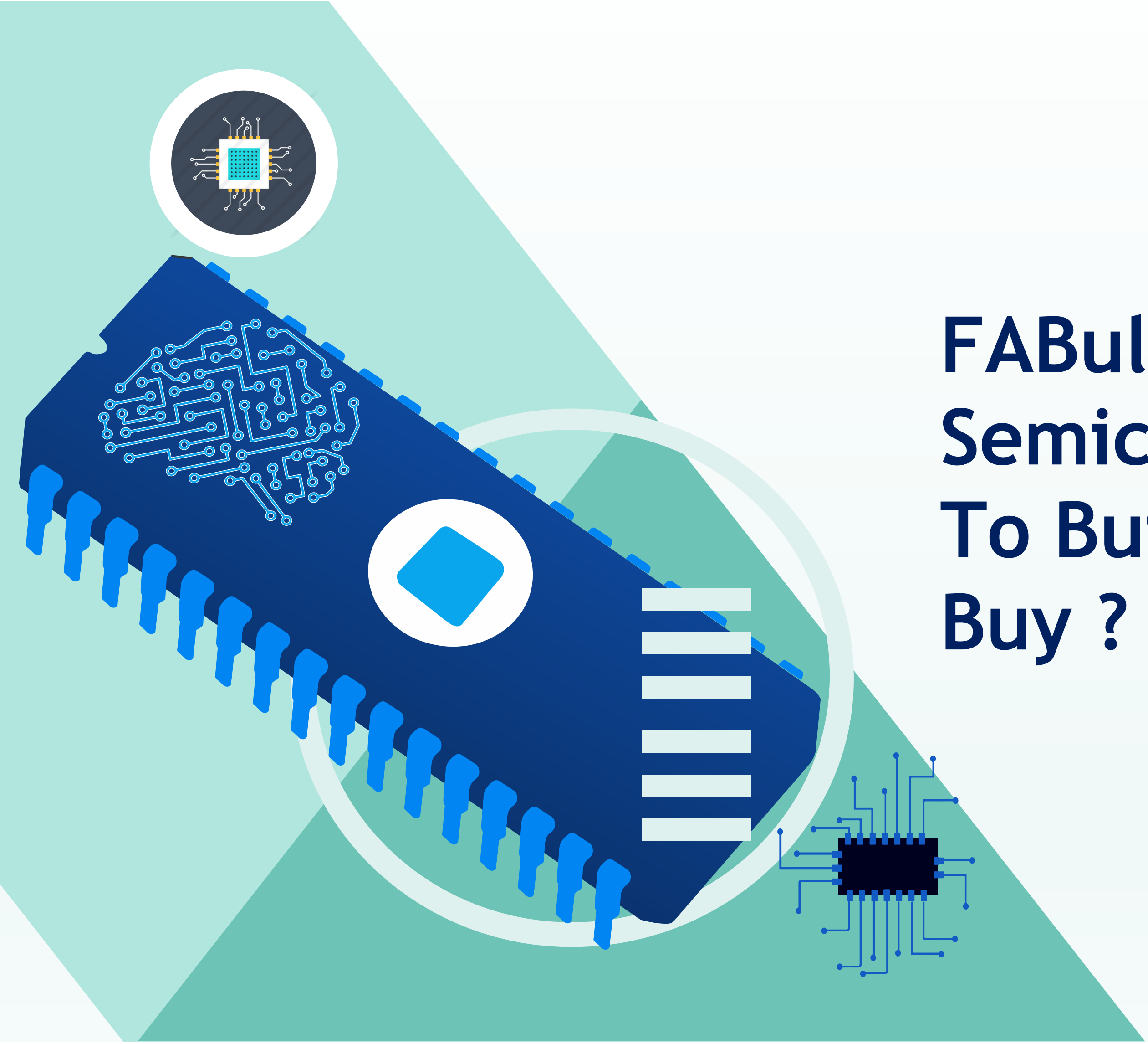
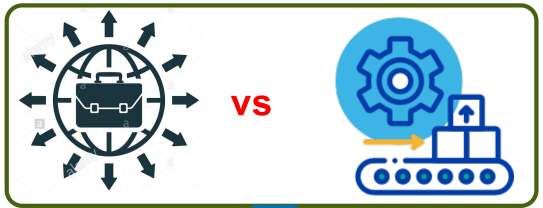
NUS Business Analytics Case Competition 2021



FABulous Semiconductor: To Build or To Buy ?

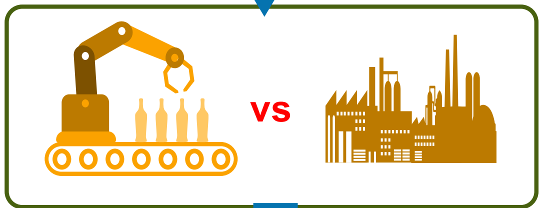
CONTENT



01

Outsourcing v.s In-house Manufacturing

- Cost of Building Fab vs Cost of Outsourcing.
- Confidentiality Leakage.
- Reliability on Supply Chain



02

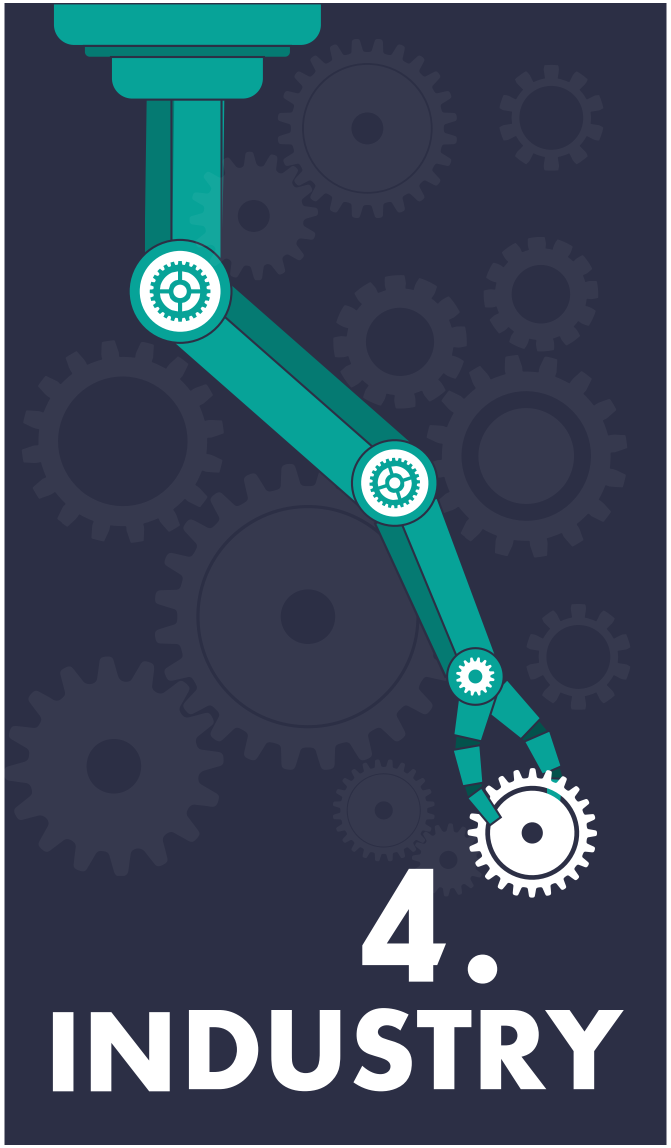
Fab Manufacturing: Expansion v.s New Construction

- Get a modern PowerPoint Presentation that is beautifully designed.
- Easy to change colors, photos and Text..
- This text can be replaced with your own text
- I hope and I believe that this Template will your Time, Money and Reputation.

