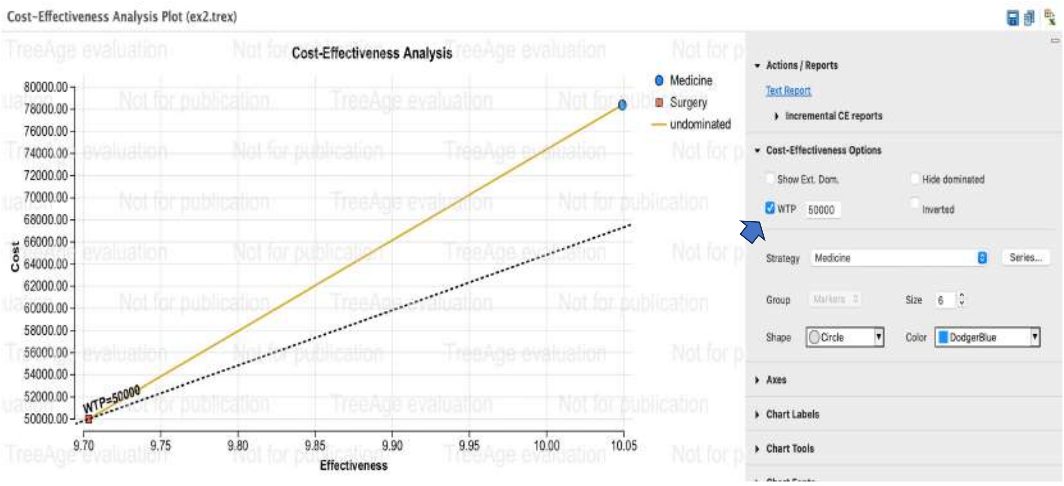
記得在每次設定完後，點選「Roll Back」以查看計算出的數值

Example 2- Analyze the tree (run Cost-Effectiveness)



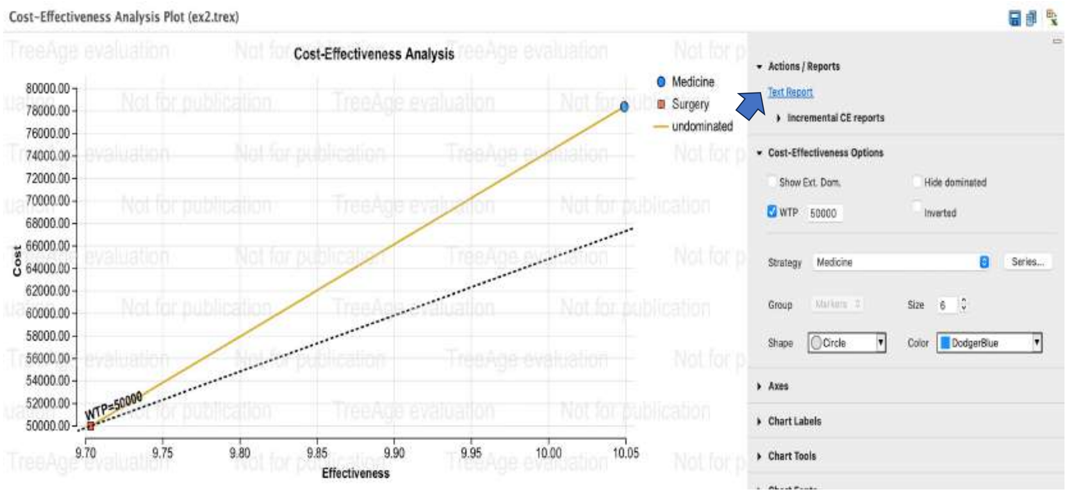
做任何操作前，先取消Roll Back，再點選 Analysis / Cost-Effectiveness

Example 2- Analyze the tree (run Cost-Effectiveness and add WTP)



這條線是成本效益前沿(cost effectiveness frontier)，連接兩個策略。
垂直距離表示增加的成本，水平方向表示增量效果，這使得斜率為 ICER（增量成本效益比）。通常會將ICER值與我們的支付意願(WTP)進行比較。

Example 2- Analyze the tree (run Rankings)



要查看數值的成本效益分析結果，點右邊 Text Report

<產生排序報表>
Mac:點 Rankings
Windows: 點Text Report

Example 2- Analyze the tree (run Rankings)

Cost-Effectiveness Rankings Report (ex2.trex)

Category	Strategy	Cost	Incr. Cost	Effectiveness	Incr. Effectiveness	ICER (IC/IE)	NMB
All (no dominance)							
undominated	Surgery	50000.00		9.70			435160.00
undominated	Medicine	78400.00	28400.00	10.05	0.35	82128.40	424050.00

The optimal strategy will have the highest Net Benefit value

- Net Monetary Benefits (NMB) = Effectiveness * WTP - Cost
- Net Health Benefits (NHB) = Effectiveness - Cost / WTP

What if the willingness to pay threshold is 100,000/QALY?

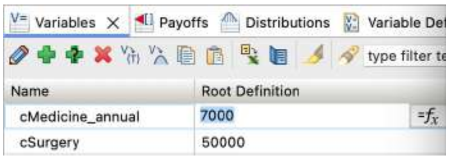
此份報告呈現了成本和效果的預期值。
如果ICER小於支付意願，則模型建議轉向更有效的策略；相反，如果ICER大於支付意願，則應保留較便宜的策略。

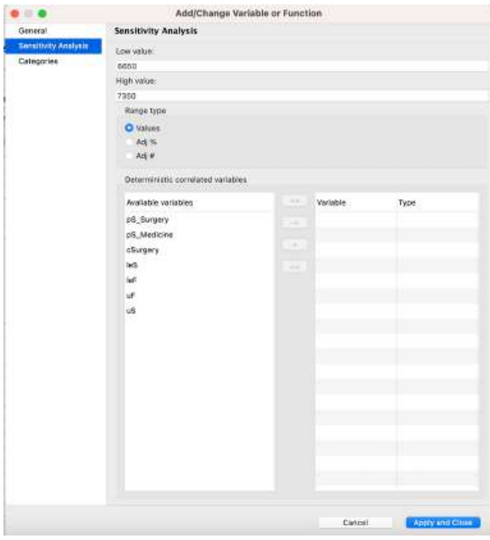
TreeAge Pro 可使用淨貨幣收益（NMB）來選擇在固定支付意願下的最佳策略。
具有最高淨貨幣收益值的策略是最具成本效益的（選擇較大者）。
這種方法總是與將ICER與支付意願進行比較所得到的最佳策略相同。

❑ 單元七：
Sensitivity Analysis

Example 2-One-way Sensitive Analysis

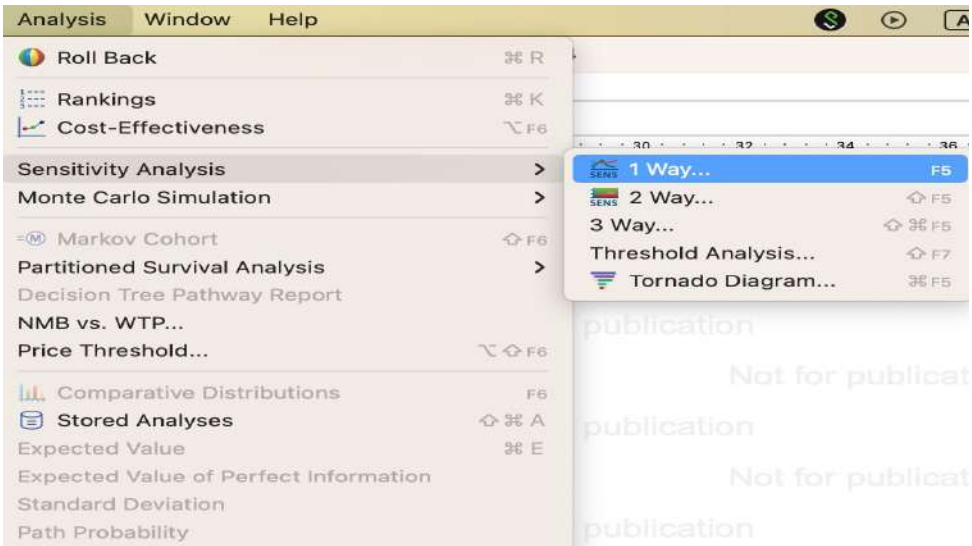
Variable	Value(range)
pS_surgery	0.78 (0.72-0.82)
pS_medicine	0.85 (0.84-0.93)
cSurgery	5,0000 (45,000-55,000)
cMedicine_annual	7,000 (6,650-7,350)





1. 點Variables
2. 選擇要分析的值
3. 點左邊Sensitivity Analysis
4. 對應上表編輯數值
5. Apply and Close
6. 完成4項設定

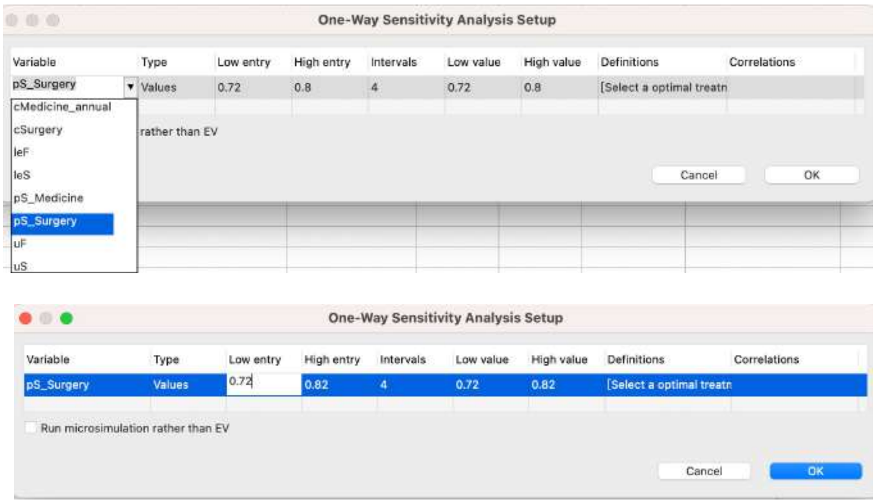
Example 2-One-way Sensitive Analysis



敏感度分析為當數值在一個範圍內變化單個參數時，基準情況之結果將會如何改變。
在任何給定參數的範圍內，可能會出現稱為成本效益閾值的策略變化。

1. 點Analysis
2. 選Sensitivity Analysis
3. 選1Way

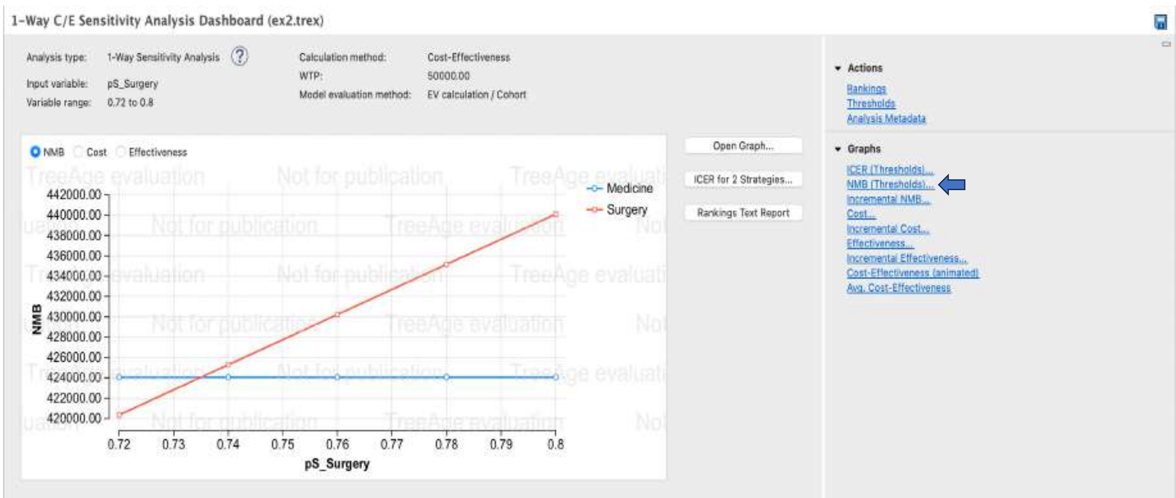
Example 2-One-way Sensitive Analysis



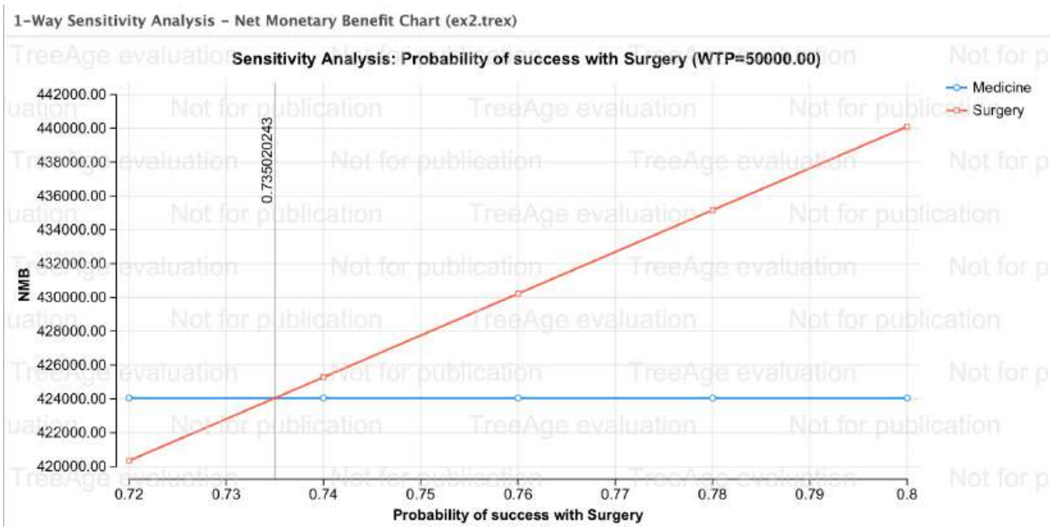
下拉選單選擇要分析的Variables
這邊選pS_Surgery
按ok

如果前面設定錯誤，還可以直接在這邊更改，如上圖。

Example 2-Net Monetary Benefits Chart

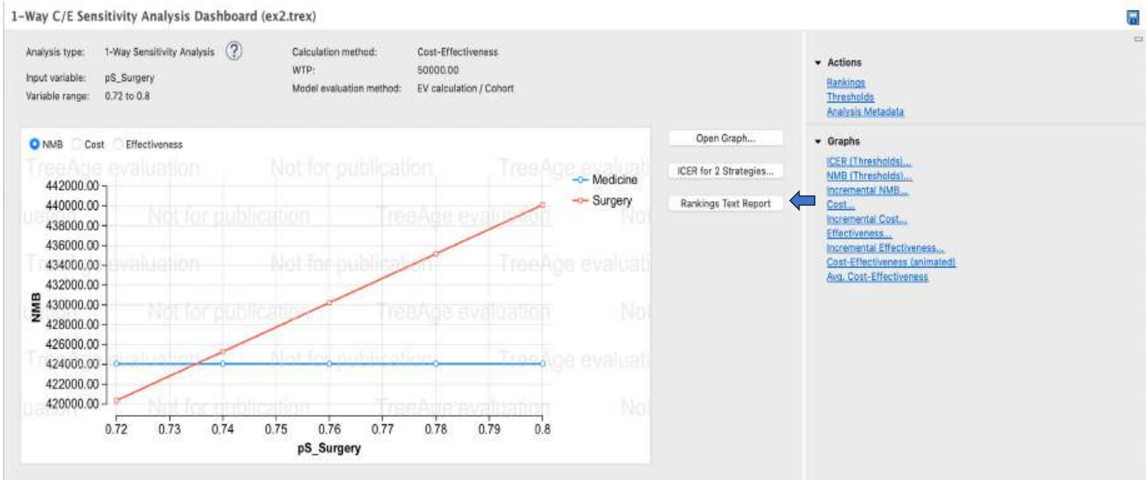


Example 2-One-way Sensitive Analysis-Net Monetary Benefits Chart



圖說：隨著手術治療效果(x軸)越好，其NMB值(y軸)就越大

Example 2-Net Monetary Benefits Chart



Example 2-One-way Sensitive Analysis

Medicine is the optimal strategy

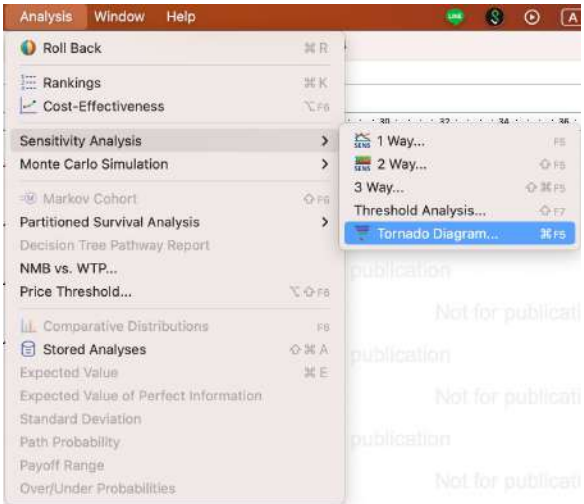
Surgery is the optimal strategy

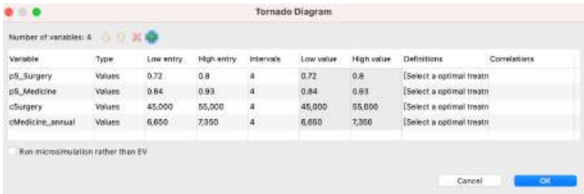
1-Way Sensitivity Analysis - C/E Text Report (ex2.trex)

pS_Surgery	Strategy	Cost	Incr. Cost	Effectiveness	Incr. Effectiveness	ICER	NMB	C/E	Dominance
0.72									
0.72	Surgery	50000.00	0.00	9.41	0.00	0.00	420340.00	5315.30	
0.72	Medicine	78400.00	28400.00	10.05	0.64	44222.98	424050.00	7801.77	
0.74									
0.74	Surgery	50000.00	0.00	9.51	0.00	0.00	425280.00	5260.06	
0.74	Medicine	78400.00	28400.00	10.05	0.54	52263.53	424050.00	7801.77	
0.76									
0.76	Surgery	50000.00	0.00	9.60	0.00	0.00	430220.00	5205.95	
0.76	Medicine	78400.00	28400.00	10.05	0.44	63877.64	424050.00	7801.77	
0.78									
0.78	Surgery	50000.00	0.00	9.70	0.00	0.00	435160.00	5152.94	
0.78	Medicine	78400.00	28400.00	10.05	0.35	82128.40	424050.00	7801.77	
0.8									
0.8	Surgery	50000.00	0.00	9.80	0.00	0.00	440100.00	5101.00	
0.8	Medicine	78400.00	28400.00	10.05	0.25	114979.76	424050.00	7801.77	

pS-Sugery等於0.72，選擇Medicine；大於等於0.74則選Surgery

Example 2-Tornado Diagrams





在Analysis 中，選擇Sensitivity Analysis / Tornado Diagram。

龍捲風分析將各種單向敏感性分析的結果結合起來，突顯出參數對增量成本效益的影響。

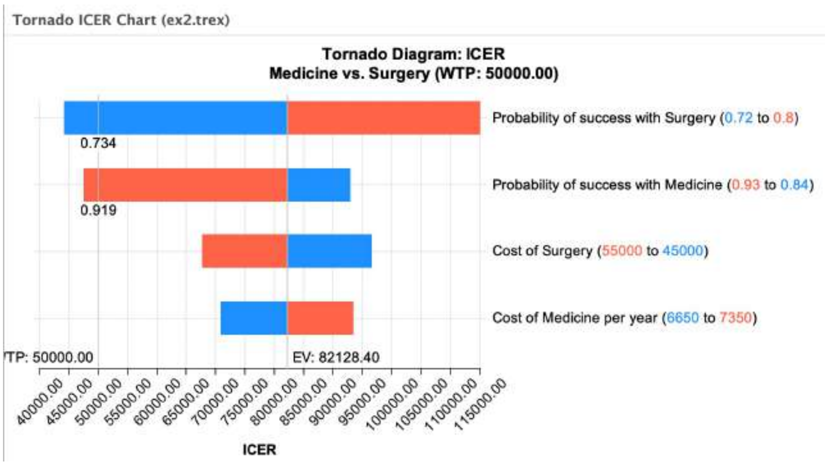
模型中影響最大的參數以視覺方式呈現，強調關鍵的閾值。

Example 2-Tornado Diagrams

點ICER Chart

Example 2-Tornado Diagrams

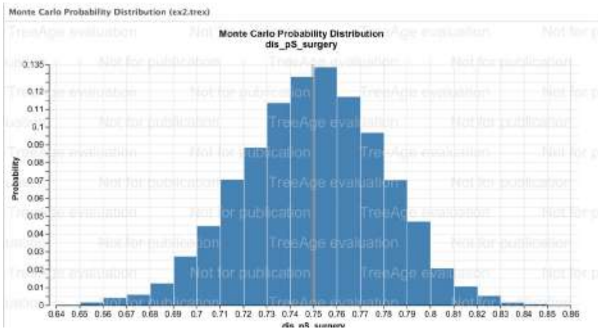
A set of one-way sensitivity analysis brought together in a single graph