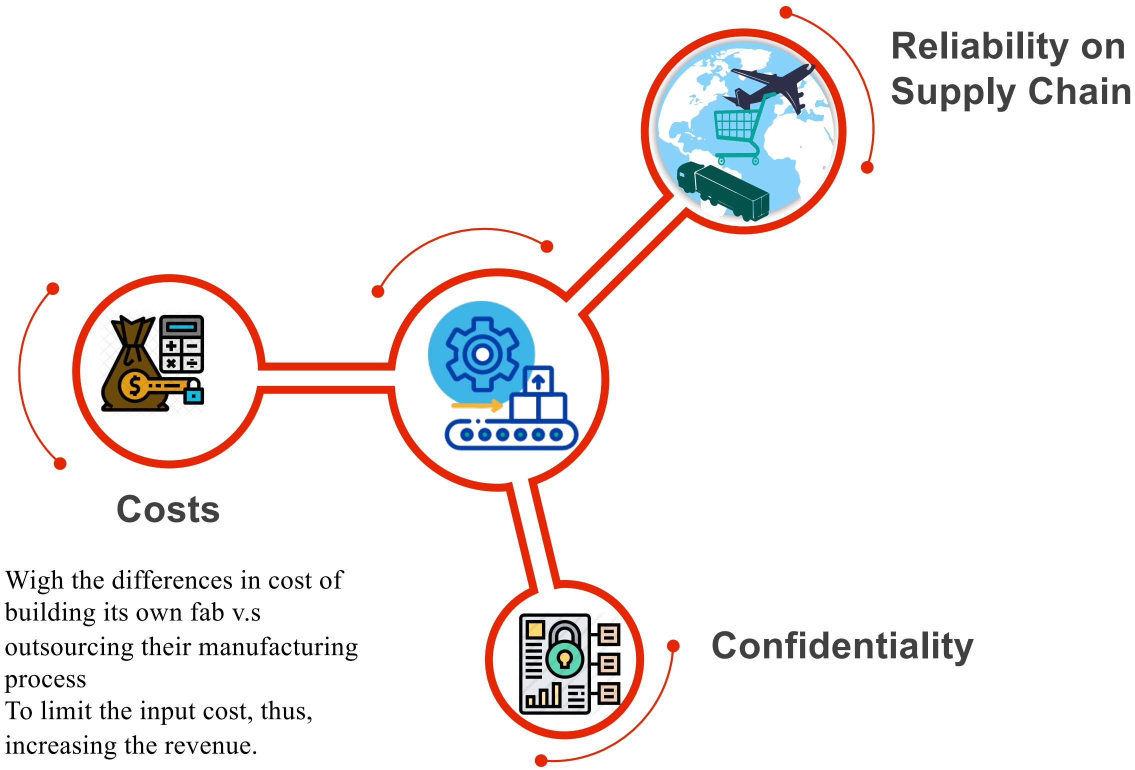
03

Fab Expansion Analysis

- Break-even Analysis – Micron’s Assessment
- Demand Projection Forecast – Micron’s Assessment
- R&D: Technologies – Micron’s Assessment

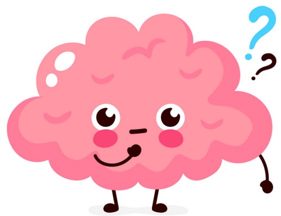


1. Outsourcing v.s Fab Manufacturing

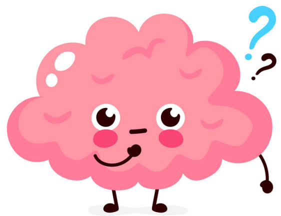


- Wigh the differences in cost of building its own fab v.s outsourcing their manufacturing process
- To limit the input cost, thus, increasing the revenue.

What can you do with money ?



What can you do with this money ?



What can you do with this money ?

What can you do with this money ?

1.1. Costs – Building Fab

Averagely, 1 semiconductor plan would cost…..

$3 billion

2004

$4 billion

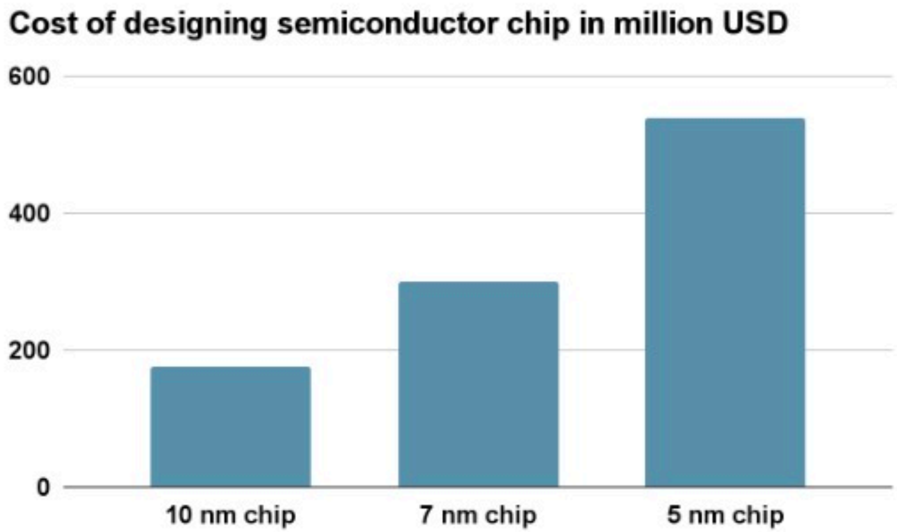
2011

~ $20 billion

2020

1.1. Costs – Building Fab

- Semiconductor fabrications generally **require retooling** every few years
- Companies are expected to keep spending a substantial amount for R&D
- Yet, cost of developing the latest technologies is exorbitant



Cost of designing semiconductor chip

1.1. Costs – Outsourcing

1/3 Industry Revenue generated by fabless companies

Cooperation

Pool production with other fabless companies in 3rd party foundries

Production Advantages

Take advantage of lower foreign wages and weaker environmental standards

Lower input costs

Greater Profit earned

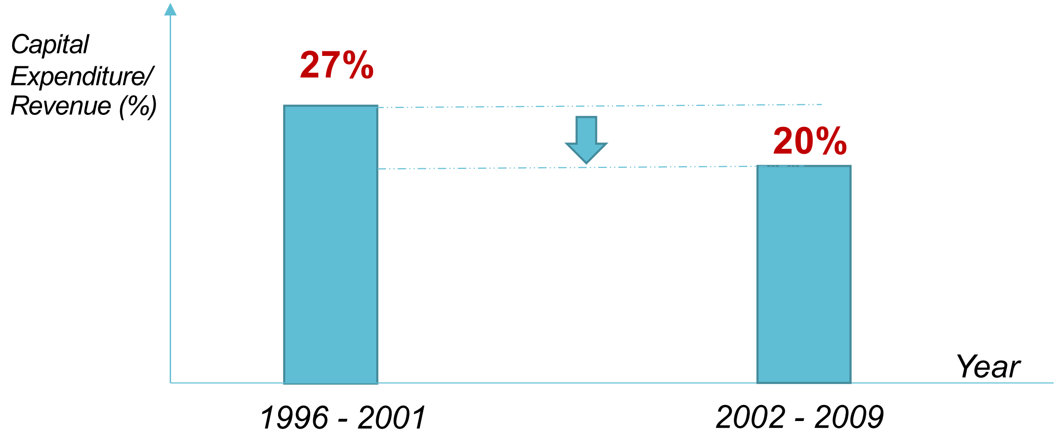
Cooperation

Production Advantages

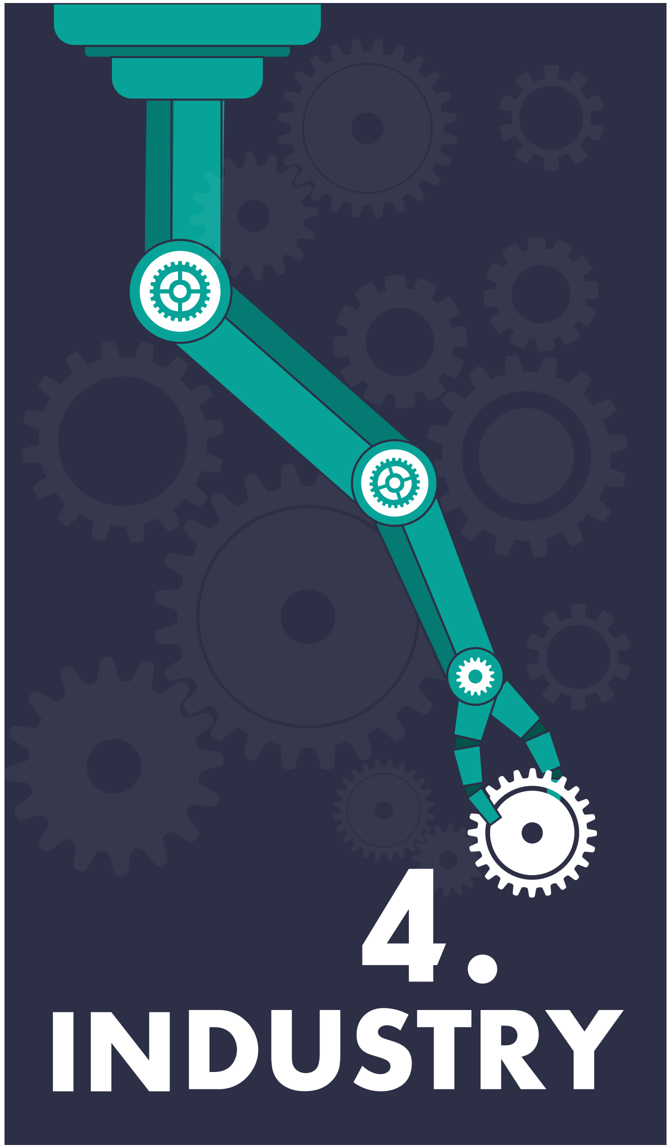
Lower input costs

Outsourcing

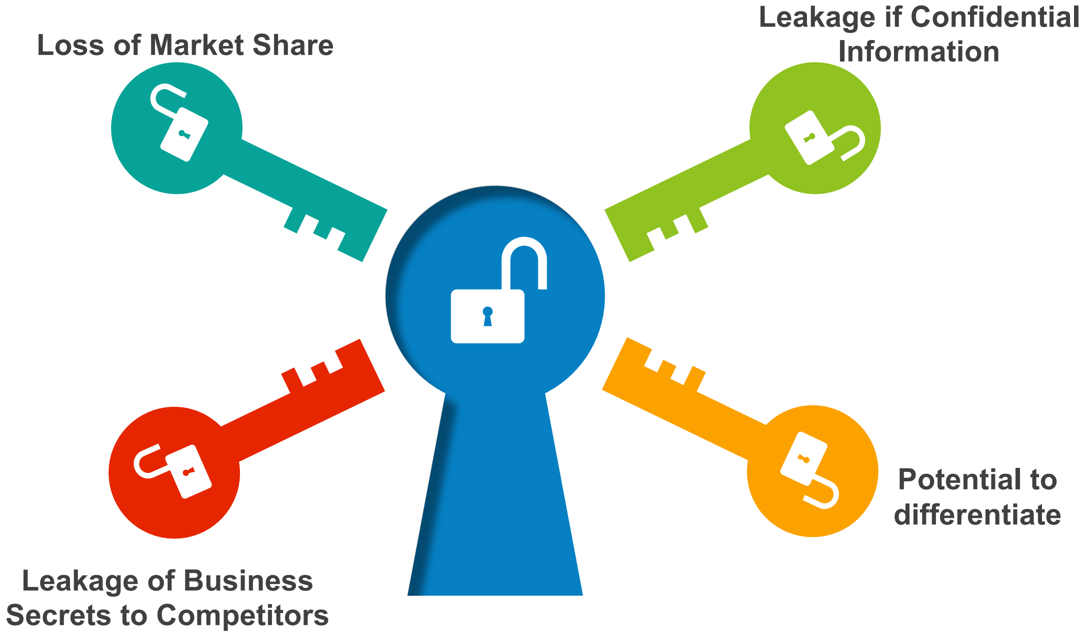
Overall <u>net reduction IN capital expenditures</u> in the industry…..



1/3 Industry Revenue generated by fabless companies

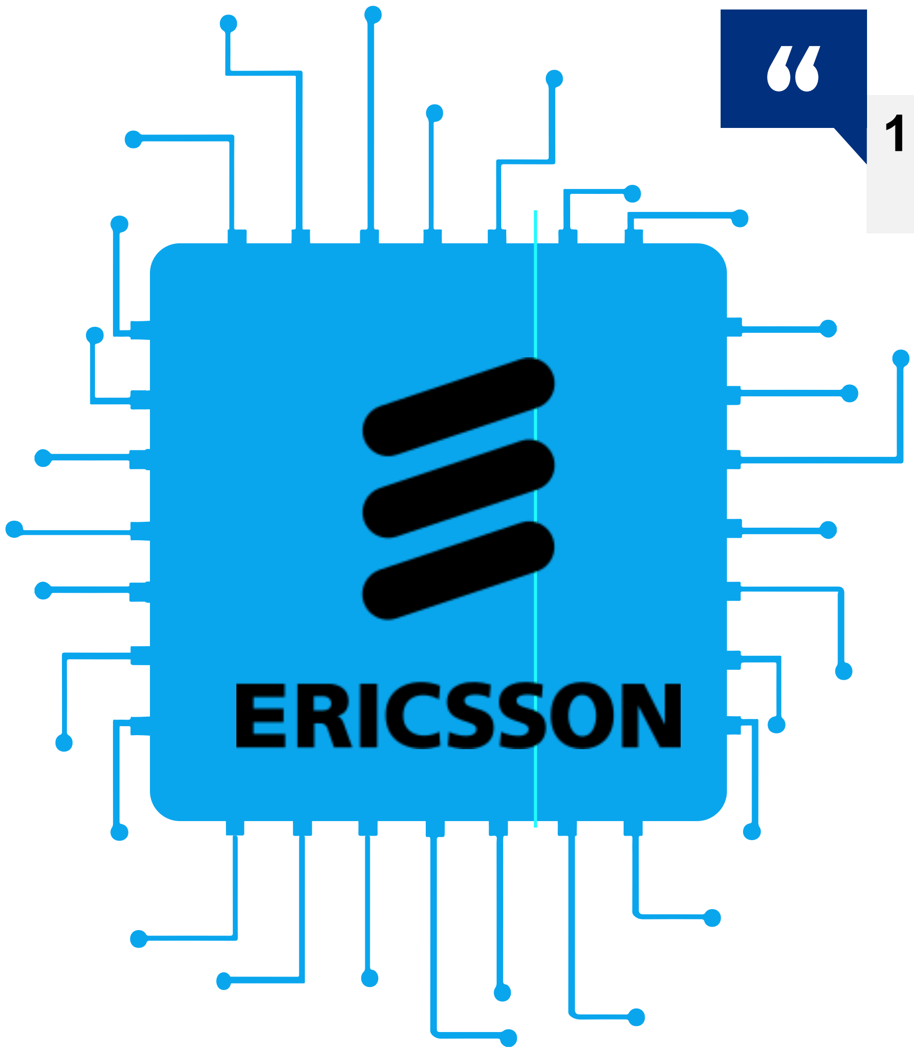


1.2. Confidentiality



1.2. Case Study of L.M Ericsson (2002) Outsourcing

*"We have to do it ourselves [internally] because the typical DSPs on the external markets are like an estate wagon with a powerful engine… **But if we know the algorithms well enough, we may very well be able to come up with more optimized task-specific designs**. We do **not want to make those designs available to our customers by sharing the knowledge through the suppliers"***



1.2. Case Study of L.M Ericsson (2002)
In-house Manufacturing

*“Many suppliers would like to be involved in the design and manufacturing of the most important chips to get a glimpse of our algorithms for Radio Base Station (RBS), but **we do not want to risk sharing our own jewels with our competitors through the suppliers**”*