圖表顯示了與每個參數的不確定性範圍相關的 ICER範圍。對於每個參數，對 ICER 影響最大的參數顯示在最上面。最上面的條是變數 p (Probability of success with Surgery)，它對 ICER 影響最大。

Example 2- Probabilistic Sensitivity Analysis(PSA)

- Uncertainty always exists in multiple parameters in a model



- Different parameter combinations could impact the optimal strategy
- PSA results estimate the total impact of uncertainty on the model, or the confidence that can be placed in the analysis results.

Example 2- Probabilistic Sensitivity Analysis(PSA)

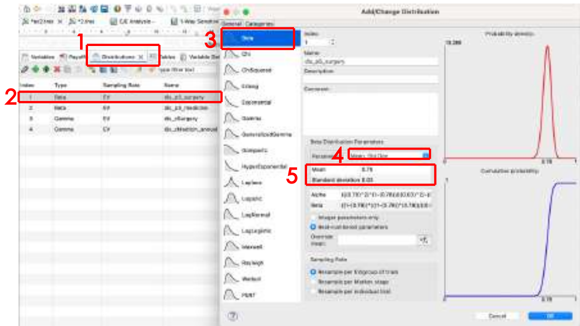
- PSA involves sampling model parameter values from distributions imposed on variables in the model.
- Data sources for parameter estimation
  - primary data, secondary data, and expert opinion.
- Choosing distributions for parameters

Distribution	interval	parameter
Beta distribution	[0,1]	• Transition probabilities • utility
Gamma distribution	[0,+∞]	• Cost • disutility
log-normal distribution		• Cost • Treatment effects • disutility

當我們擁有一組基於估算模型輸入的模型結果時，我們通常希望衡量整體不確定性對結果的影響。
我們可以使用機率敏感性分析來做到這一點，簡稱 PSA。
PSA 進行一系列模型重新計算，每次使用一組不同的參數分佈樣本。
一些重新計算將確認我們的基準情況，而另一些則不會。確認我們基準情況的重新計算越多，我們對結果的信心就越高。

Example 2-PSA- Set up distributions for 4 parameters

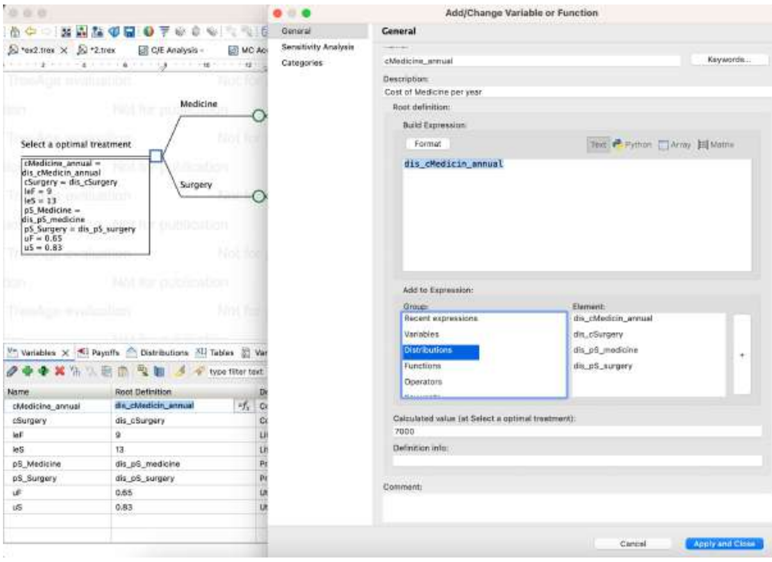
Variable	New name	Type	Mean	SD
pS_surgery	dis_pS_surgery	Beta	0.78	0.03
pS_medicine	dis_pS_medicine	Beta	0.85	0.02
cSurgery	dis_cSurgery	Gamma	50,000	3,000
cMedicine_annual	dis_cMedicine_annual	Gamma	7,000	600



在模型中，我們將重點關注四個參數的不確定性。
為了對這些參數進行機率敏感度分析（PSA），我們需要為這四個參數選擇分佈。
然後，我們可以從這些分佈中進行抽樣，而不是使用基準情況的點估計。
依步驟設定 4 項 Distribution

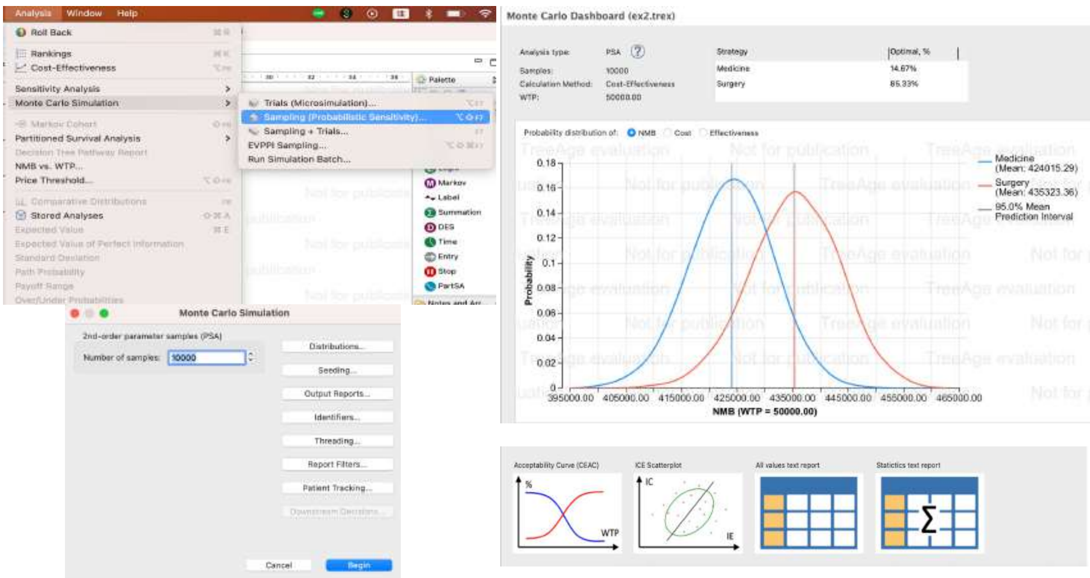
Distribution button在決策樹編輯區域下方的bar (variables那一列上)

Example 2-PSA- Set up distributions for 4 parameters



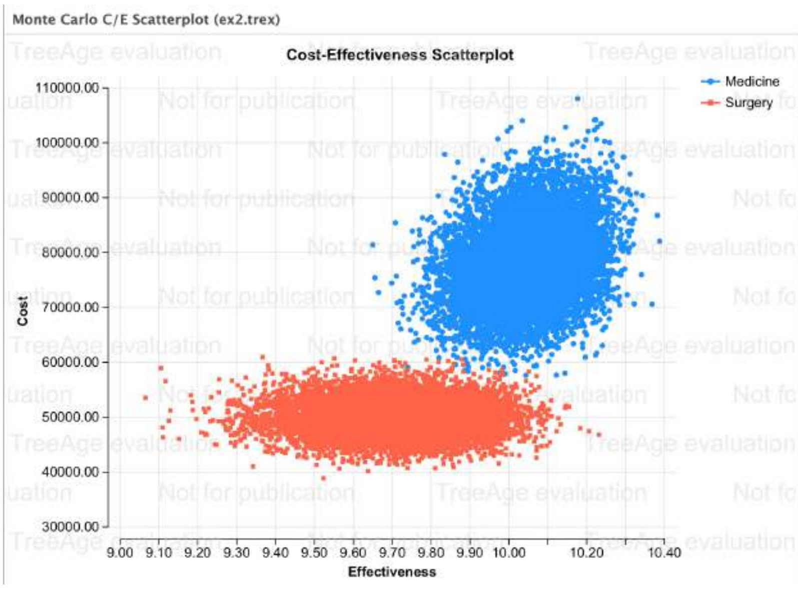
一旦創建了 distribution，模型需要引用這些distribution 我們將編輯root definition，並將其設置為等於對應上表的distribution。

Example 2-Monte Carlo Simulation



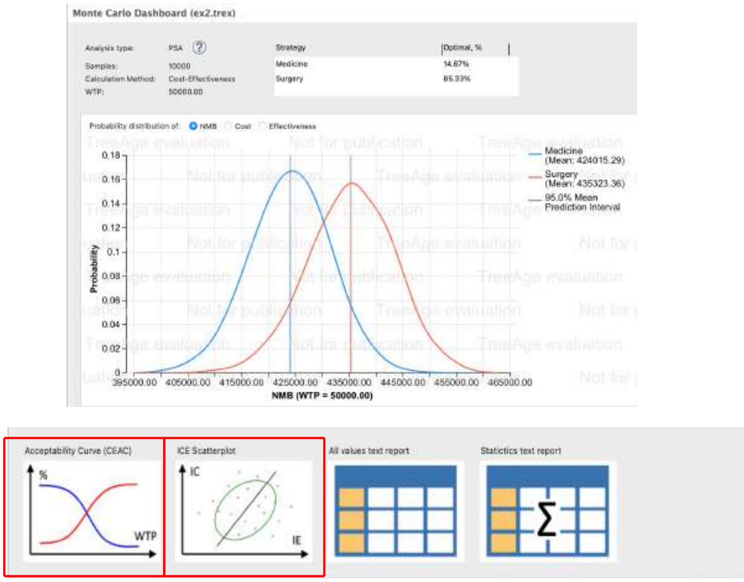
選擇Analysis / Monte Carlo Simulation / Sampling。
接下來，我們選擇樣本數量，設定為10000，然後運行分析。
因爲是抽樣，所以後面數據不一定會完全一樣，但不會差太多。

Example 2-Monte Carlo Simulation



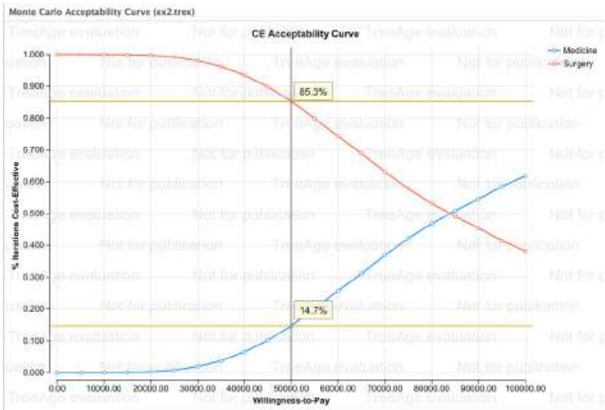
我們生成成本效益散布圖(Scatterpoint)，以查看不同樣本參數集所產生的輸出變異性，此圖呈現不確定性的整體影響

Example 2-Monte Carlo Simulation



分別點選這下方兩個圖

Example 2-Monte Carlo Simulation-Acceptability Curve



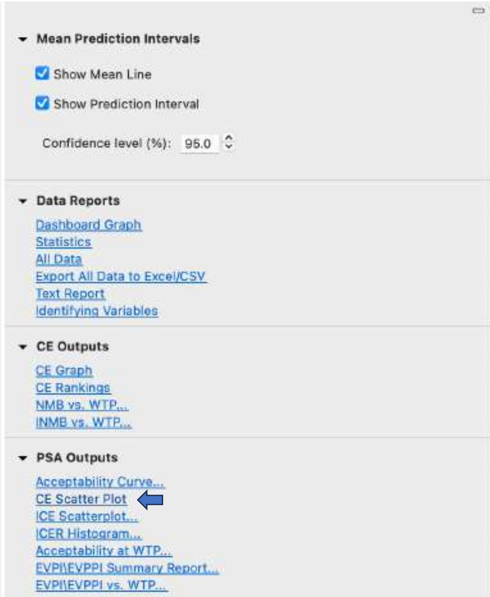
Monte Carlo Acceptability Text (ex2.trex)

Willingness-to-Pay	Strategy	Acceptability
0.00	Surgery	1
0.00	Medicine	0
5000.00	Surgery	1
5000.00	Medicine	0
10000.00	Surgery	0.9998
10000.00	Medicine	0.0002
15000.00	Surgery	0.9992
15000.00	Medicine	0.0008
20000.00	Surgery	0.9971
20000.00	Medicine	0.0029
25000.00	Surgery	0.9922
25000.00	Medicine	0.0078
30000.00	Surgery	0.9806
30000.00	Medicine	0.0194
35000.00	Surgery	0.9628
35000.00	Medicine	0.0372
40000.00	Surgery	0.9348
40000.00	Medicine	0.0652
45000.00	Surgery	0.8983
45000.00	Medicine	0.1017
50000.00	Surgery	0.8533
50000.00	Medicine	0.1467
[illegible]	Surgery	[illegible]
55000.00	Medicine	0.2014
60000.00	Surgery	0.7426
60000.00	Medicine	0.2574
65000.00	Surgery	0.6892
65000.00	Medicine	0.3108
70000.00	Surgery	0.6306
70000.00	Medicine	0.3694
75000.00	Surgery	0.5784

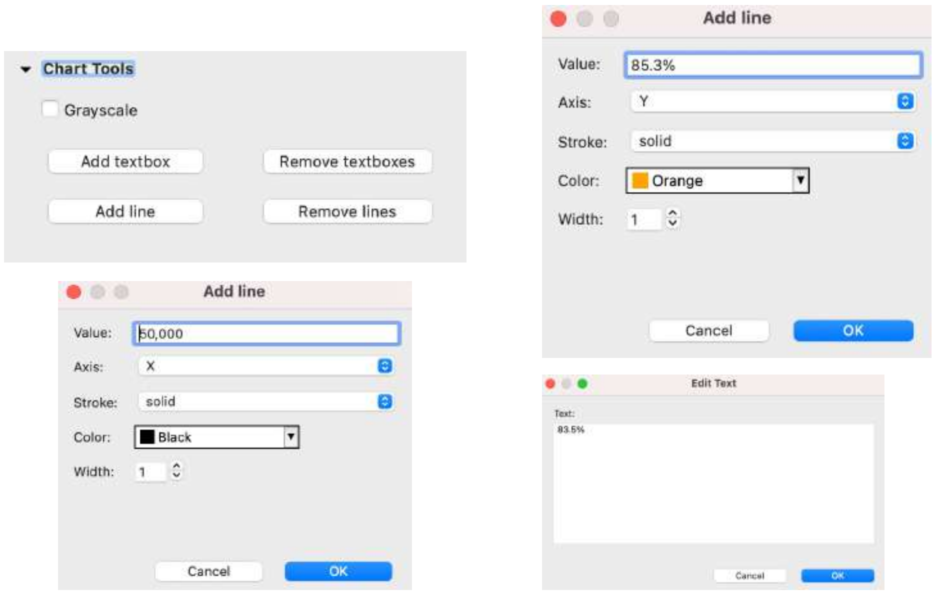
我們可以使用可接受性曲線查看在不同支付意願範圍內策略之間的分布情況，特別是可以看到支持每個策略的模型計算百分比。

曲線和數值請閱讀下一頁說明

Example 2-Monte Carlo Simulation



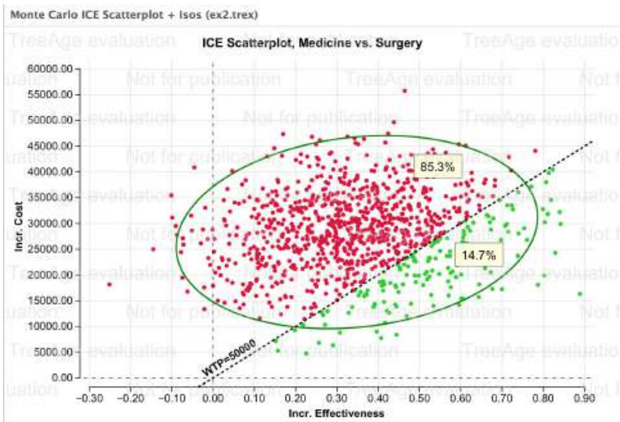
Example 2-Monte Carlo Simulation- ICE Scatterplot : Medicine vs Surgery



1. 點開右邊Chart Tools
2. 選Add Line
3. 拉開Axis 選X, Value 設50000 (WTP)
4. 拉開Axis 選Y Value 設85.3%
5. 重複另Value 設14.7%
6. 顏色拉開可選
7. 點 Add textbox 分別輸入83.5%和14.7%

Example 2-Monte Carlo Simulation- ICE Scatterplot : Medicine vs Surgery

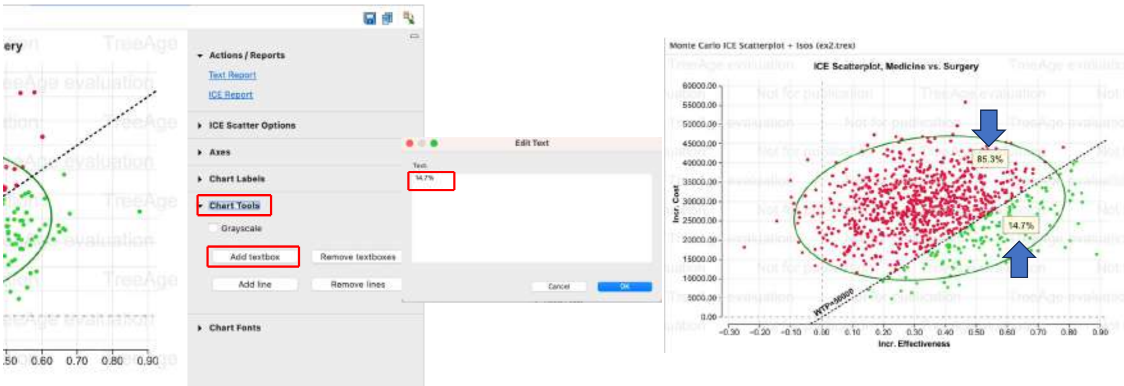
-85.3% favored the less expensive strategy ,Surgery, as depicted by the dots above and to the left o the WTP line on the graph.