1.2. Confidentiality

In-house Manufacturing

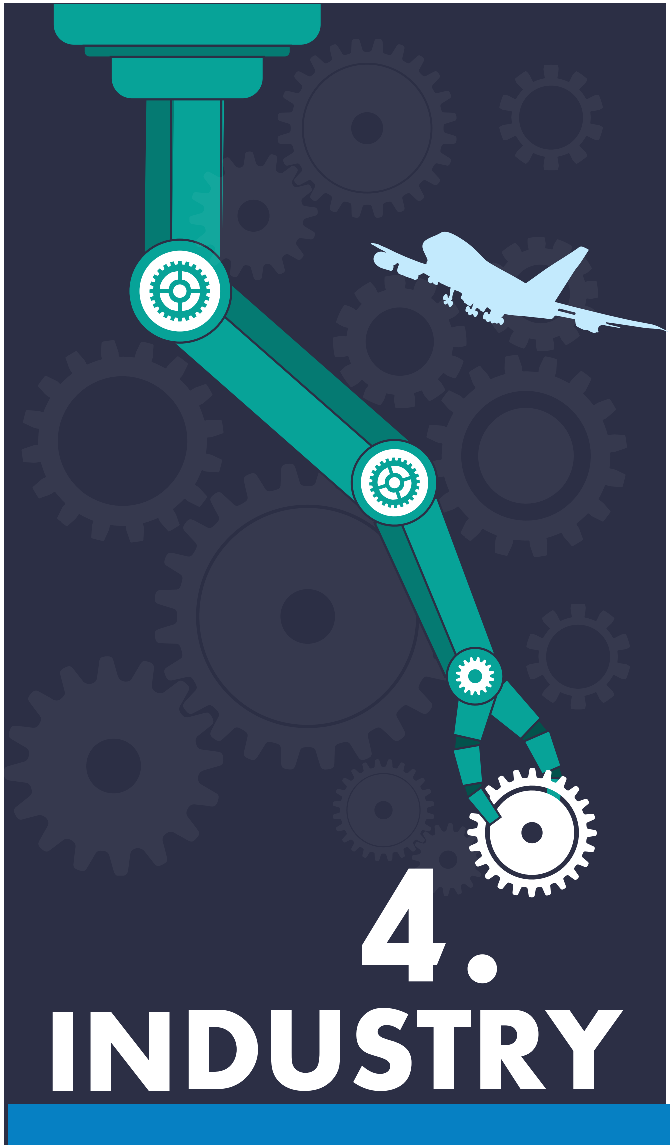
Leakage of Confidential Information

Lack of Legal Bounds

Potential to Gain Market Share

Information Protection Legal Terms

Outsourcing



1.3 Reliability on Supply Chain

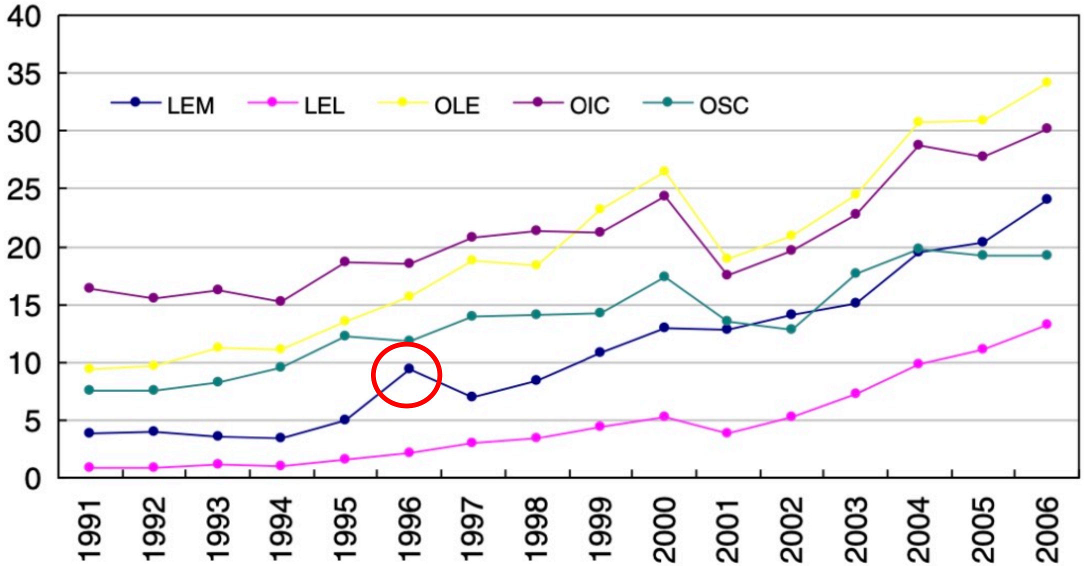


Fig 2: *Worldwide demand of microchips by product segments[7] (Source, Int.J.Production Economics, 2007)*

<u>Worldwide Demand for Microchips</u>:

- LEM, LEL, OLE, OIC, OSC are different categories of microchips
- Overall Increasing Trend
- Variance of Increase is uncertain

SEMICONDUCTOR MARKET

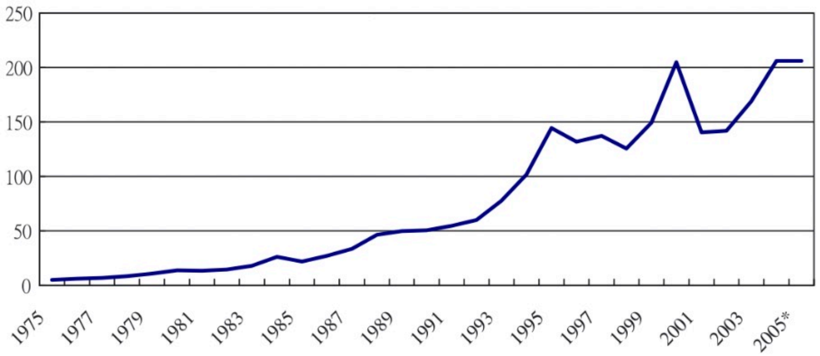
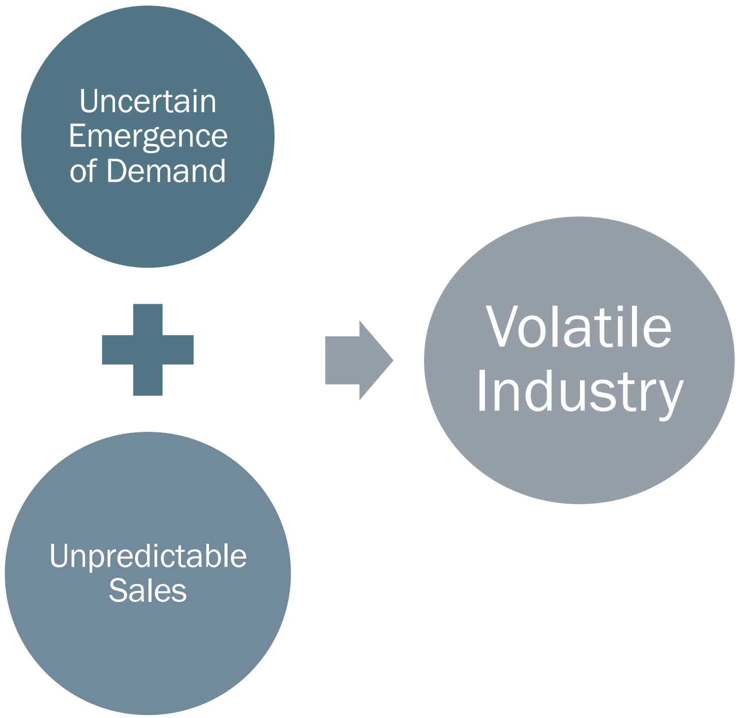
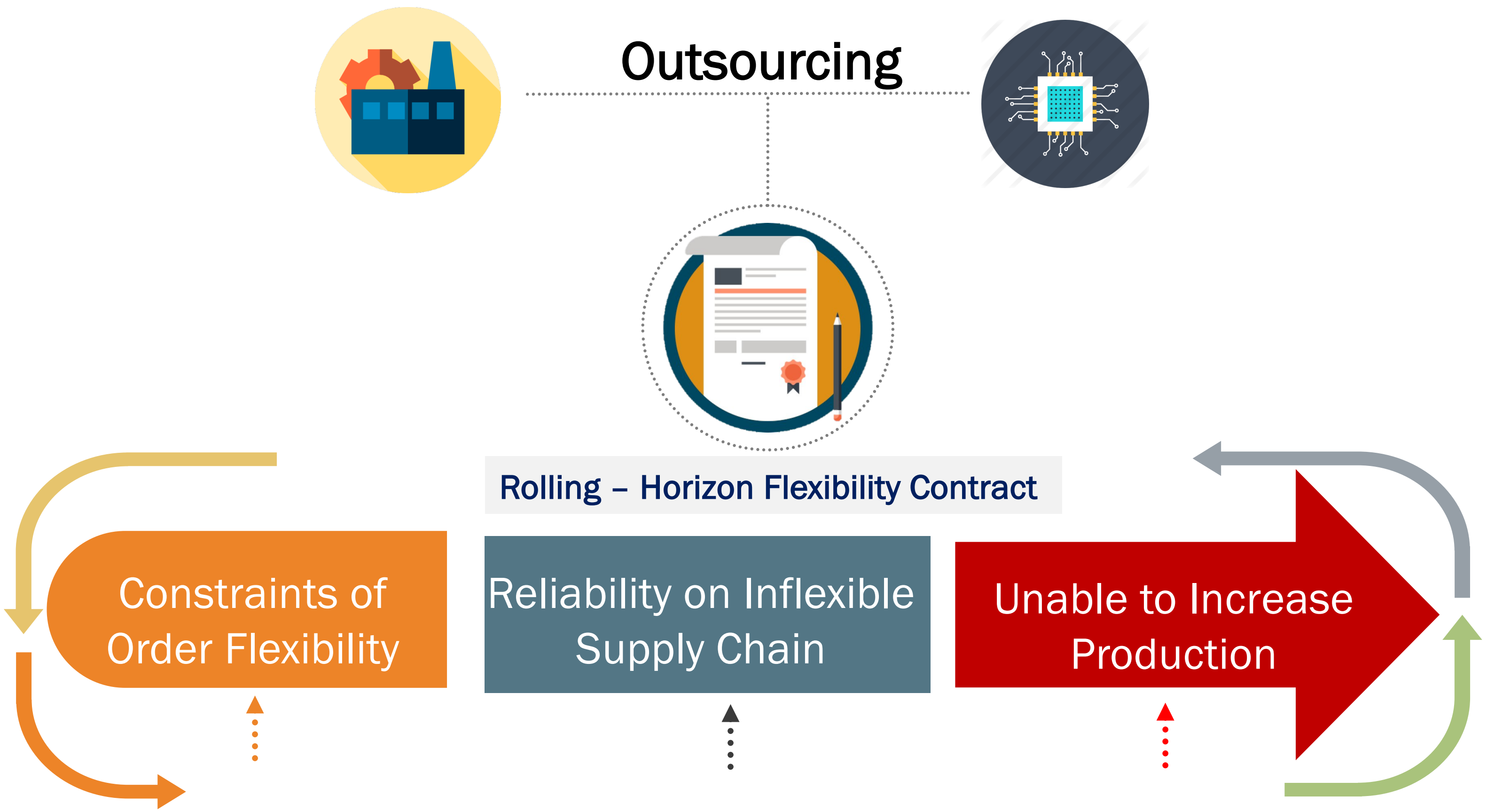


Fig 3: *Global sales of Microchips (in $ billion), from 1975 to 2005*

Fig 4: *Global sale of semiconductors from 2017 to 2021 (Source: Y Chart 2021)*

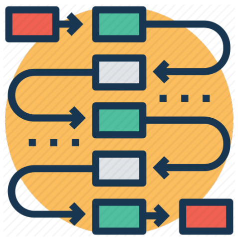


1.3 Reliability on Supply Chain



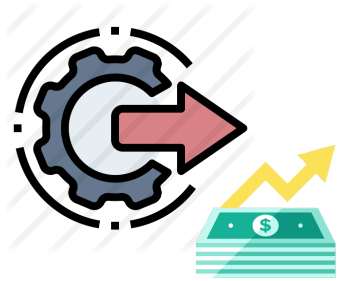
1.3 Reliability on Supply Chain

IN-HOUSE MANUFACTURING



- Adopt better scientific & Industrial procedures

- Thus, improve manufacturing yield



- Able to increase outputs of products if demand increases
- Make more revenues

1.3 Reliability on Supply Chain

IN-HOUSE **MANUFACTURE**

Bound by Legal Contract

CAPACITY PLANNING

Autonomy in Production

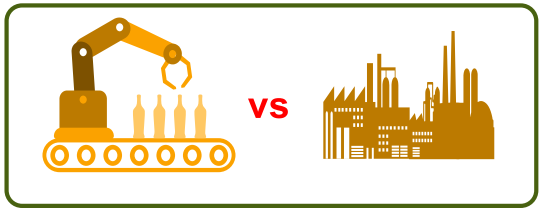
Inflexible in Production

Flexible in Production

OUTSOURCING

2. Manufacturing: Fab Expansion v.s Building new Fab

Assumptions



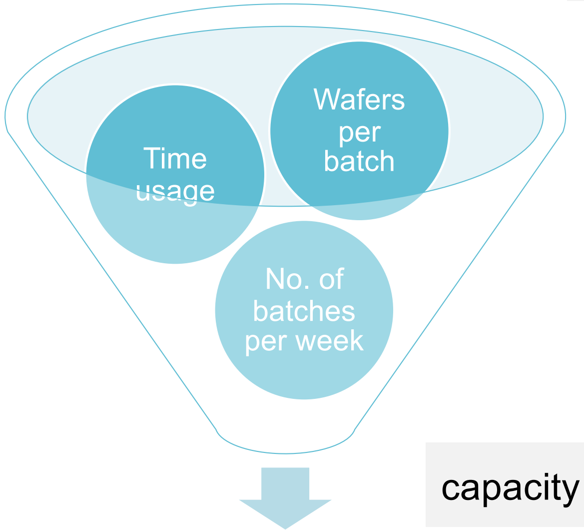
01
Utilisation (%) and Availability (%) always stay constant over time

02
Every machine has already been working for a period of time

03
Waiting time is negligible

04
There is an unlimited number of FOUPs available

2.1 Capacity per week of machine



Machine Capacity at each step per week

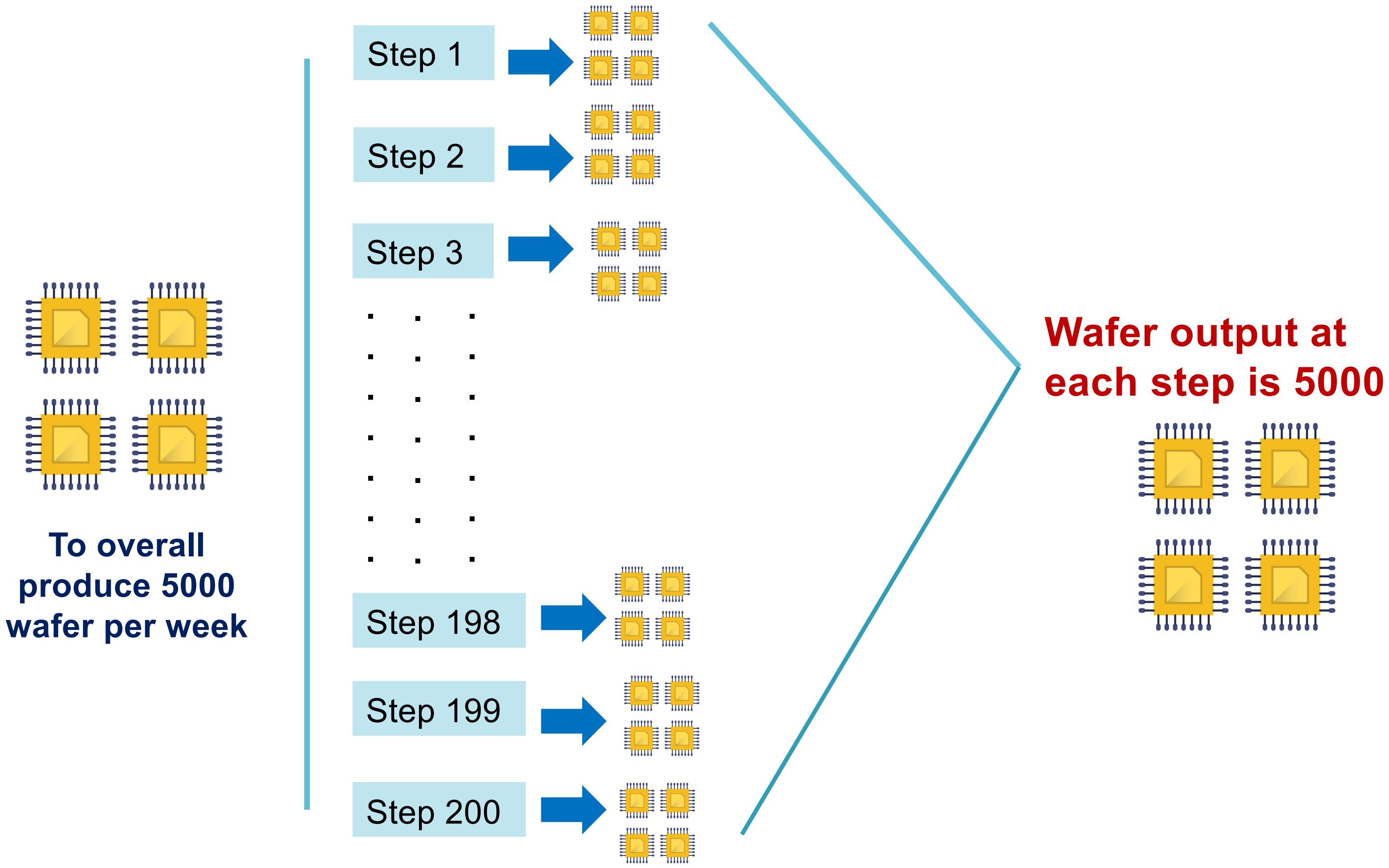
$$time\ of\ machine\ usage\ per\ week = 7 \times 24 \times 60 \times Utilisation\%$$

$$\text{batches of wafers produced in a week} = \left\lfloor \frac{7 \times 24 \times 60 \times Utilisation\%}{RPT} \right\rfloor$$

$$\text{number of wafers per batch} = load\ size\ x\ chamber\ count$$

$$\text{capacity at each step} = load\ size \times chamber\ count \times \left\lfloor \frac{7 \times 24 \times 60 \times Utilisation\%}{RPT} \right\rfloor$$