在這個模型中，我們只有兩個策略，但比較最昂貴和最便宜的策略會產生正增量結果。每個點代表一次單獨的迭代，顯示增加成本與增加效果的關係。
在所有的模型計算中，85.3% 的結果支持選擇成本較低的策略，即為手術，這一點可以從圖表中 WTP（支付意願）線上方和左側的點來看出。

這些點代表了那些增加成本效果比（ICER）小於願付價格的情況，顯示手術的效果優於其他較昂貴的策略。
因此，這一比例表明，大多數情況下，手術被認為是更具成本效益的選擇。

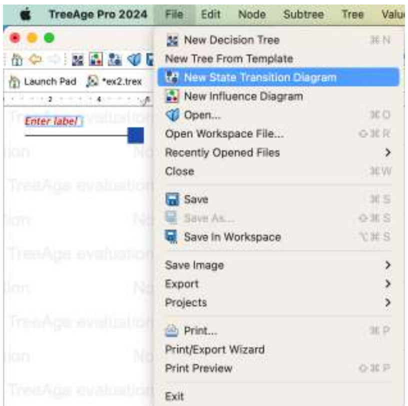
Example 2-Monte Carlo Simulation- ICE Scatterplot : Medicine vs Surgery

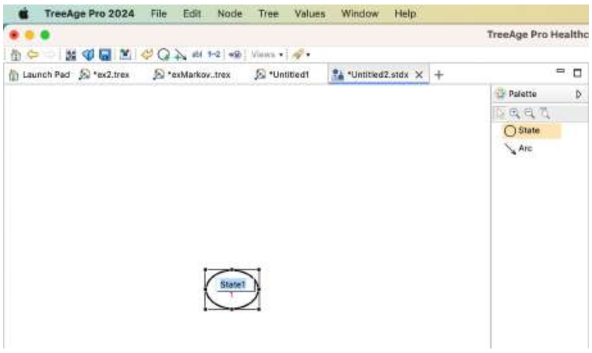


編輯數值
1. 點開右邊Chart Tools
2. 點下方Add Textbox
3. 分別輸入數值
4. 可以移動數值方塊

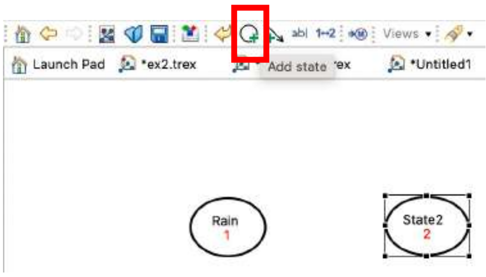
❑ 單元八：
Markov Model in TreeAge

Example 3-Markov Model

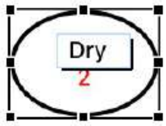




Example 3-Markov Model



點兩下改Label



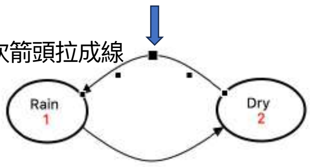
Or點這裡改Label

Example 3-Markov Model

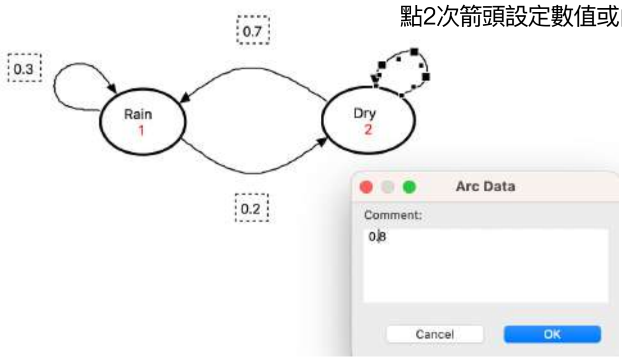
點箭頭

Example 3-Markov Model

點1次箭頭拉成線

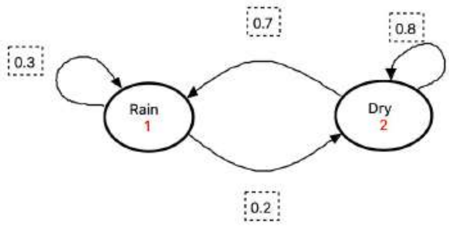


點2次箭頭設定數值或內容



Example 3-Markov Model

- A Markov Model is a stochastic model used to **model randomly changing systems** where it is assumed that future states depend only on the current state, not on the events that occurred before it (Markov property or memorylessness).



Key Elements of Markov Models

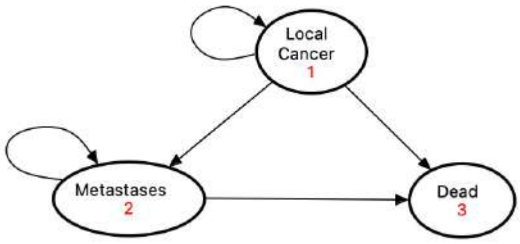
- **States**: ex. well 、ill 、dead 、 head 、tail 、 sunny 、rain...)
- **Transitions** : individuals transit from one state to the another ,
  each transition has a probability (transition probabilities /rates)
- **Cycle**: transition happen over a period of time
- **Cost & effectiveness** : each state can have a cost and /or effectiveness
  associated to it (called rewards in Markov model, payoffs in decision model)

Markov Models的重要元素包含：健康狀態、轉移機率、週期、成本與效益

Example 3-Markov Model

Developing the Markov model

- **State**
- **Transitions**



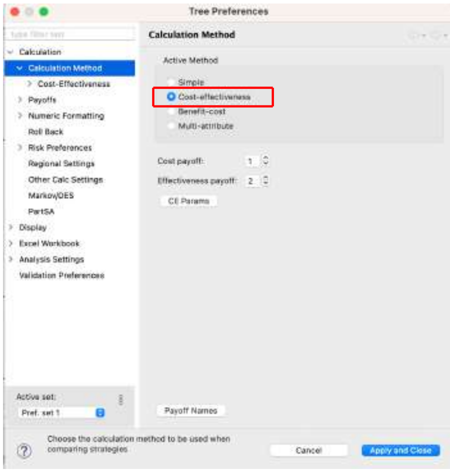
- **Cycle**

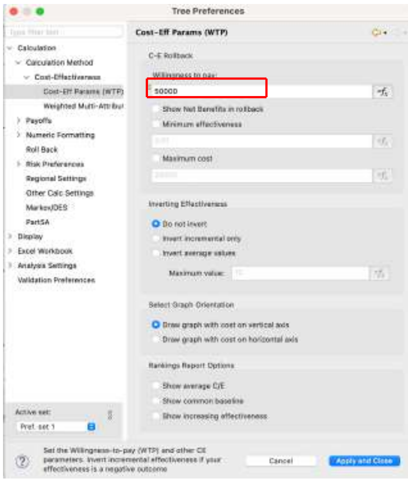
  Length of each cycle: 1year

  Total cycles : 20 years (time horizon)

Example 3-Markov Model-Set calculation Method as “Cost-effectiveness

Tree\Tree Preferences\Calculation Method





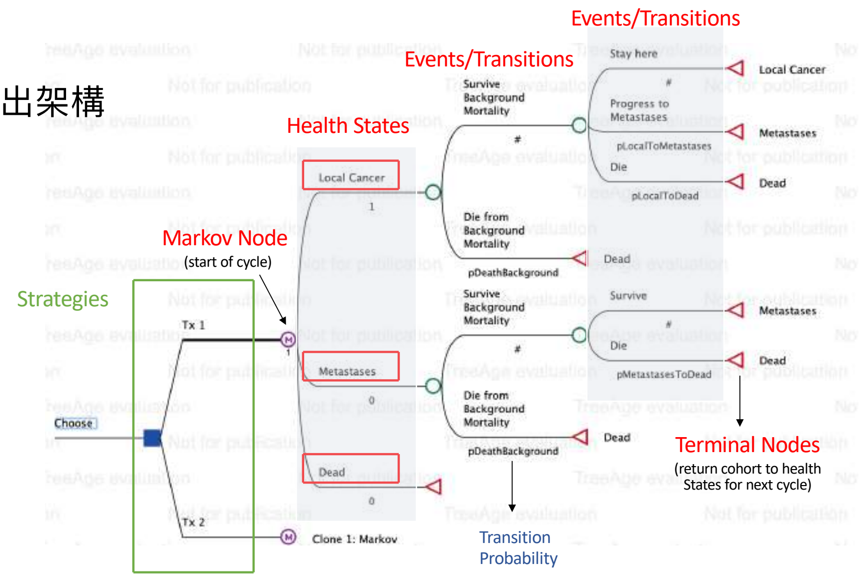
1.從啟動面板創建一個新的決策樹，系統會跳出我們通過模型設置向導來設置計算偏好，按下Yes
2.在這個模型中，我們將計算方法設為成本效益分析
3.並將願付價格（willingness to pay）設為50,000，其他設定按Next跳過即可
4.最後按下Finish

Or

點Tree / Tree Preference
點左邊 Calculate Method / 選Cost-Effectiveness
Cost-Effectiveness點開/選下面WTP / 設置為50000
點下面 Apply and Close 就完成了!

Example 3-Markov Model Structure

先畫出架構



我們將重點關注治療一 Markov 模型中的計算，使用 Markov 群體報告進行群體分析。Markov 群體分析將患者群體導入模型，這樣可以驗證群體流動以及每週期的成本和效用累積

Example 3-Markov Model Structure

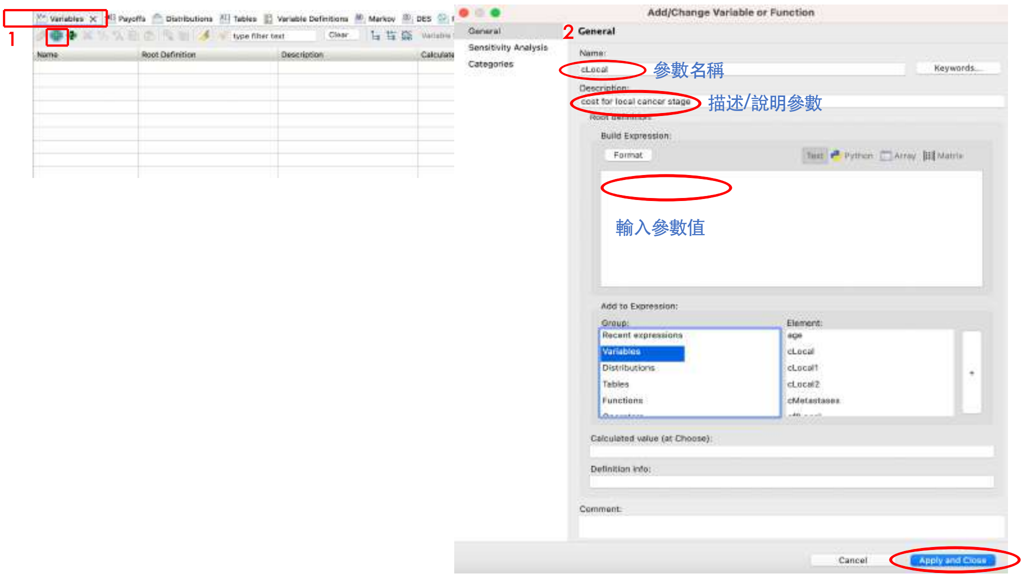
Parameter	Variable name	Value
age in each cycle	Age	startAge+_stage
cost for local cancer stage	cLocal	
	TX1:cLocal1	20,000
	TX2:cLocal2	23,000
cost for metastases stage	cMetastases	50,000
QALY for local cancer state	effLocal	0.96
QALY for metastases state	effMetastases	0.88
probability of death from other causes	pDeathBackground	
probability of death from local cancer	pLocalToDead	
	TX1:pLocalToDead1	0.04
	TX2:pLocalToDead2	0.02
probability of metastases from local cancer	pLocaltoMetastases	0.16
probability of death from metastases	pMetastasesToDead	0.1
	startAge	50
number of years for model(time horizon)	totalCycles	20

cost

effectiveness

Transition probabilities

Example 3-Add variables and their value at the root node



透過建立變數以添加數值模型輸入，對應上一頁的表格，輸入15個數值。

1. 選擇Variables，點擊綠色加號來創立新變數
2. 並為新變數命名，然後在根據定義輸入其值
3. 點選Variables
4. Apply and Close
5. 完成15項數值

Example 3-Add variables and their value at the root node

Variables | Payoffs | Distributions | Tables | Variable Definitions | Markov | Clone Masters/Copies

type filter text | Clear | Variable Set: Default

Name	Root Definition	Description	Calculated Value
age	startAge + _stage		50
cLocal		QALY for Local Cancer State	
cLocal1	20000		20,000
cLocal2	23000		23,000
cMetastases	50000	QALY for Metastases State	50,000
effLocal	0.96	QALY for Local Cancer State	0.96
effMetastases	0.88	QALY for Metastases State	0.88
pDeathBackground			
pLocalToDead		Prob. of Death from Local Cancer	
pLocalToDead1	0.04		0.04
pLocalToDead2	0.02		0.02
pLocalToMetastases	0.16	Prob. of Progression from Local ...	0.16
pMetastasesToDead	0.1	Prob. of Death from Local Cancer	0.1
startAge	50		50
totalCycles	20	Number of years for model	20

對照表格，檢查是否正確

Example 3- Time-dependence variables

Life Tables (Background Mortality)

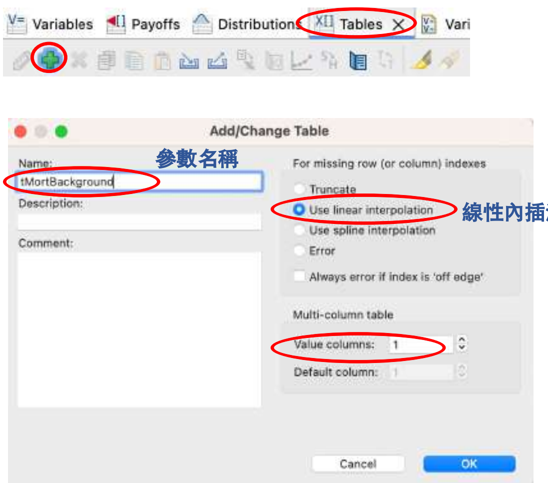
age	mortality
0	0.0080000
1	0.0003150
5	0.0001700
15	0.0008150
25	0.0010360
35	0.0020160
45	0.0043320
55	0.0094090
65	0.0225500
75	0.0546310
85	0.1459330
95	0.2500000
120	1.0000000

打開Excel

Example 3-Markov Model Structure- create a Table for Background Mortality

1

2

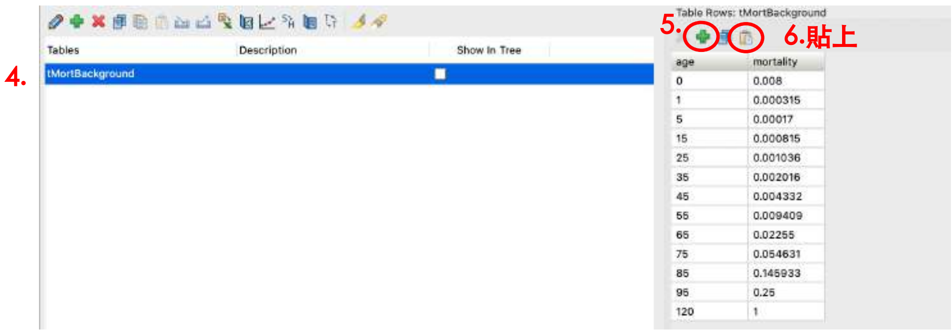


3.到Excel 全選複製

age	mortality
0	0.0080000
1	0.0003150
5	0.0001700
15	0.0008150
25	0.0010360
35	0.0020160
45	0.0043320
55	0.0094090
65	0.0225500
75	0.0546310
85	0.1459330
95	0.2500000
120	1.0000000

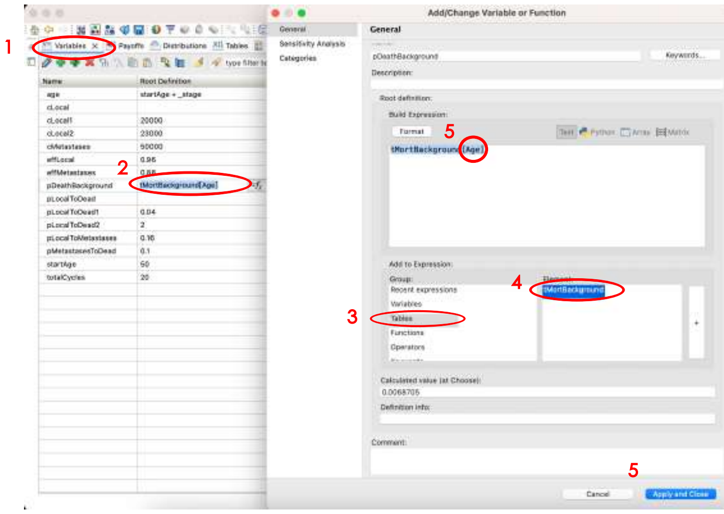
Example 3-Markov Model Structure

create a Table for Background Mortality



Example 3-Add value definition(pMortBackgrourd[age] for pDeathBackground)

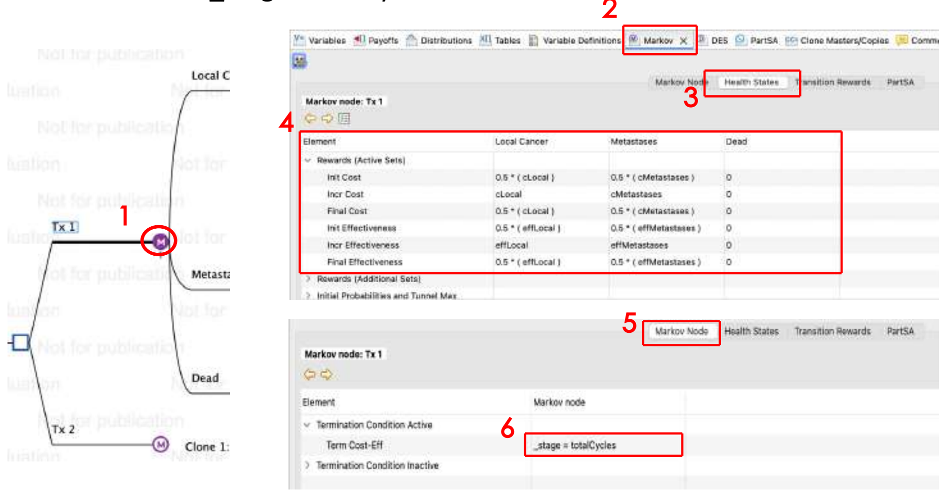
-startAge=50
-age= startAge+_stage



1. 選Variables
2. 改pDeathBackground的Root Definition
3. Group 選 Tables
4. 選tMortBackground
5. 在中括號中打 Age

Example 3-Markov Model Structure

- The half-cycle correction (0.5*outcome) can improve the accuracy of the results.
- Set termination:_stage=totalCycles

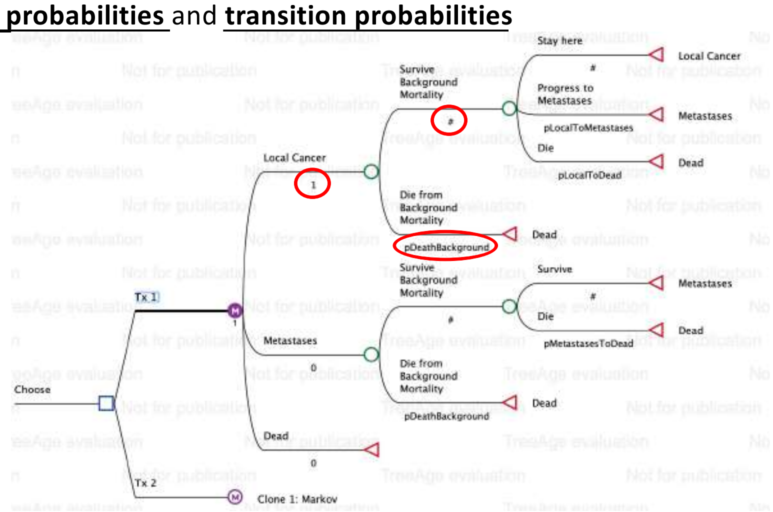


該模型現在遵循疾病進展，但我們仍需要添加成本和效用數值。
們可以透過 Markov State來完成這一步，並在任何健康狀態或事件節點上累積成本和效用

1. 需選擇Markov節點
2. 點Markov
3. 然後點 Health States
4. 輸入圖中相應的數值
5. 點 Markov Node
6. _stage=totalCycles

Example 3-Markov Model Structure

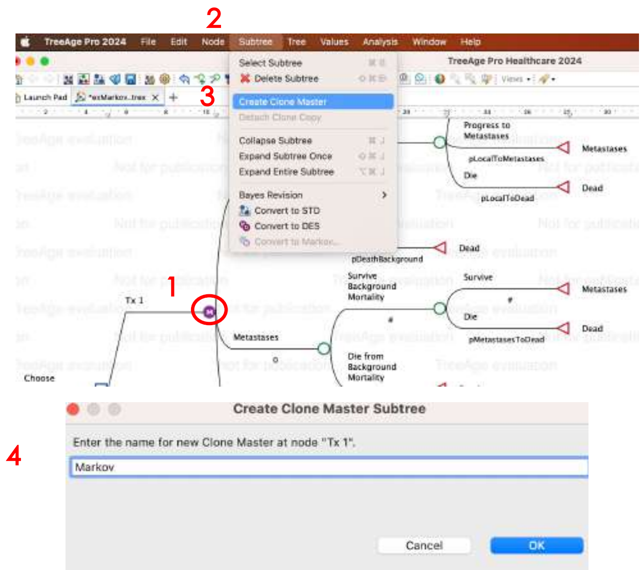
- Add **initial probabilities** and **transition probabilities**



每個患者路徑結束一個週期，選擇該路徑的患者必須返回到一個健康狀態以開始下一個週期。當你用終端節點結束每條路徑時，請選擇一個健康狀態作為下一週期的開始狀態。

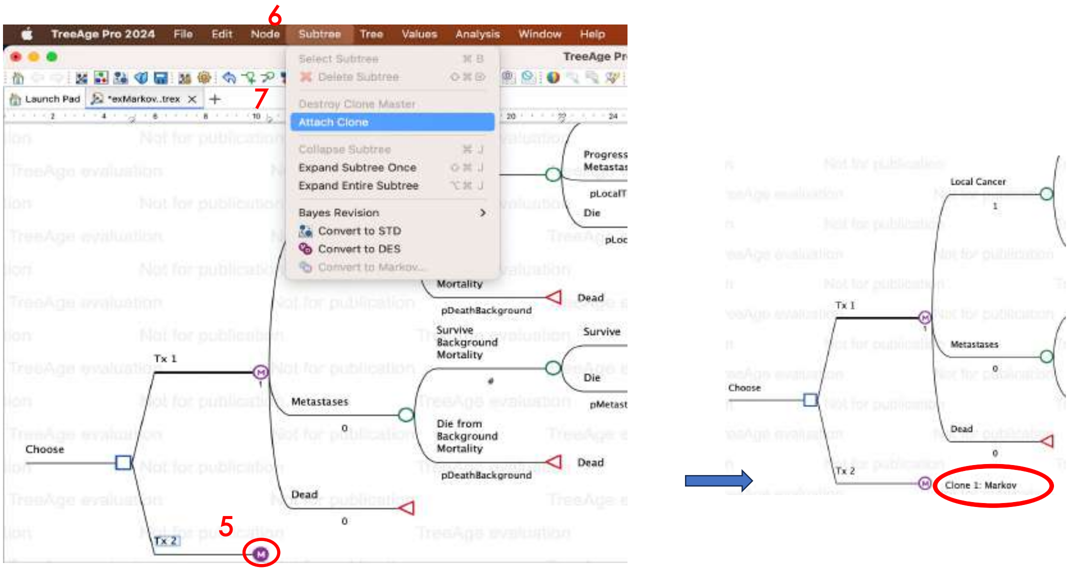
1. 點2下設定機率的地方
2. 選取Variables,選擇對應的機率（這是我們前面設定的）
3. 在另一個分支下方，我們輸入井號（#），表示互補機率，系統會自動計算1減去該概率的值。
4. 設定完以上機率

Example 3-Markov Model Structure-Create clone master



1. 點選Tx1Markov節點
2. 點Subtree
3. 點Create Clone Master
4. 輸入名稱

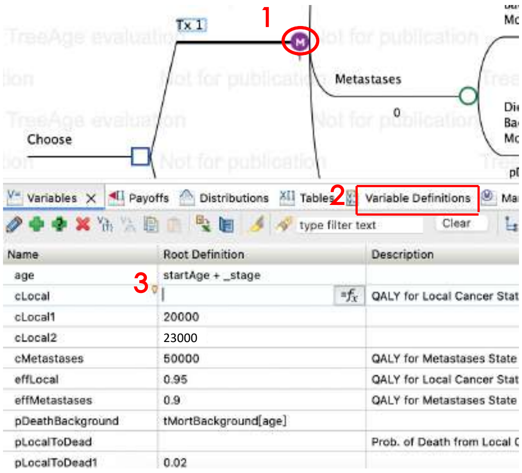
Example 3-Markov Model Structure-Attach clone to the Markove node of Tx2

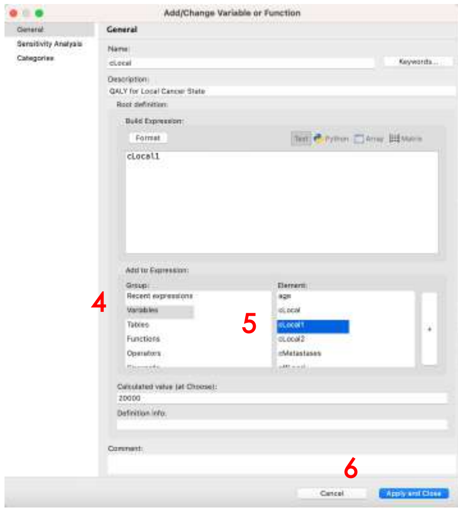


1. 點選Tx2Markov節點
2. 點Subtree
3. 點Attach Clone Master

Example 3-Markov Model Structure-Define variables

-Tx1: **cLoocal**= cLoocal1, **pLocalToDead**=pLocalToDead1

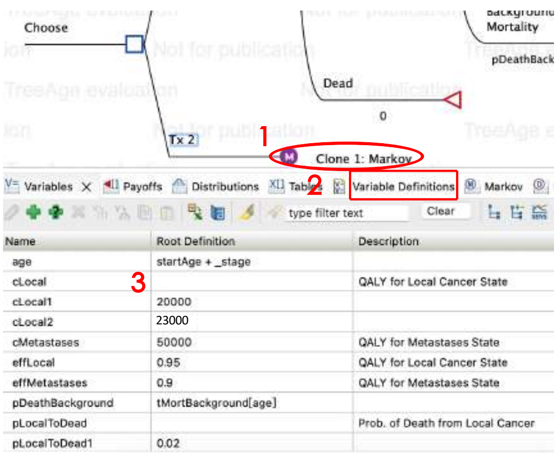


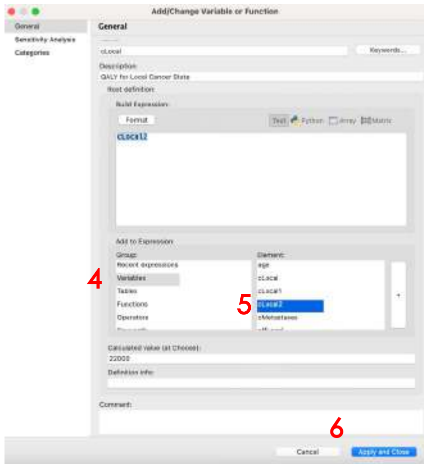


為避免待會在設定Tx2時，將Tx2被覆蓋掉，Tx1: cLocal= cLoocal1, pLocalToDead=pLocalToDead1 請在”Variable Definitions”進行設定

Example 3-Markov Model Structure-Define variables

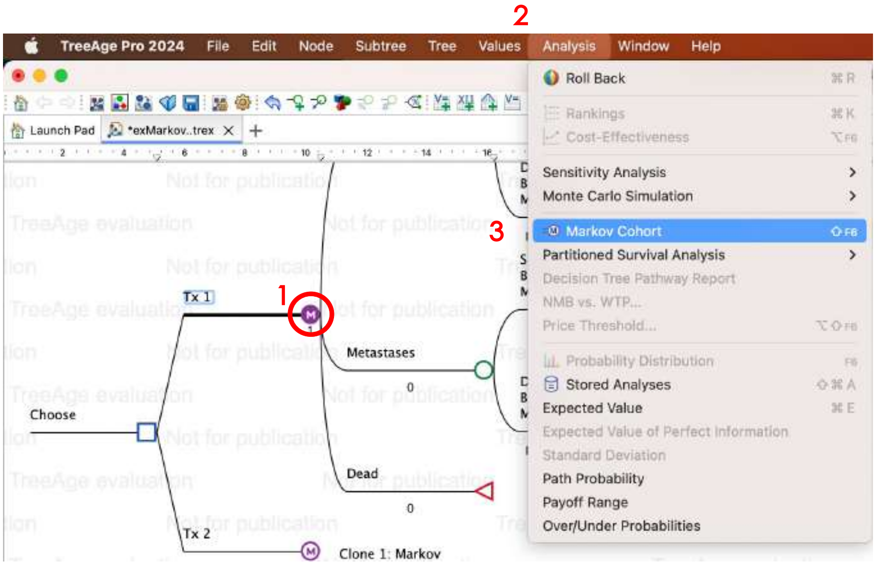
-Tx2: **cLoocal**= cLoocal2, **pLocalToDead**=pLocalToDead2



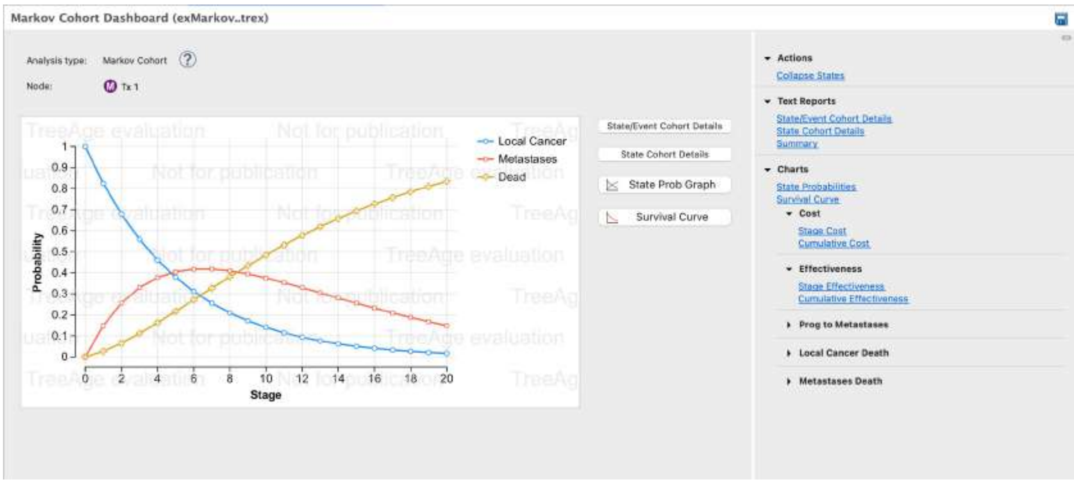


此頁同樣參照上頁的做法，在”Variable Definitions”設定 Tx2: cLoocal= cLoocal2, pLocalToDead=pLocalToDead2

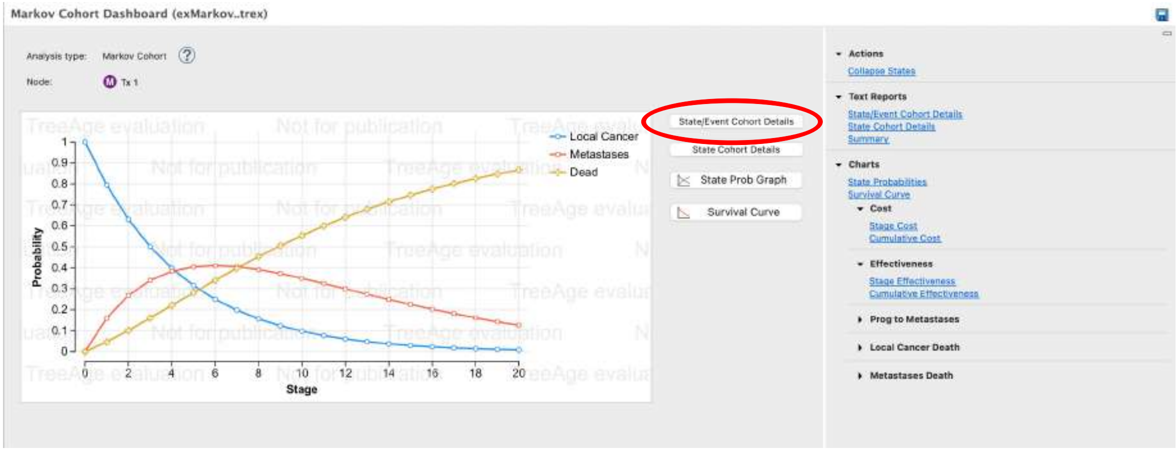
Example 3-Markov Model Structure-Check the model



Example 3-Markov Model Structure-Check the model



Example 3-Markov Model Structure-State/Event Cohort Details



Example 3-Markov Model Structure-State/Event Cohort Details

50yr background mortality=0.007

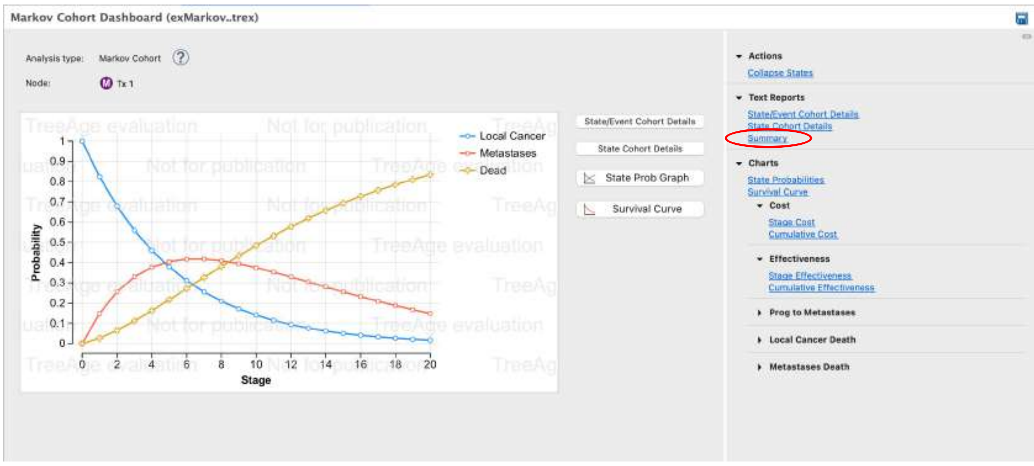
Markov Cohort Extended Report C/E (exMarkov..trex)