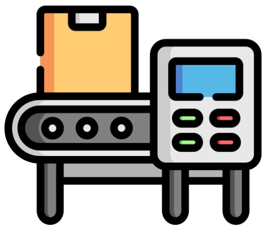
Understanding of Process



Understanding of Process

- **If RPT basis (no. steps can be processed at the same time) > 1**

After each step in the WS, <u>if the capacity has not reached yet</u>….



Workstation: Apes

Step 28

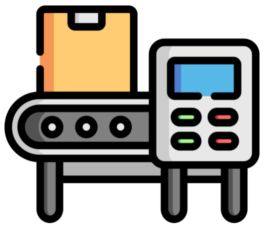
Step 32

Step 39

Last batch of Step 28 can be processed with 1st batch of Step 32

Last batch of Step 32 can be processed with 1st batch of Step 39

- **If RPT basis (no. steps can be processed at the same time) = 1**



Workstation: Apes

Step 28

Step 32

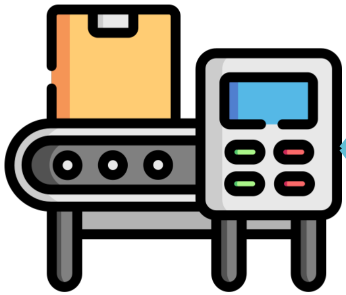
Step 39

- Cannot take advantage of extra capacity to process

2.2 Number of Machines Needed

- Let the ***Raw Processing Time*** be ***RPT***.
- Let the ***capacity per week of the Workstation (WS) in a specific step*** be ***a***.
- Let the ***number of wafers*** that can be produced in 1 batch be ***b***.
- Let the ***number of machines*** required for each step be ***n***.
- Let the ***extra minutes of utilisation*** of the workstation after finishing 5000 outputs for 1 step be ***c***
- *The **subtext** symbolizes **the order of a step** in the workstation. For example, a_i symbolizes the capacity per week of the WS of the first step among the same type of machines.*

Example:



Workstation: Apes

Require n machines Apes

Step 25 → a_1

Step 28 → a_2

Step 32 → a_3

Step 39 → a_4

a_1 denotes the capacity per week of machine Apes in 1st step of the WS Apes *(which is step 25)*

c_1 denotes the extra minutes of utilisations of machine Apes after machine has finished 5000 outputs in 1st step of the WS Apes *(which is step 25)*

2.2 Number of Machines Needed

- **If RPT basis (no. steps can be processed at the same time) = 1**

$$r_x = \left(\left\lfloor \frac{c_{x-1}}{RPT_x} \right\rfloor \times b_x + a_x\, n_x - (5000 - r_{x-1})\right) \%\, b_x$$

Starting with the first step of each WS, **determine no. of machines needed for the first step**

$$n = \left\lceil \frac{5000}{capacity\ per\ week} \right\rceil$$

Usable Remaining time at workstation after finishing 5000 outputs for the first step

No . of outputs for next step of WS produced with that amount of usable remaining time

X Repeat till last step

$$c_1 = \left\lfloor \frac{(n)(capacity\ per\ week)\ -\ (5000 - r_{x-1})}{(wafers\ per\ batch)} \right\rfloor \times RPT_1$$

Find n_x for the last step in the workstation

$$\left\lfloor \frac{c_{x-1}}{RPT_x} \right\rfloor \times b_x + a_x\, n_x - 5000 > 0$$

Sum of no. of machines needed in each step = total number of machines

$$\sum_{i=1}^{x} n_x$$

2.2 Number of Machines Needed

- **If RPT basis (no. steps can be processed at the same time) > 1**

•1 chamber cannot carry out 2 steps at the same time,
$r \leq$ load size × multiple of chamber

Starting with the first step of each WS, **determine no. of machines needed for the first step**

$$n = \left\lceil \frac{5000}{capacity\ per\ week} \right\rceil$$

No. of wafers produced together with the last batch of the previous step (processing 2 steps together), symbolised as *r*

If $r <$ load size × lowest number chamber count

➡ r = load size × (chamber count - 1)

Else: ➡

r = load size x number of chamber count that is smaller than chamber count

X Repeat till last step

No. of outputs for the next step produced with that amount of time by the equation:

Sum of machines needed in each step = total no. of machines

$$\sum_{i=1}^{x} n_x$$

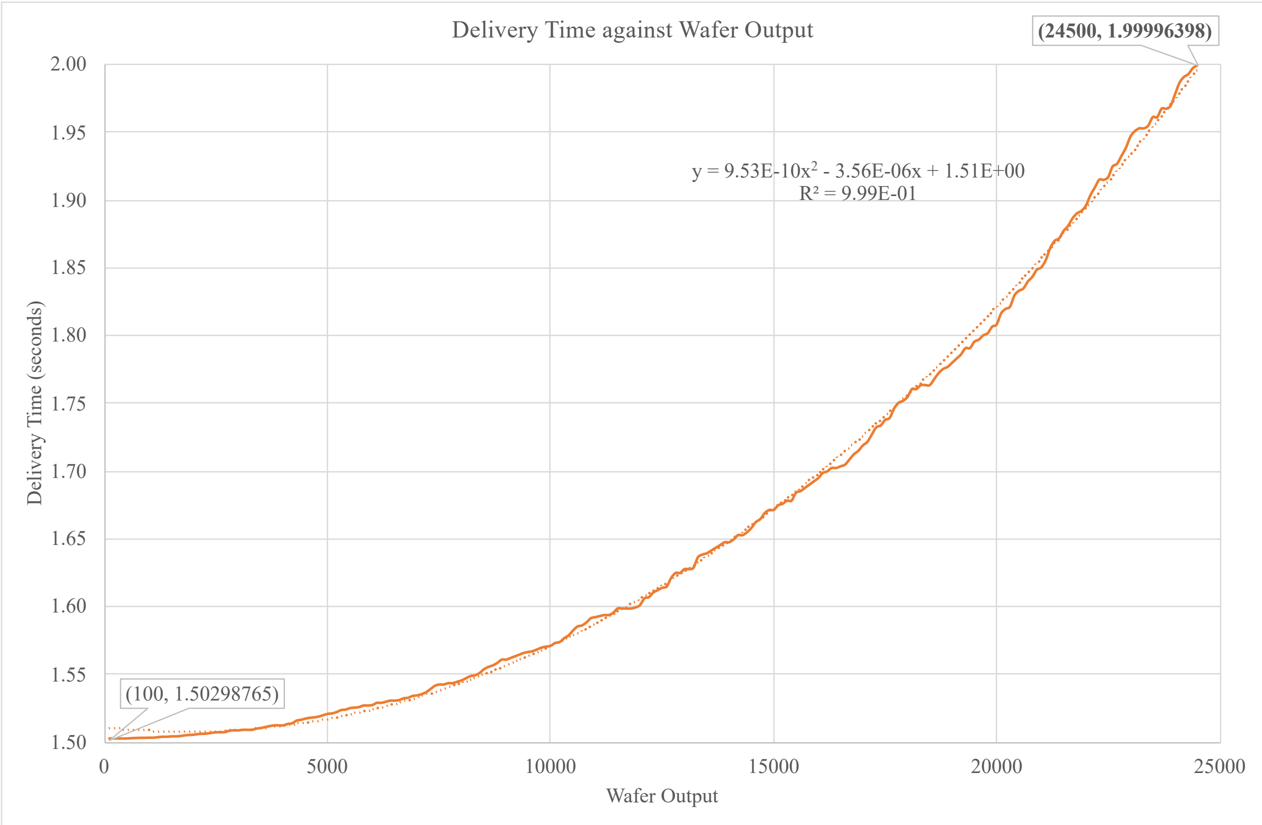
2.2 Number of Machines Needed – Cost for Machines

No. of Machines of Each Type × Price per Machine of Each Type = Cost for Machines of Each Type

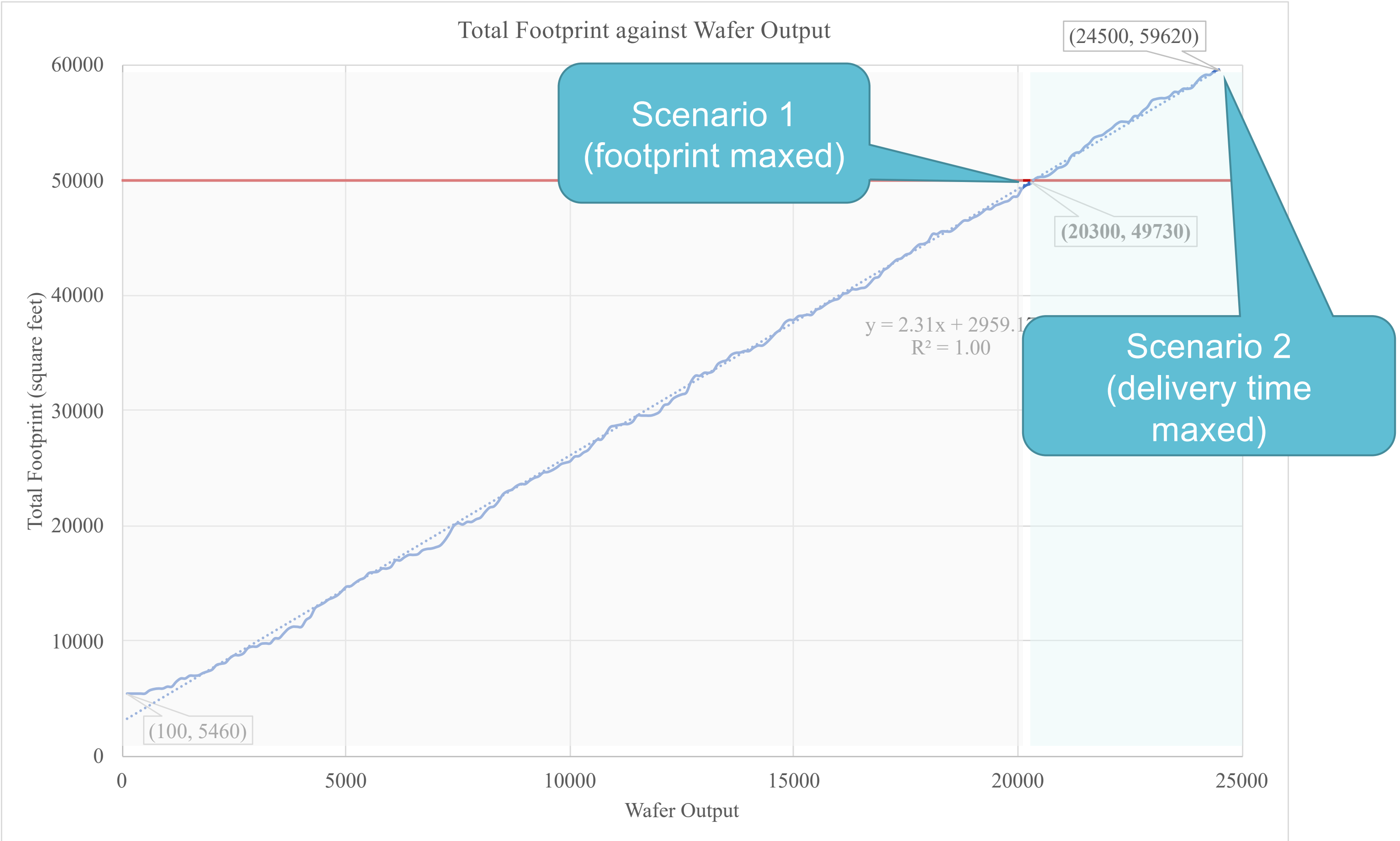
$\sum$

Total Cost for All Machines

2.3 Wafer Output & Delivery Time

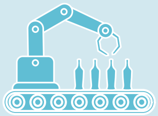


2.5 Wafer Output & Footprint Requirement



2.6 Wafer Output & Capital Investment

- **Scenario 1: Footprint Maximised**

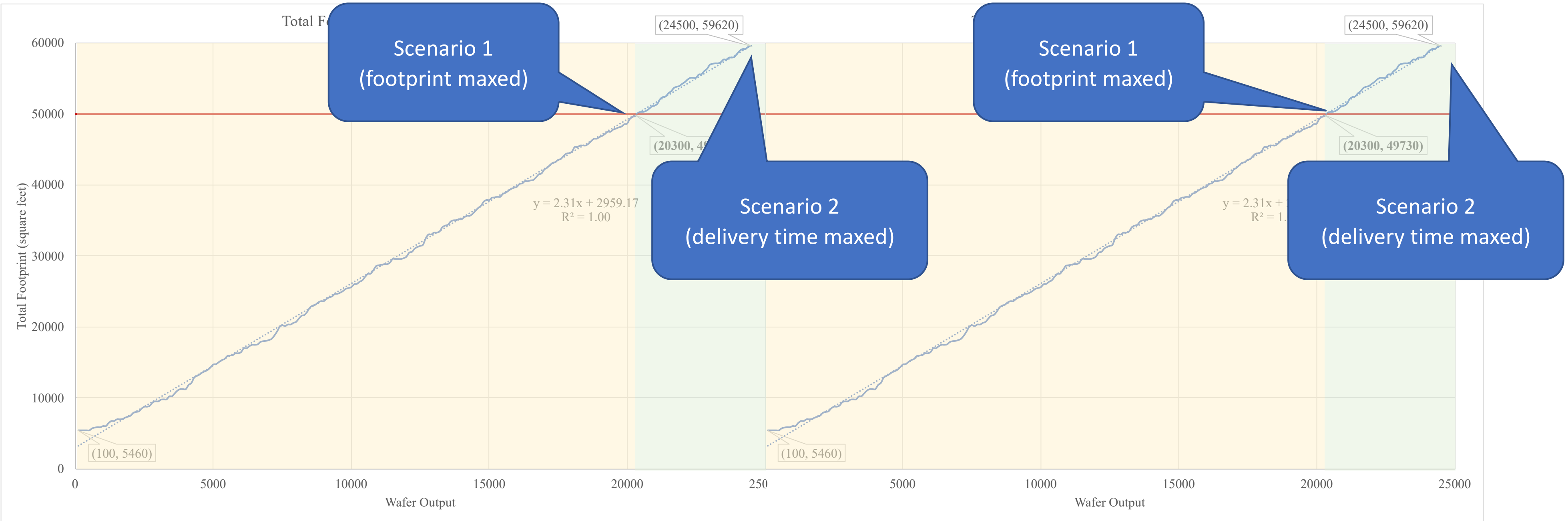
Options (wafer output = 20,400)	Expand in original location by constructing a 2nd building	Build in a new location by constructing a 1st building
		
Cost of additional machines in owned location	\$1,757,300,000 (461 machines needed)	\$1,737,300,000 (459 machines needed)
Cost of additional machines in new location	\$0 (0 machines needed)	\$301,600,000 (53 machines needed)
Cost of additional construction	\$1,070,000,000	\$1,000,000,000
Deducting the cost to acquire machines that are already owned to produced a wafer output of 5,000	- \$586,200,000	- \$586,200,000
Total	**\$2,241,100,000**	**\$2,452,700,000**