Half correction

State/Transition	Stage	Cohort %	Cost Entry	Cost	Cum Cost	Effectiveness Entry	Effectiveness	Cum Effectiveness	Prog to Metastases Entry	Prog to Metastases	Cum Prog to Metastases	Local Cancer Death Entry	Local Cancer Death	Cum Local Cancer Death	Metastases De Entry
Summary	0			10,000	10,000		0.48	0.48		0.159	0.159		0.040	0.040	
Local Cancer	0	1.000	10,000	10,000		0.48	0.48		0.000	0.000		0.000	0.000		0.000
Metastases	0	0.000	25,000	0		0.44	0.00		0.000	0.000		0.000	0.000		0.000
Dead	0	0.000	0	0		0.00	0.00		0.000	0.000		0.000	0.000		0.000
Summary	1			23,835	33,835		0.90	1.38		0.126	0.285		0.032	0.071	
Local Cancer	1	0.795	20,000	15,890		0.96	0.76		0.000	0.000		0.000	0.000		0.000
Metastases	1	0.159	50,000	7,945		0.88	0.14		0.000	0.000		0.000	0.000		0.000
Dead	1	0.047	0	0		0.00	0.00		0.000	0.000		0.000	0.000		0.000
Summary	2			26,025	59,860		0.84	2.22		0.100	0.385		0.025	0.096	
Local Cancer	2	0.631	20,000	12,618		0.96	0.61		0.000	0.000		0.000	0.000		0.000
Metastases	2	0.268	50,000	13,407		0.88	0.24		0.000	0.000		0.000	0.000		0.000
Dead	2	0.101	0	0		0.00	0.00		0.000	0.000		0.000	0.000		0.000
Summary	3			26,994	86,854		0.78	3.00		0.079	0.465		0.020	0.116	
Local Cancer	3	0.501	20,000	10,015		0.96	0.48		0.000	0.000		0.000	0.000		0.000
Metastases	3	0.340	50,000	16,979		0.88	0.30		0.000	0.000		0.000	0.000		0.000
Dead	3	0.160	0	0		0.00	0.00		0.000	0.000		0.000	0.000		0.000
Summary	4			27,070	113,923		0.72	3.72		0.063	0.528		0.016	0.132	
Local Cancer	4	0.397	20,000	7,945		0.96	0.38		0.000	0.000		0.000	0.000		0.000
Metastases	4	0.382	50,000	19,125		0.88	0.34		0.000	0.000		0.000	0.000		0.000
Dead	4	0.220	0	0		0.00	0.00		0.000	0.000		0.000	0.000		0.000
Summary	5			26,508	140,431		0.66	4.38		0.050	0.578		0.012	0.144	
Local Cancer	5	0.315	20,000	6,299		0.96	0.30		0.000	0.000		0.000	0.000		0.000
Metastases	5	0.404	50,000	20,209		0.88	0.36		0.000	0.000		0.000	0.000		0.000
Dead	5	0.281	0	0		0.00	0.00		0.000	0.000		0.000	0.000		0.000
Summary	6			25,505	165,936		0.60	4.98		0.040	0.617		0.010	0.154	
Local Cancer	6	0.250	20,000	4,992		0.96	0.24		0.000	0.000		0.000	0.000		0.000
Metastases	6	0.410	50,000	20,513		0.88	0.36		0.000	0.000		0.000	0.000		0.000
Dead	6	0.340	0	0		0.00	0.00		0.000	0.000		0.000	0.000		0.000

模型中的機率與群體百分比相對應，因此在每個週期中，每個健康狀態中的群體百分比由模型中的機率決定。
整個群體根據治療一中健康狀態的初始機率從局部癌症狀態開始。

Example 3-Markov Model Structure-Summary



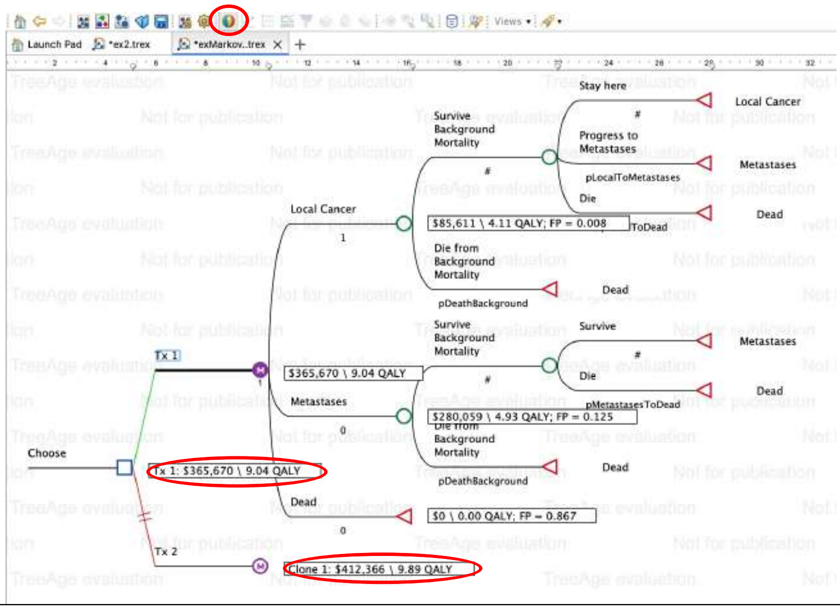
點選右方工作區域的“Summary”

Example 3-Markov Model Structure-Summary

Markov Cohort Summary Report (exMarkov..trex)

Stage	% - Local Cancer	% - Metastases	% - Dead	Cost	Cum Cost	Effectiveness	Cum Effectiveness	Prog to Metastases	Cum Prog to Metastases	Local Cancer Death	Cum Local Cancer Death	Metastases Death	Cum Metastases Death
0	1.000	0.000	0.000	10,000	10,000	0.48	0.48	0.159	0.159	0.040	0.040	0.000	0.000
1	0.795	0.159	0.047	23,835	33,835	0.90	1.38	0.126	0.285	0.032	0.071	0.016	0.016
2	0.631	0.268	0.101	26,025	59,860	0.84	2.22	0.100	0.385	0.025	0.096	0.027	0.042
3	0.501	0.340	0.160	26,994	86,854	0.78	3.00	0.079	0.465	0.020	0.116	0.034	0.076
4	0.397	0.382	0.220	27,070	113,923	0.72	3.72	0.063	0.528	0.016	0.132	0.038	0.114
5	0.315	0.404	0.281	26,508	140,431	0.66	4.38	0.050	0.578	0.012	0.144	0.040	0.154
6	0.250	0.410	0.340	25,505	165,936	0.60	4.98	0.040	0.617	0.010	0.154	0.041	0.195
7	0.198	0.405	0.398	24,190	190,126	0.55	5.53	0.031	0.648	0.008	0.162	0.040	0.235
8	0.156	0.391	0.453	22,680	212,805	0.49	6.02	0.025	0.673	0.006	0.168	0.039	0.273
9	0.123	0.372	0.505	21,063	233,869	0.45	6.47	0.019	0.692	0.005	0.173	0.037	0.310
10	0.097	0.349	0.554	19,408	253,276	0.40	6.87	0.015	0.708	0.004	0.177	0.034	0.344
11	0.076	0.325	0.599	17,761	271,037	0.36	7.23	0.012	0.720	0.003	0.180	0.032	0.376
12	0.060	0.299	0.641	16,160	287,197	0.32	7.55	0.009	0.729	0.002	0.182	0.029	0.405
13	0.047	0.274	0.679	14,627	301,824	0.29	7.83	0.007	0.737	0.002	0.184	0.027	0.432
14	0.037	0.249	0.714	13,180	315,004	0.25	8.09	0.006	0.742	0.001	0.186	0.024	0.457
15	0.029	0.225	0.746	11,827	326,831	0.23	8.31	0.005	0.747	0.001	0.187	0.022	0.479
16	0.023	0.202	0.775	10,574	337,405	0.20	8.51	0.004	0.750	0.001	0.188	0.020	0.498
17	0.018	0.181	0.801	9,404	346,809	0.18	8.69	0.003	0.753	0.001	0.188	0.018	0.516
18	0.014	0.161	0.825	8,321	355,131	0.15	8.84	0.002	0.755	0.001	0.189	0.016	0.531
19	0.011	0.142	0.847	7,328	362,459	0.14	8.98	0.002	0.757	0.000	0.189	0.014	0.545
20	0.008	0.125	0.867	3,212	365,670	0.06	9.04	0.000	0.757	0.000	0.189	0.000	0.545

Example 3-Markov Model Structure-Roll Back



Example 3-Markov Model Structure-Ranking

- 取消Roll Back/Analysis/Ranking

Cost-Effectiveness Rankings Report (exMarkov..trex)

Category	Strategy	Cost	Incr. Cost	Effectiveness	Incr. Effectiveness	ICER (IC/IE)	NMB	Prog to Metastases	Local Cancer Death	Metastases Death
All (no dominance)										
undominated	Tx 1	$365,670		9.04 QALY			$86,248	0.757	0.189	0.545
undominated	Tx 2	$412,366	$46,695	9.89 QALY	0.86 QALY	$54,515	$82,381	0.831	0.104	0.589

Willingness to Pay (WTP) for a unit of benefit =50,000

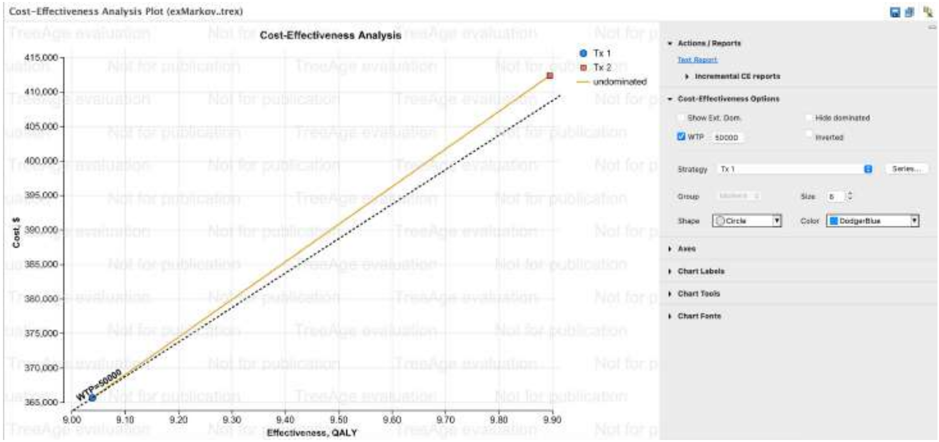
Net Monetary Benefits (NMB) = Effectiveness * WTP - Cost 淨貨幣效益

(Tx1: 9.04*50,000-365,670)

Net Health Benefits (NHB) = Effectiveness - Cost / WTP 淨健康效益

Example 3-Markov Model Structure-Results of cost-effectiveness

- Results of cost-effectiveness
  Analysis / cost-effectiveness/WTP

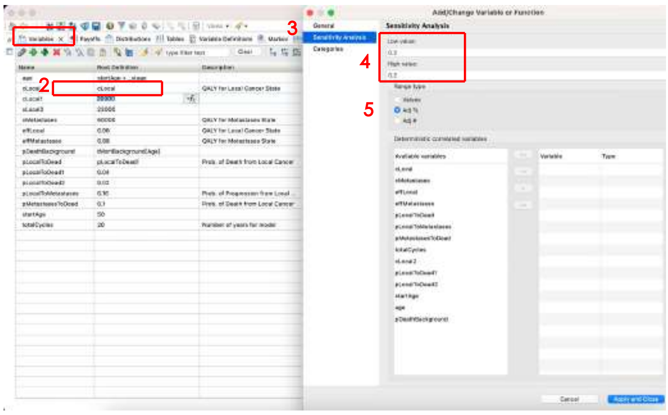


Example 3-Markov Model Structure-One way Sensitive analysis

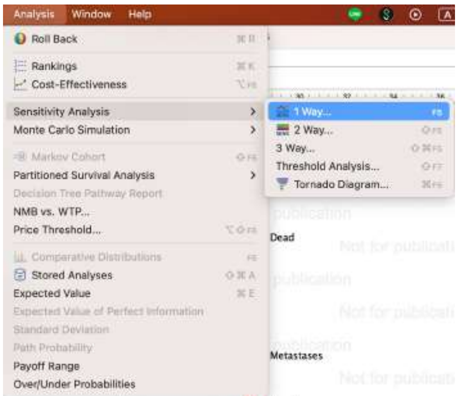
- One way Sensitive analysis

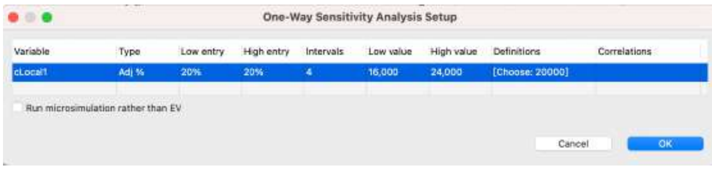
  Define low/ high value

variable	value
cLocal1	20000(+/-20%)
cLocal2	23000(+/-20%)
cMetastases	50000(+/-20%)



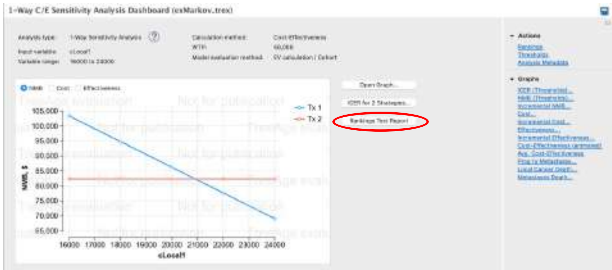
Example 3-Markov Model Structure-One way Sensitive analysis





6

Example 3-Markov Model Structure-One way Sensitive analysis



WTP=50,000

Tx1 is the optimal strategy

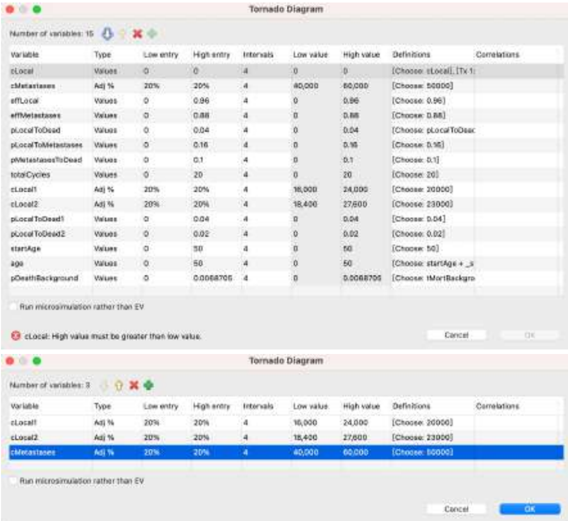
Tx2 is the optimal strategy

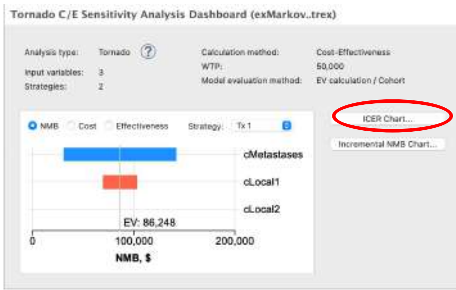
1-Way Sensitivity Analysis – C/E Text Report (exMarkov_trex)

cLocal1	Strategy	Cost	Incr. Cost	Effectiveness	Incr. Effectiveness	ICER	NMB	C/E	Dominance	Prog to Metastases	Local Cancer Death	Metastases Death
16,000												
16,000	Tx 1	348,548	0	9.04	0.00	0	103,370	38,563		0.757	0.189	0.545
16,000	Tx 2	412,366	63,818	9.89	0.86	74,504	82,381	41,674		0.831	0.104	0.589
18,000												
18,000	Tx 1	357,109	0	9.04	0.00	0	94,809	39,510		0.757	0.189	0.545
18,000	Tx 2	412,366	55,256	9.89	0.86	64,510	82,381	41,674		0.831	0.104	0.589
20,000												
20,000	Tx 1	365,670	0	9.04	0.00	0	86,248	40,458		0.757	0.189	0.545
20,000	Tx 2	412,366	46,695	9.89	0.86	54,515	82,381	41,674		0.831	0.104	0.589
22,000												
22,000	Tx 1	374,231	0	9.04	0.00	0	77,687	41,405		0.757	0.189	0.545
22,000	Tx 2	412,366	38,134	9.89	0.86	44,520	82,381	41,674		0.831	0.104	0.589
24,000												
24,000	Tx 1	382,792	0	9.04	0.00	0	69,126	42,352		0.757	0.189	0.545
24,000	Tx 2	412,366	29,573	9.89	0.86	34,525	82,381	41,674		0.831	0.104	0.589

Example 3-Markov Model Structure-Tornado Diagrams

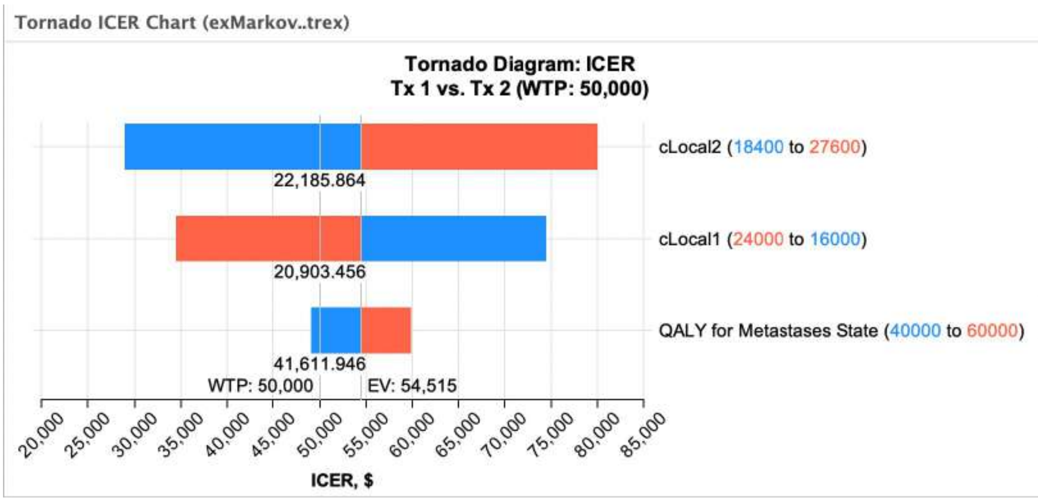
1





1. 將不需要的數據按 X 刪掉
2. 只留下3個需要的數值
3. 按ICER Chart

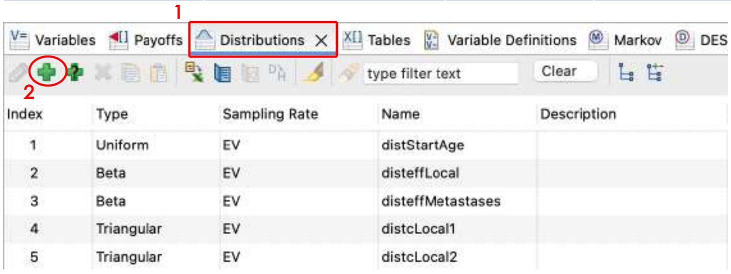
Example 3-Markov Model Structure-Tornado Diagrams



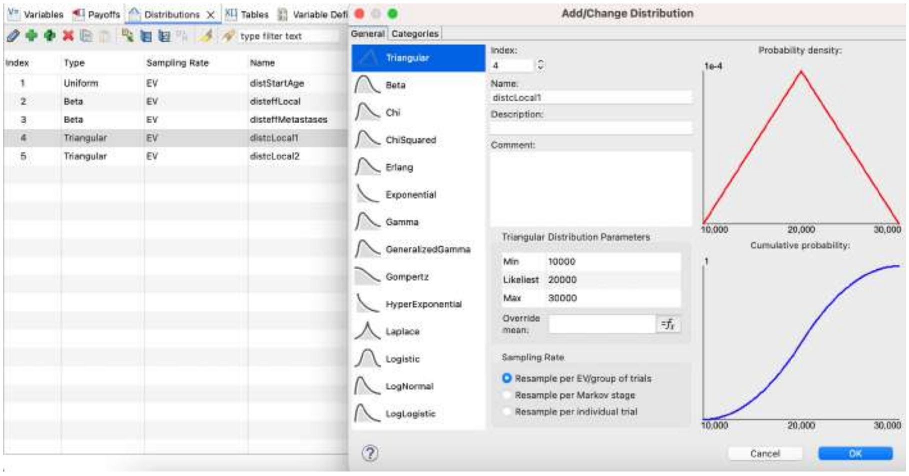
上圖 Tornado ICER 是用於比較兩種治療方案 (Tx 1 和 Tx 2) 的增量成本效果比 (ICER)，並顯示不同變數對 ICER 的影響。圖表顯示了三個變數（cLocal2、cLocal1 和 QALY for Metastases State）對 ICER 的敏感度分析。每個變數的藍色和紅色區域表示該變數在不同範圍內的影響，範圍數值括號內顯示（例如，cLocal2 從 18,400 到 27,600）。ICER 基於 50,000 美元的支付意願 (WTP) 線進行分析。當 ICER 小於 WTP 時，表示該策略更具成本效益！

Example 3-PSA-Set up distribution for 5 variables

Variable	New name	distribution	parameters
StartAge	distStartAge	Uniform	Min=5 ,Max=30
effLocal	disteffLocal	Beta	Mean=0.96,SD=0.03
effMetastases	disteffMetastases	Beta	Mean=0.88, SD=0.02
cLocal1	distcLocal1	Triangular	min=10,000 ,Likeliest=20,000,Max=30,000
cLocal2	distcLocal2	Triangular	min=16,000, Likeliest=23,000,Max=34,000



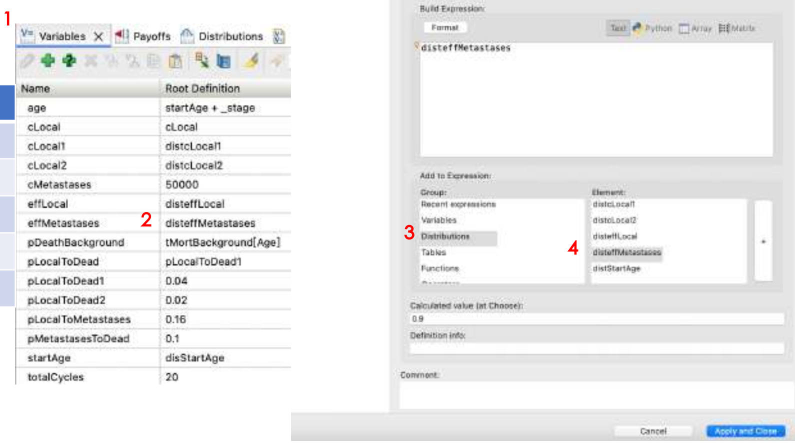
Example 3-PSA-Set up distribution for 5 variables



設定 Type of Distribution，再輸入Min, Likeliest, Max數值

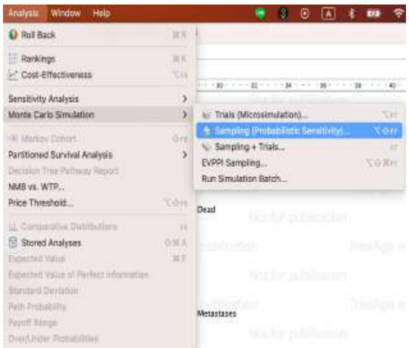
Example 3-PSA-Change 5 variable’s root definition

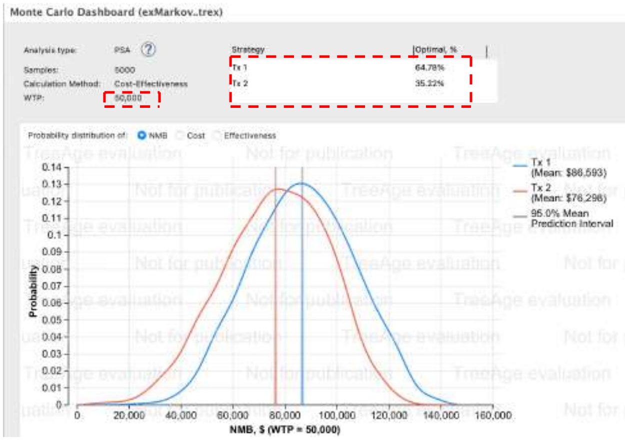
Variable	New name
StartAge	distStartAge
effLocal	disteffLocal
effMetastases	disteffMetastases
cLocal1	distcLocal1
cLocal2	distcLocal2



Example 3-PSA-Monte Carlo Dashboard

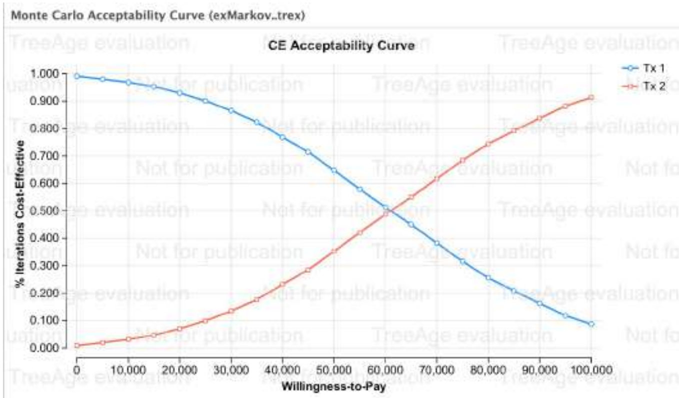
Analysis/Monte Carlo Simulation/ Sampling/sample:5000





Example 3-PSA-Monte Carlo Acceptability Curve

CEAC/Text Report

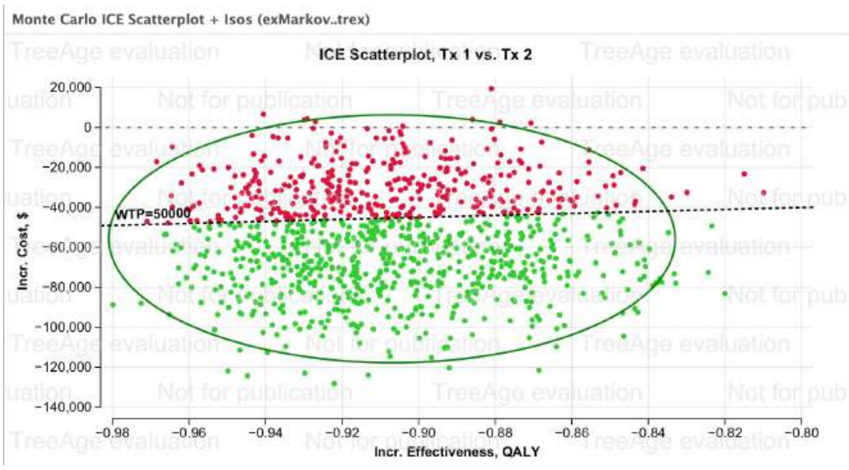


Monte Carlo Acceptability Text (e:

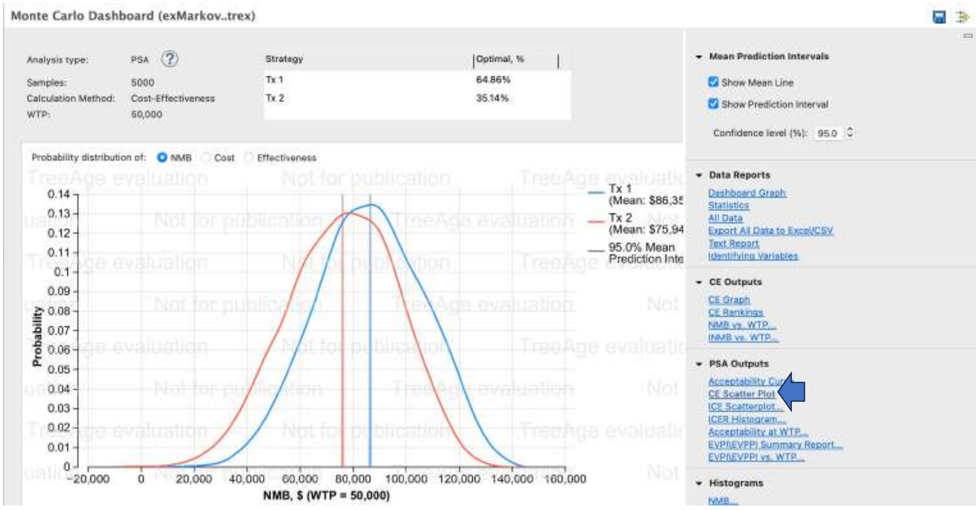
Willingness-to-Pay	Strategy	Acceptability
0	Tx 1	0.991
0	Tx 2	0.009
5,000	Tx 1	0.9802
5,000	Tx 2	0.0198
10,000	Tx 1	0.9684
10,000	Tx 2	0.0316
15,000	Tx 1	0.953
15,000	Tx 2	0.047
20,000	Tx 1	0.9296
20,000	Tx 2	0.0704
25,000	Tx 1	0.9008
25,000	Tx 2	0.0992
30,000	Tx 1	0.8654
30,000	Tx 2	0.1346
35,000	Tx 1	0.8234
35,000	Tx 2	0.1766
40,000	Tx 1	0.7684
40,000	Tx 2	0.2316
45,000	Tx 1	0.7146
45,000	Tx 2	0.2854
50,000	Tx 1	0.6478
50,000	Tx 2	0.3522
55,000	Tx 1	0.5792
55,000	Tx 2	0.4208
60,000	Tx 1	0.5126
60,000	Tx 2	0.4874
65,000	Tx 2	0.5496
65,000	Tx 1	0.4504
70,000	Tx 2	0.6174
70,000	Tx 1	0.3826
75,000	Tx 2	0.6842

Example 3-PSA-Monte Carlo ICE Scatterplot : Tx1 vs.Tx2

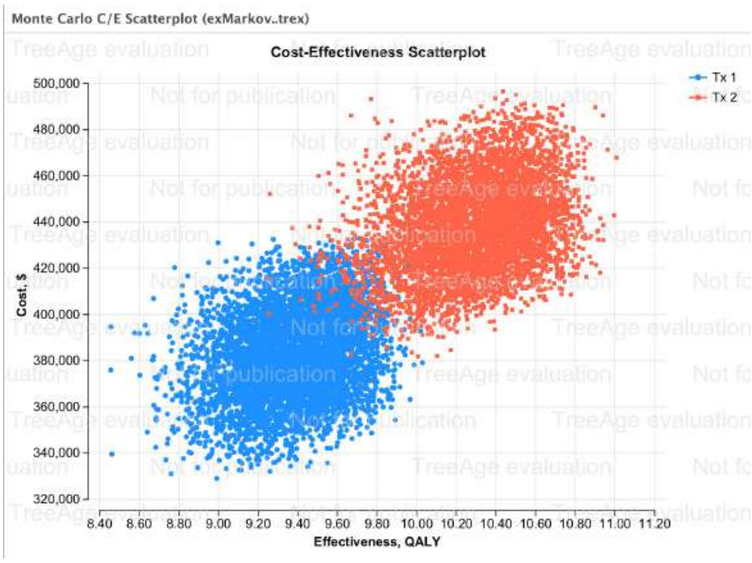
64.78% favored Tx1



Example 3-PSA



Example 3-PSA-C/E Scatterplot



上圖為成本效益散佈圖，呈現出兩種治療方案 (Tx 1 與 Tx 2) 的成本與效果比較。
橫軸為效果（QALY 生活品質調整生命年數），縱軸為成本（美元）。藍色點代表治療方案 Tx 1，紅色點代表 Tx 2。可以觀察到 Tx 1 的成本較低且效果略低，而 Tx 2 的成本和效果都較高。

Example 3- Discount

The Global Discounting worksheet has the discount rate which needs to be applied to each payoff, each cycle (_stage). The discount rate formula is given below:

$$\frac{1}{(1+rate)^{time}}$$

•**No Discount**: The value of the payoff before discounting based on State Details worksheets. All payoffs will have a No Discount column.

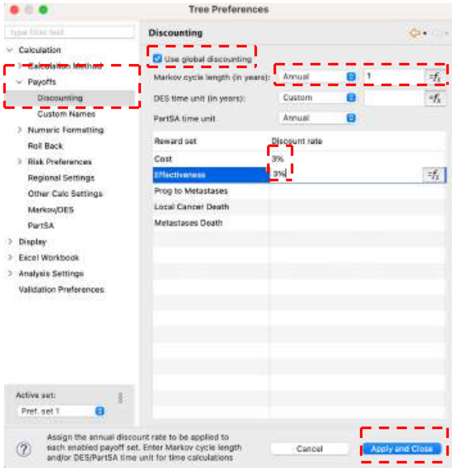
•**Discounted:** This only appears if the payoff is discounted. It is the payoff amount for this cycle with discounting applied.

•**Cum Disc:** This is the cumulative value of the payoffs as the cycle (_stage) increases. If the payoff has been discounted it uses the discounted values.

Example 3- Discount

If the Markov Model has Global Discounting turned on, then the *Strategy Results* worksheet changes and there is an additional *Global Discounting* worksheet.
In the Health Care Tutorial Example, Markov Conversion Model Discounting .trex, global discounting is already setup on for the cost and effectiveness payoffs with a discount rate of 3% through the variable integrate. See below.

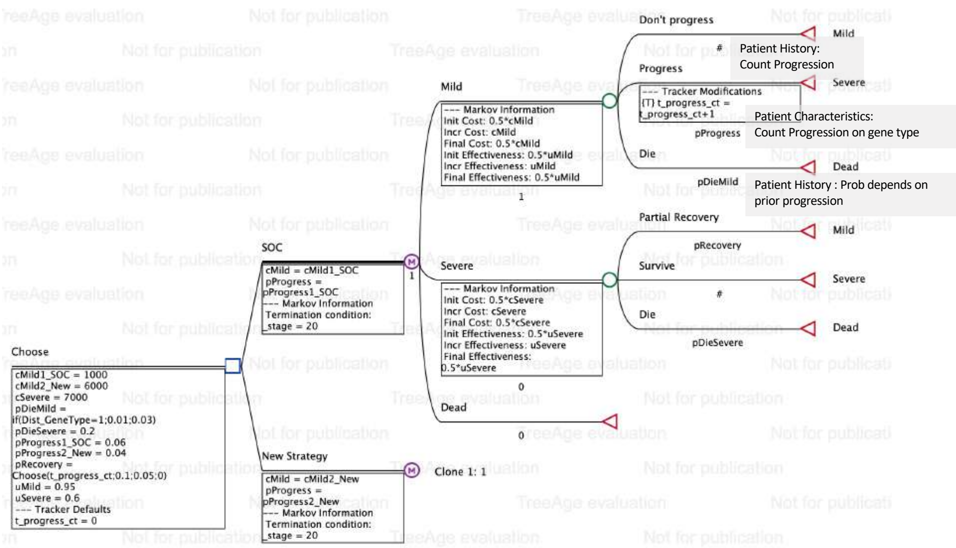
Tree/TreePreferences/Payoffs/Discounting



點Tree /選 Tree Preferences / Payoffs / Discounting
依照上圖設定

❑ 單元九:
TreeAge Microsimulation

Example 4-Patient Level Simulation



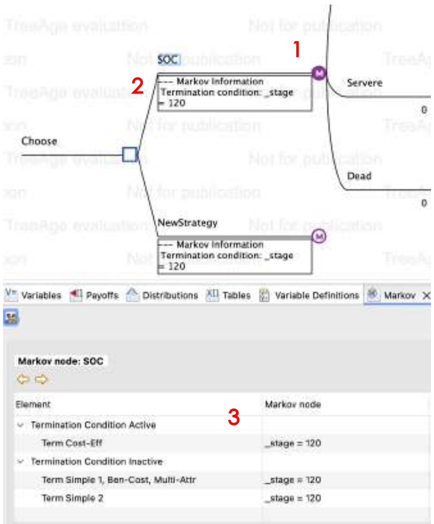
病人特徵（如基因類型）和進展歷史會影響模型中的結果。例如，不同基因類型改變死亡機率，而先前的進展事件會影響恢復的可能性。某些疾病需要比群體模型更高的靈活性，Microsimulation Model 擴展了群體模型，更靈活地代表複雜的疾病進展。具體來說，患者模擬允許添加患者特徵，例如：年齡、性別、種族，以及患者病史，包括：不良事件、疾病進展和感染等，病人特徵（如：基因類型）和進展歷史會影響模型中的結果。例如，不同基因類型改變死亡機率，而先前的進展事件會影響恢復的可能性。這些特定的患者及數據可能影響模型中的任何數值，如：機率、成本和效用。

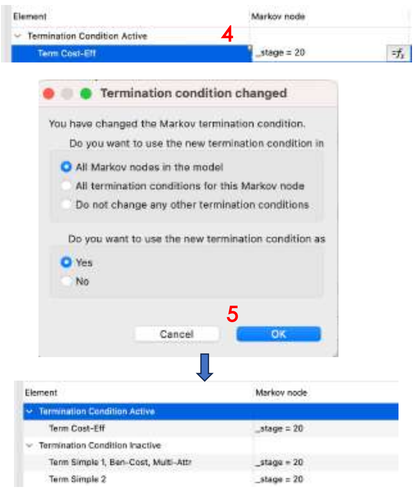
Example 4-Patient Level Simulation

Variable name	Variable
cMild	
cMild1_SOC	1000
cMild2_New	6000
cSevere	7000
pDieMild	0.02
pDieSevere	0.2
pProgress	
pProgress1_SOC	0.06
pProgress2_New	0.04
pRecovery	0.1
uMild	0.95
pSevere	0.6

先依上一頁做架構，再於Variables設置表格數值，並在架構中設定機率

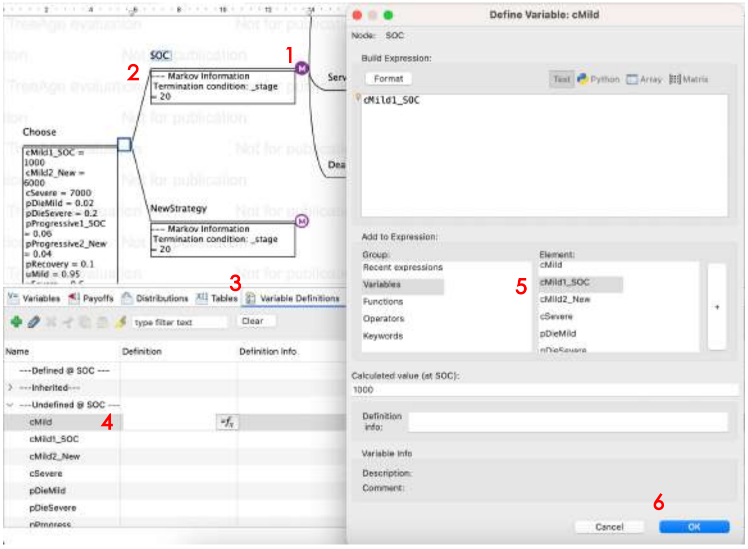
Example 4-Patient Level Simulation



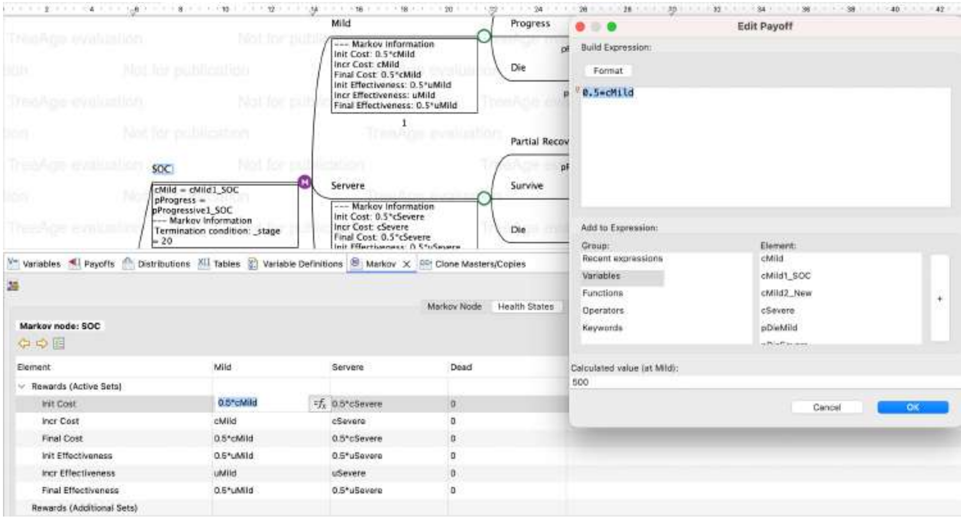


Example 4-Patient Level Simulation

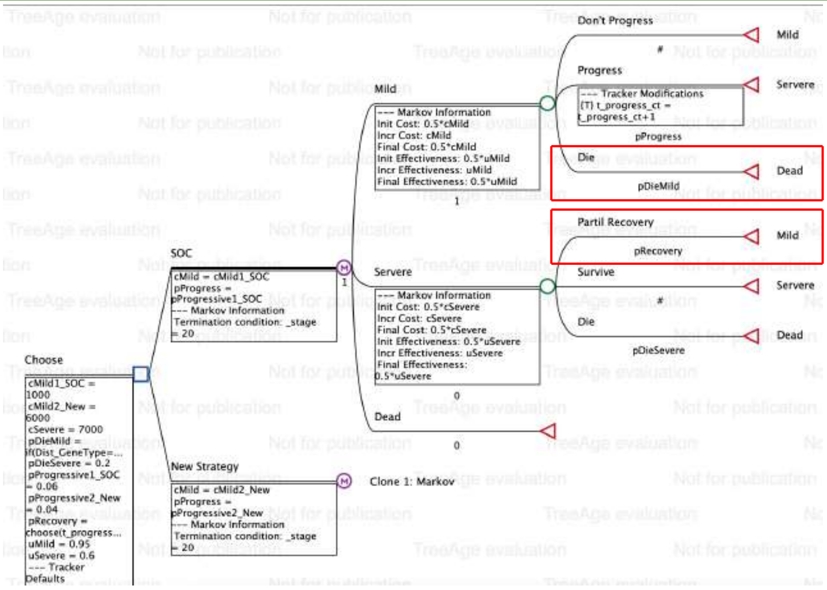
SOC	NewStrategy
cMild=cMild1_SOC	cMild=cMild1_New
pProgress=pProgress1_SOC	pProgress=pProgress2_New



Example 4-Patient Level Simulation



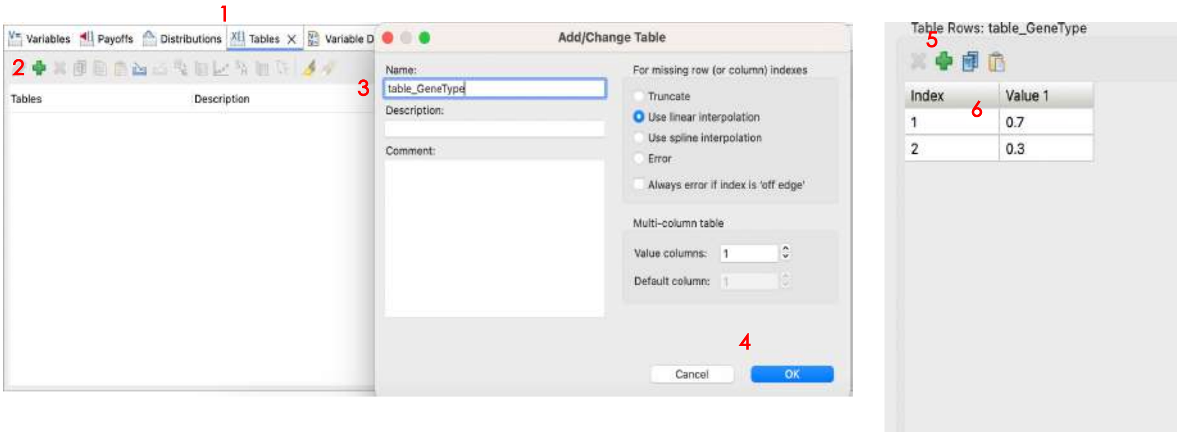
Example 4-Patient Level Simulation



此模型包括有關基因型的人口統計數據、影響死亡風險等機率。Tracker會計算患者歷經不同階段的頻率，其影響了從嚴重狀態中恢復等機率。

Example 4-Patient Level Simulation

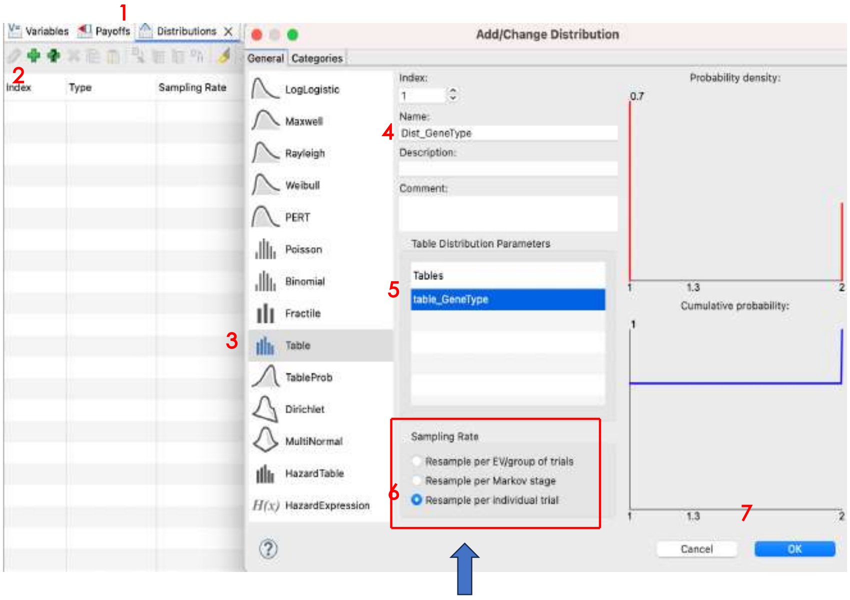
This is loaded in a table seventy percent of the population have gene type one and thirty percent of the population have gene type two the table gene type stores the demographic data in the model.



在此模型中，遇到一個問題為死亡機率取決於患者的基因類型，因此建立模型需要知道知道患者的特徵。

我們有描述患者人群基因類型的數據，這些數據存儲在表格中，顯示70% 的人群為基因類型一，30% 的人群為基因類型二。表格“gene type”在模型中儲存這些人口統計數據，並使用分布來為每位患者分配特定的基因類型。

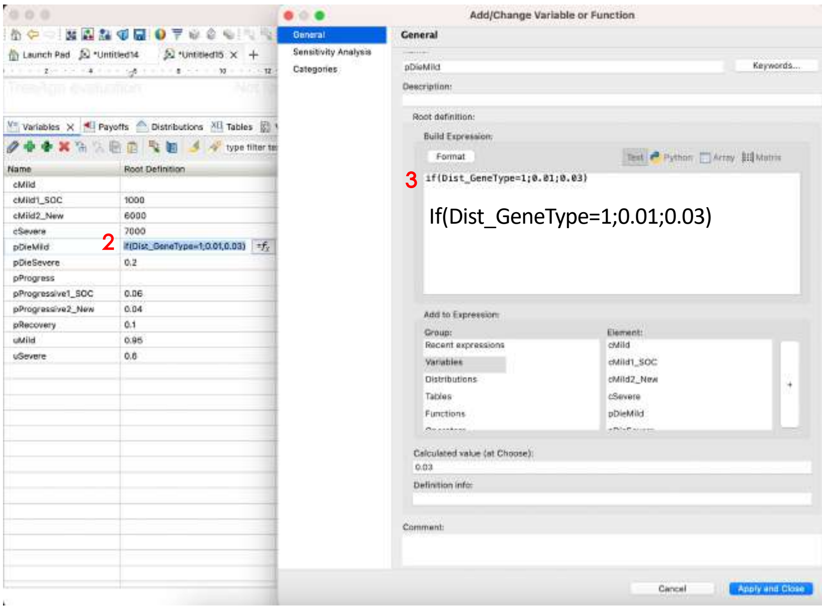
Example 4-Patient Level Simulation



根據人口統計數據中基因類型的分佈，使用一個分佈來為每位患者分配一個特定的基因類型。我們使用的分佈來源於一張表格，該表格總結並表示了適當的基因類型分佈。

當模型運行時，將根據分佈為每位模擬患者分配一個基因類型。隨後，每當基因類型在模型中對患者產生影響時，就可以參照該分佈。

Example 4-Patient Level Simulation

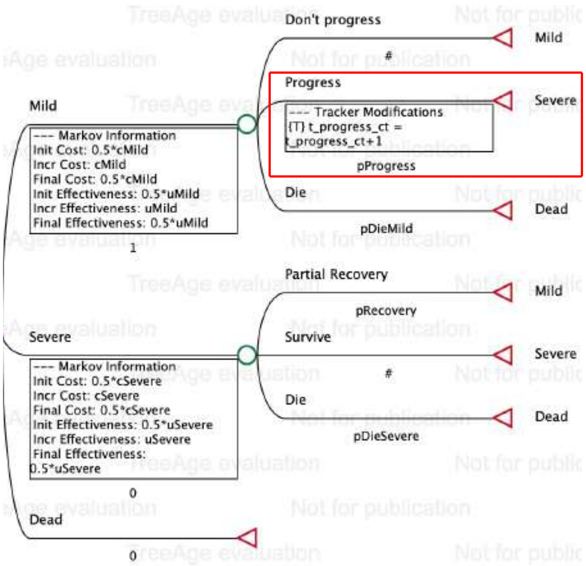


在模型中，如果要根據患者特徵（如基因類型）動態調整某個事件（如死亡）的機率，可以使用條件語句 if函數來改變機率。這樣可以根據不同的基因類型或特徵設定不同的機率數值。

GeneType=1,pDieMild=0.01

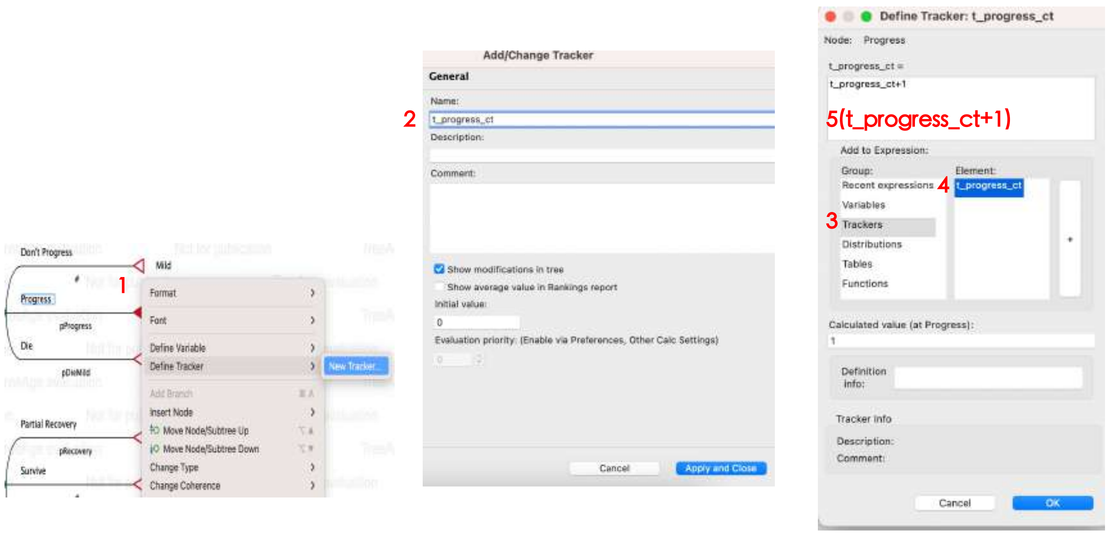
GeneType=2,pDieMild=0.03

Example 4-Patient Level Simulation-The Tracker



在這個模型中，患者從「輕度」狀態進展到「重度」狀態的次數會影響他們從重度狀態恢復的機率。因此，我們需要追蹤並記錄患者從輕度到重度的進展次數，以便用於動態調整恢復的機率。

Example 4-Patient Level Simulation-The Tracker

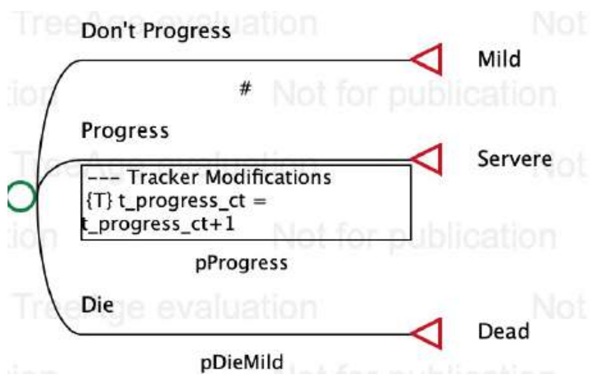


在此模型中，患者從輕度進展到重度的次數會影響其從重度狀態恢復的機率，因此我們需要使用追蹤器(Tracker)記錄這種進展病史。Tracker可以記錄任何類型的患者病史，包括事件是否發生、發生次數和最後一次發生的時間。

在進展事件模式中，我們創建了一個Tracker來計數患者的進展次數。

Example 4-Patient Level Simulation-The Tracker

Trackers record progression history, increasing by one each time a patient progresses. The progression count is referenced to adjust recovery probabilities, with limits set as progression increases.

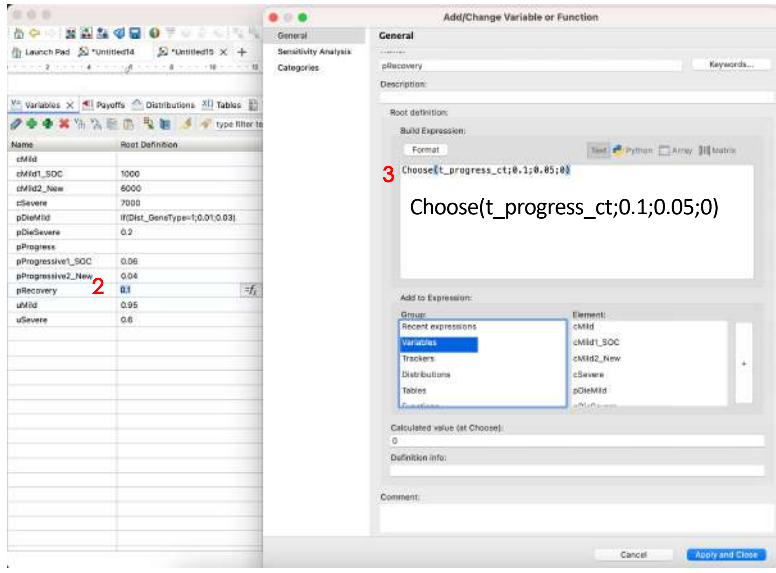


每次試驗通過該節點時，t progress 的值增加一，生成進展次數

Example 4-Patient Level Simulation-The Tracker

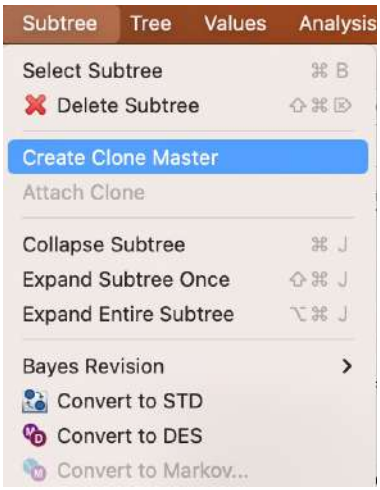
t_progress_ct=1,pRecovery=0.1
t_progress_ct=2,pRecovery=0.05
t_progress_ct=3,pRecovery=0

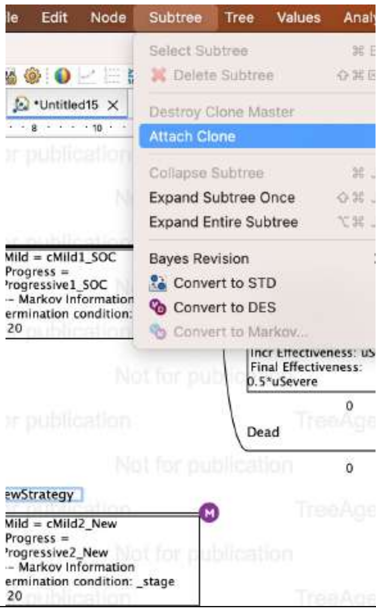
當追蹤器為1時，將返回值0.1；
當追蹤器為2時，將返回值0.05；
當追蹤器進展計數為3時，恢復
率將為0，且不再可能恢復。



Example 4-Patient Level Simulation

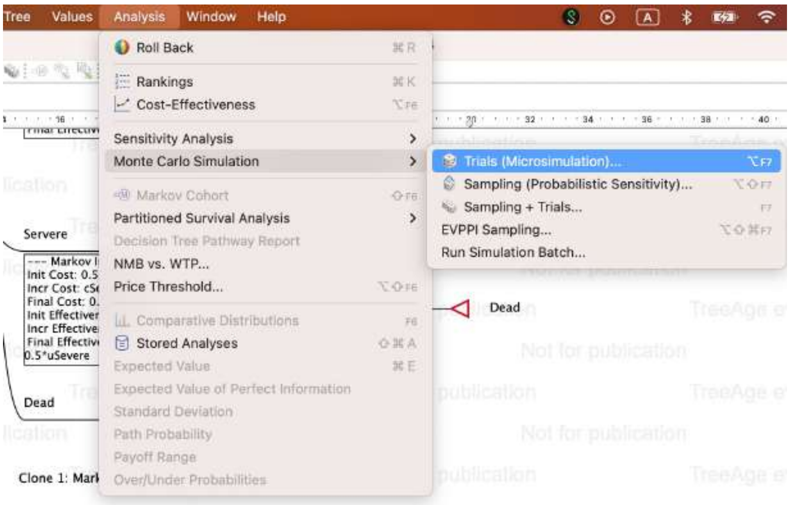
1. Clone SOC
2. Attach NewStrategy





Example 4-Patient Level Simulation

Simulated patients go through the model, with pathways chosen based on probabilities. Monte Carlo simulations with 10,000 trials generate average cost and effectiveness data for comparison between strategies.



Example 4-Patient Level Simulation

Monte Carlo Summary Text Report (Untitled15)

Attribute	Statistic	SOC	NewStrategy
Cost	Mean	26805.80	89637.45
Cost	Std Deviation	18408.36	39026.75
Cost	Minimum	500.00	3000.00
Cost	2.5%	1500.00	9000.00
Cost	10%	7500.00	27000.00
Cost	Median	20000.00	118000.00
Cost	90%	51500.00	122000.00
Cost	97.5%	77000.00	126500.00
Cost	Maximum	137000.00	137000.00
Cost	Sum	268058000.00	896374500.00
Cost	Size (n)	10000.00	10000.00
Cost	Variance	338867786.36	1523087082.50
Cost	Variance/Size	33886.78	152308.71
Cost	SQRT[Variance/Size]	184.08	390.27
Cost	95% Lower Bound	26445.00	88872.54
Cost	95% Upper Bound	27166.60	90402.36
Eff	Mean	12.21	13.37
Eff	Std Deviation	6.25	6.20
Eff	Minimum	0.47	0.47
Eff	2.5%	1.07	1.07
Eff	10%	2.98	3.33
Eff	Median	13.57	16.52
Eff	90%	19.00	19.00
Eff	97.5%	19.00	19.00
Eff	Maximum	19.00	19.00
Eff	Sum	122063.30	133685.63
Eff	Size (n)	10000.00	10000.00
Eff	Variance	39.05	38.48
Eff	Variance/Size	0.00	0.00
Eff	SQRT[Variance/Size]	0.06	0.06
Eff	95% Lower Bound	12.08	13.25

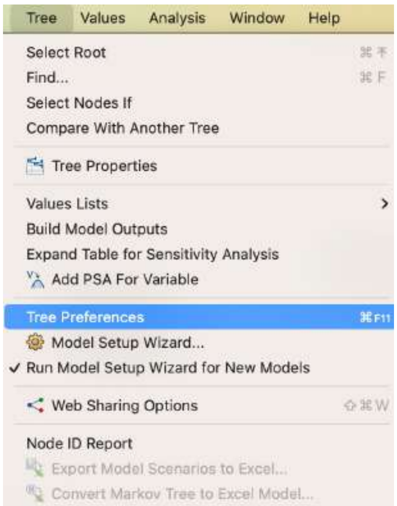
每位患者將經過模型並累積總成本和效果值，然後將每位患者的結果彙總為平均值，以提供每位患者的平均成本和效果。在微觀模擬模型中，我們仍然需要做出最佳決策。

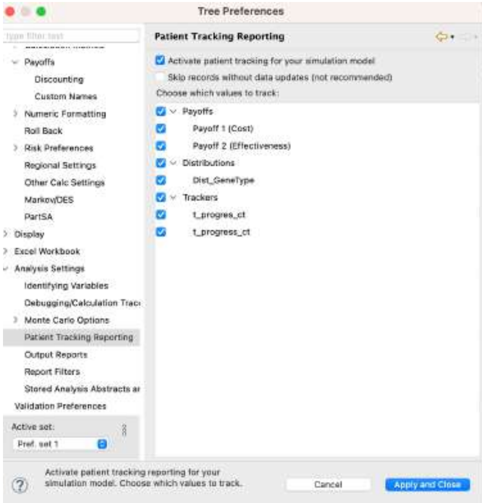
Monte Carlo C/E Rankings Report (Untitled15)

Category	Strategy	Cost	Incr. Cost	Effectiveness	Incr. Effectiveness	ICER (IC/IE)	NMB
All (no dominance)							
undominated	SOC	26805.80		12.21			-26805.80
undominated	NewStrategy	89637.45	62831.65	13.37	1.16	54061.17	-89637.45

得到患者模擬結果，就可以使用每位患者的平均值通過排名和成本效益比較策略。圖表中的排名格式與群體分析結果相同，仍然會得到增量成本效益比（ICER）和淨貨幣效益（NMB）值，以識別最具成本效益的策略。

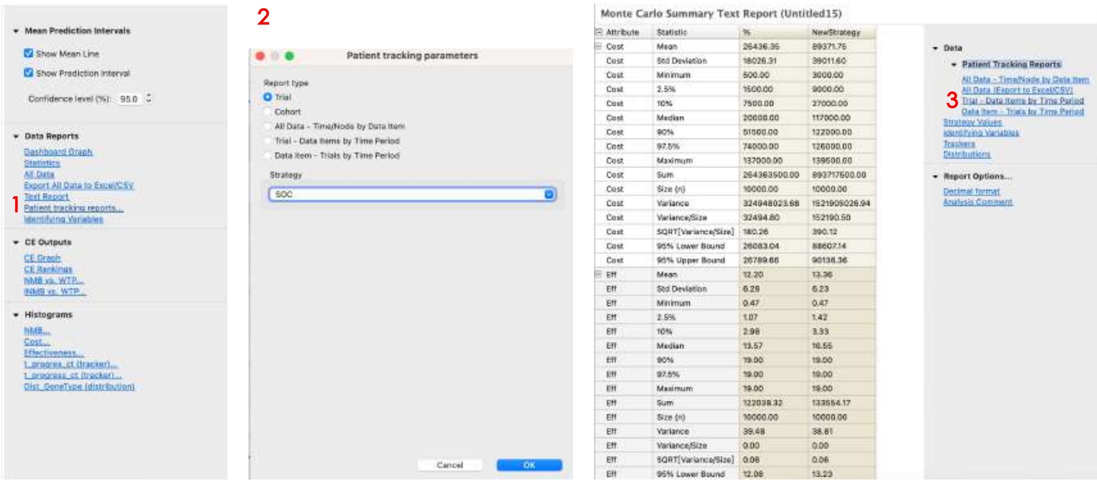
Example 4-Patient Level Simulation





在Markov cohort中，患者追蹤報告展示了單個患者及整體cohort flow情況，確保了模型的透明性。要啟用患者追蹤功能，需要在Tree preferences中的分析選項裡進行設置。運行分析後，我們將能夠獲取新的患者追蹤報告以進行檢查。

Example 4-Patient Level Simulation



Attribute	Statistic	%	NewStrategy
Cost	Mean	26436.36	89371.75
Cost	Std Deviation	18026.31	39011.60
Cost	Minimum	500.00	3000.00
Cost	2.5%	1500.00	9000.00
Cost	10%	7500.00	27000.00
Cost	Median	20000.00	117000.00
Cost	90%	51500.00	122000.00
Cost	97.5%	74000.00	126000.00
Cost	Maximum	137000.00	139500.00
Cost	Sum	264363500.00	893717500.00
Cost	Size (n)	10000.00	10000.00
Cost	Variance	324948023.68	1521905026.94
Cost	Variance/Size	32494.80	152190.50
Cost	SQRT[Variance/Size]	180.26	390.12
Cost	95% Lower Bound	26083.04	88607.14
Cost	95% Upper Bound	26789.66	90136.36
Eff	Mean	12.20	13.36
Eff	Std Deviation	6.28	6.23
Eff	Minimum	0.47	0.47
Eff	2.5%	1.07	1.42
Eff	10%	2.98	3.33
Eff	Median	13.57	16.56
Eff	90%	19.00	19.00
Eff	97.5%	19.00	19.00
Eff	Maximum	19.00	19.00
Eff	Sum	122038.32	133554.17
Eff	Size (n)	10000.00	10000.00
Eff	Variance	39.48	38.81
Eff	Variance/Size	0.00	0.00
Eff	SQRT[Variance/Size]	0.06	0.06
Eff	95% Lower Bound	12.08	13.23

每位患者都將透過模型累積總成本和效果值，然後將個別患者結果匯總為平均值，以提供每位患者的平均成本和效果

Example 4-Patient Level Simulation

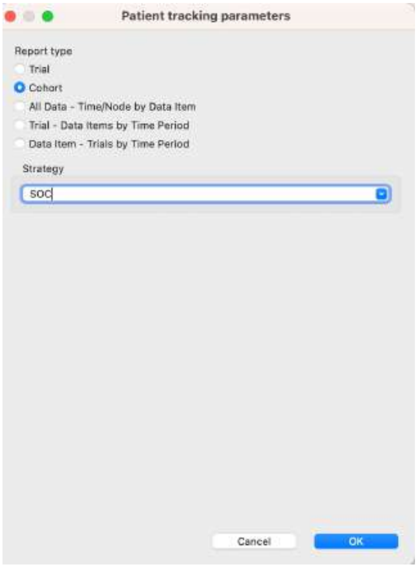
Individual trails unique paths through the model

Monte Carlo Patient Tracking Trial Report (Untitled15)

Trial: 1 of 10000 Go to trial: Go

State/Transition	Stage	Cost	Cum Cost	Effectiveness	Cum Effectiveness	Distribution Dist_GeneType	Tracker t_progres_ct	Tracker t_progress_ct
Mild	0	500.00	500.00	0.47	0.47	2	0	0
Dont Progress	0	0.00	500.00	0.00	0.47	2	0	0
Mild	1	1000.00	1500.00	0.95	1.42	2	0	0
Dont Progress	1	0.00	1500.00	0.00	1.42	2	0	0
Mild	2	1000.00	2500.00	0.95	2.38	2	0	0
Dont Progress	2	0.00	2500.00	0.00	2.38	2	0	0
Mild	3	1000.00	3500.00	0.95	3.33	2	0	0
Dont Progress	3	0.00	3500.00	0.00	3.33	2	0	0
Mild	4	1000.00	4500.00	0.95	4.28	2	0	0
Dont Progress	4	0.00	4500.00	0.00	4.28	2	0	0
Mild	5	1000.00	5500.00	0.95	5.23	2	0	0
Dont Progress	5	0.00	5500.00	0.00	5.23	2	0	0
Mild	6	1000.00	6500.00	0.95	6.18	2	0	0
Progress	6	0.00	6500.00	0.00	6.18	2	0	1
Servere	7	7000.00	13500.00	0.60	6.78	2	0	1
Survive	7	0.00	13500.00	0.00	6.78	2	0	1
Servere	8	7000.00	20500.00	0.60	7.38	2	0	1
Survive	8	0.00	20500.00	0.00	7.38	2	0	1
Servere	9	7000.00	27500.00	0.60	7.97	2	0	1
Survive	9	0.00	27500.00	0.00	7.97	2	0	1
Servere	10	7000.00	34500.00	0.60	8.57	2	0	1
Survive	10	0.00	34500.00	0.00	8.57	2	0	1
Servere	11	7000.00	41500.00	0.60	9.17	2	0	1
Survive	11	0.00	41500.00	0.00	9.17	2	0	1
Servere	12	7000.00	48500.00	0.60	9.77	2	0	1
Survive	12	0.00	48500.00	0.00	9.77	2	0	1
Servere	13	7000.00	55500.00	0.60	10.37	2	0	1
Die	13	0.00	55500.00	0.00	10.37	2	0	1
Dead	14	0.00	55500.00	0.00	10.37	2	0	1

Example 4-Patient Level Simulation



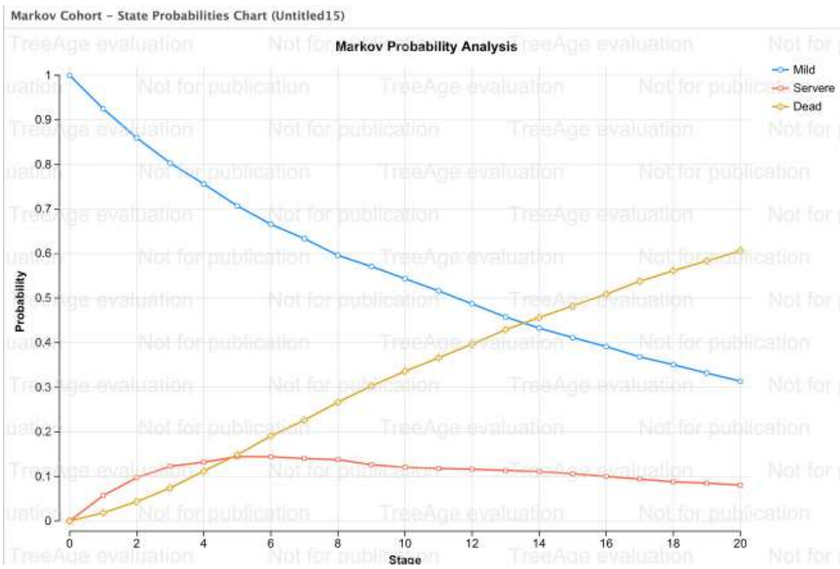
Cohort report for patient level simulation model

Monte Carlo Patient Tracking Cohort Report (Untitled15)

State/Transition	Stage	Cohort %	Cost	Cum Cost	Effectiveness	Cum Effectiveness	Tracker t_progres_ct	Tracker t_progress_ct
Summary	0		500.00	500.00	0.47	0.47	0	0.0569
Mild	0	1.000	500.00		0.47			
Servere	0	0.000	0.00		0.00			
Dead	0	0.000	0.00		0.00			
Summary	1		1323.20	1823.20	0.91	1.39	0	0.1125
Mild	1	0.925	924.90		0.88			
Servere	1	0.057	398.30		0.03			
Dead	1	0.018	0.00		0.00			
Summary	2		1539.30	3362.50	0.87	2.26	0	0.1657
Mild	2	0.860	859.60		0.82			
Servere	2	0.097	679.70		0.06			
Dead	2	0.043	0.00		0.00			
Summary	3		1661.40	5023.90	0.84	3.10	0	0.2123
Mild	3	0.803	803.20		0.76			
Servere	3	0.123	858.20		0.07			
Dead	3	0.074	0.00		0.00			
Summary	4		1680.10	6704.00	0.80	3.90	0	0.2639
Mild	4	0.756	756.10		0.72			
Servere	4	0.132	924.00		0.08			
Dead	4	0.112	0.00		0.00			
Summary	5		1717.20	8421.20	0.76	4.66	0	0.3071
Mild	5	0.707	707.10		0.67			
Servere	5	0.144	1010.10		0.09			
Dead	5	0.149	0.00		0.00			
Summary	6		1673.70	10094.90	0.72	5.37	0	0.3444
Mild	6	0.666	665.70		0.63			
Servere	6	0.144	1008.00		0.09			
Dead	6	0.190	0.00		0.00			
Summary	7		1614.20	11709.10	0.69	6.06	0	0.3841
Mild	7	0.633	633.50		0.60			

我們還可以將所有個體（例如：SOC下）匯整到Cohort model模型中，這可能會代表每個策略的cohort flow。

Example 4-Patient Level Simulation-Patient Tracking



對於微觀模擬模型的每種策略，狀態機率圖表使用同期群模型呈現獲得的等效輸出。

Congratulations

🎉 恭喜！你成功完成了這本內容精實的手冊！ 🎉

你現在已經是成本效益分析的模型高手了！
能看懂文獻中絕大部分的模型，走路都有風～

📊💪 未來的你：
當別人提到 Markov 模型、決策樹或敏感度分析時，
你可以自信滿滿地說：「這些我都懂！」

👏 為自己鼓掌吧，學習過程辛苦了！ 👏

Source: Shiba Says