2.6 Wafer Output & Capital Investment

- **Scenario 2: Delivery Time Maximised**

Options (wafer output = 20,400)	Expand in original location by constructing a 2nd building	Build in a new location by constructing a 1st building
Cost of additional machines in original location	$5,389,500,000 (549 machines)	$1,737,300,000 (456 machines)
Cost of additional machines in bought location	$1,757,300,000 (461 machines)	$1,737,300,000 (456 machines)
Cost of additional machines in new location	$0 (0 machines needed)	$510,700,000 (119 machines)
Cost of additional construction	$2,140,000,000	$2,000,000,000
Deducting the cost to acquire machi nes that are already owned to produc ed a wafer output of 5,000	- $586,200,000	- $586,200,000
Total	**$8,700,600,000**	**$5,399,100,000**

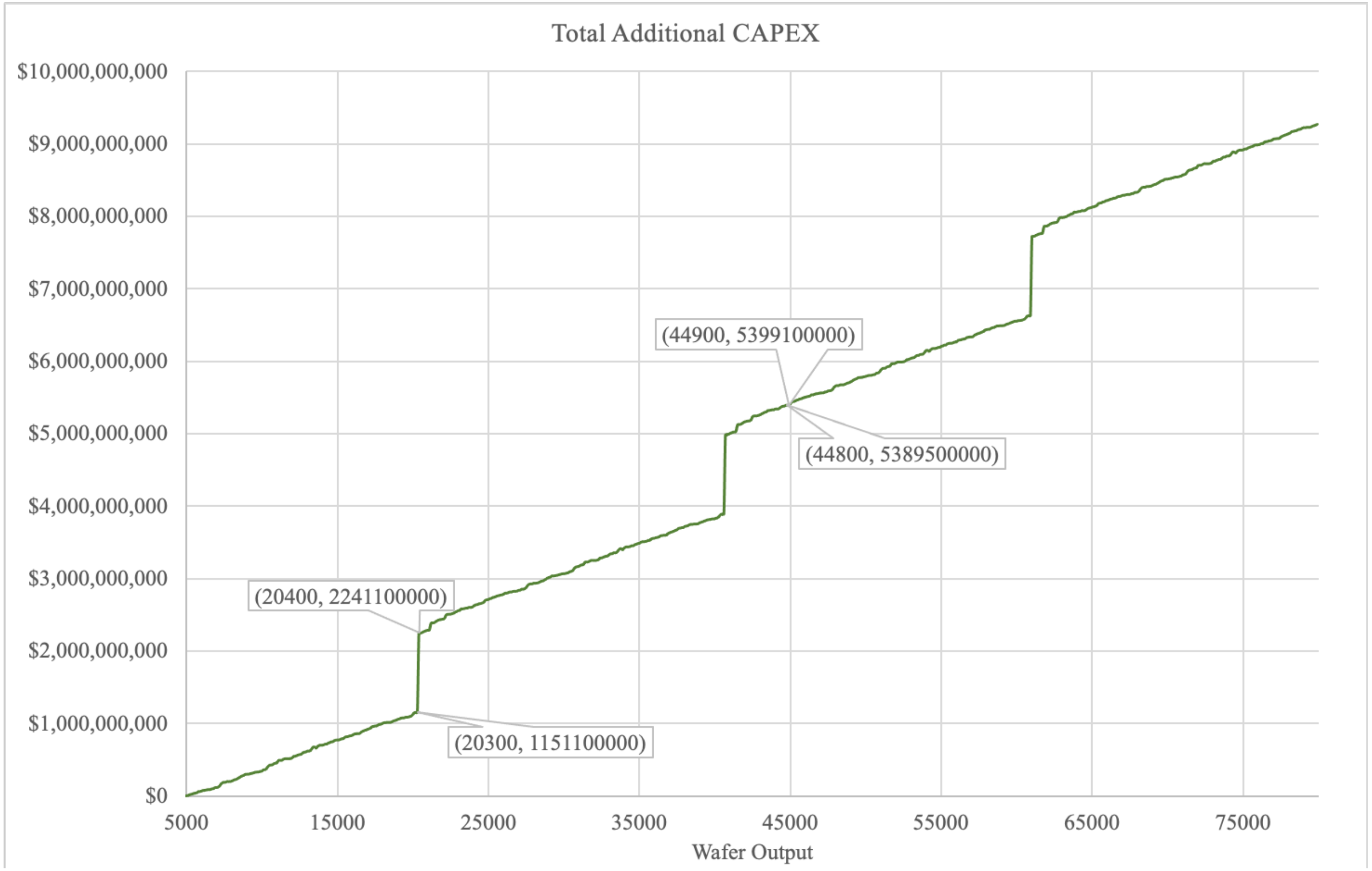
2.6 Wafer Output & Capital Investment



Location 1

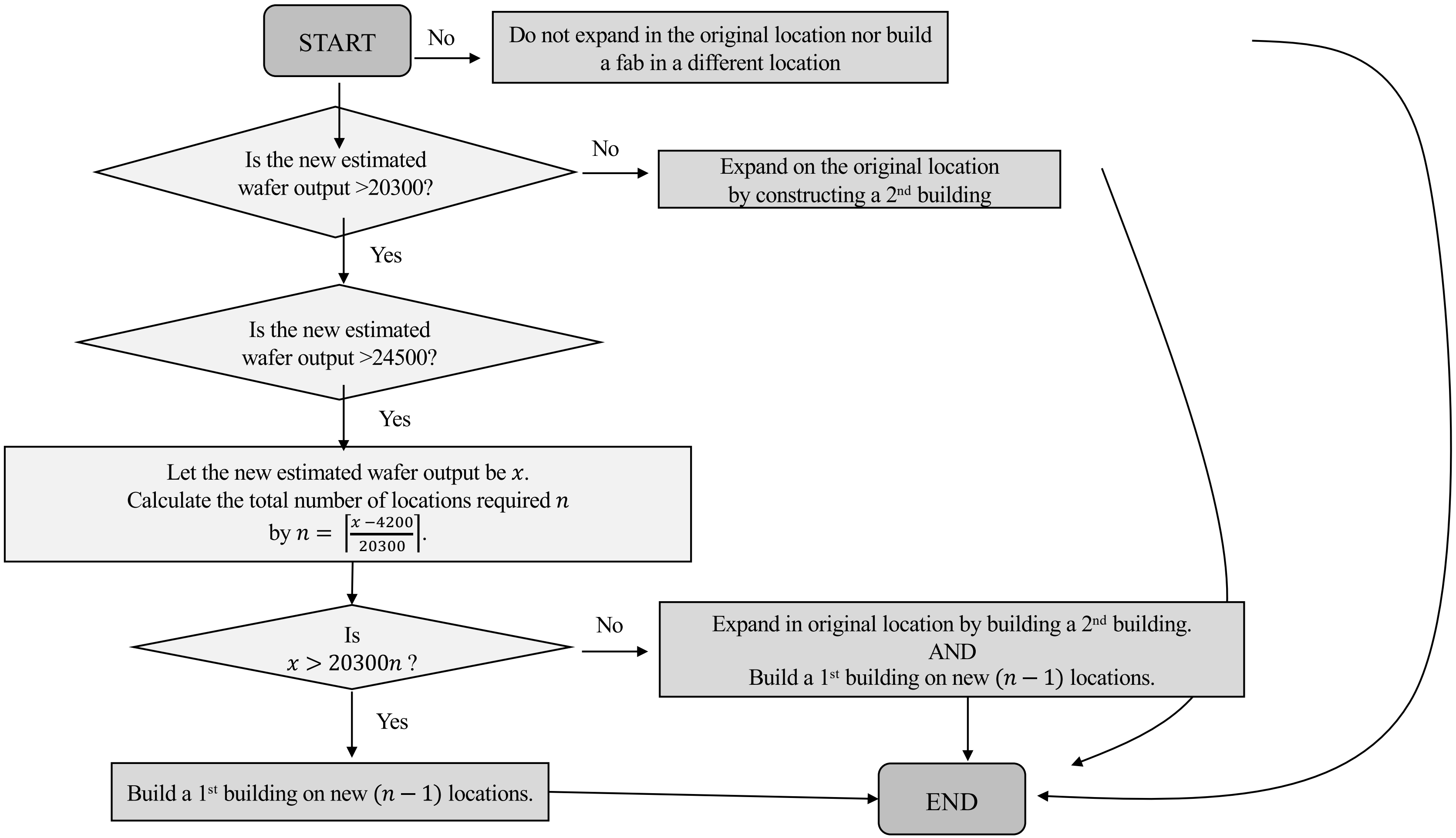
Location 2

2.6 Wafer Output & Capital Investment

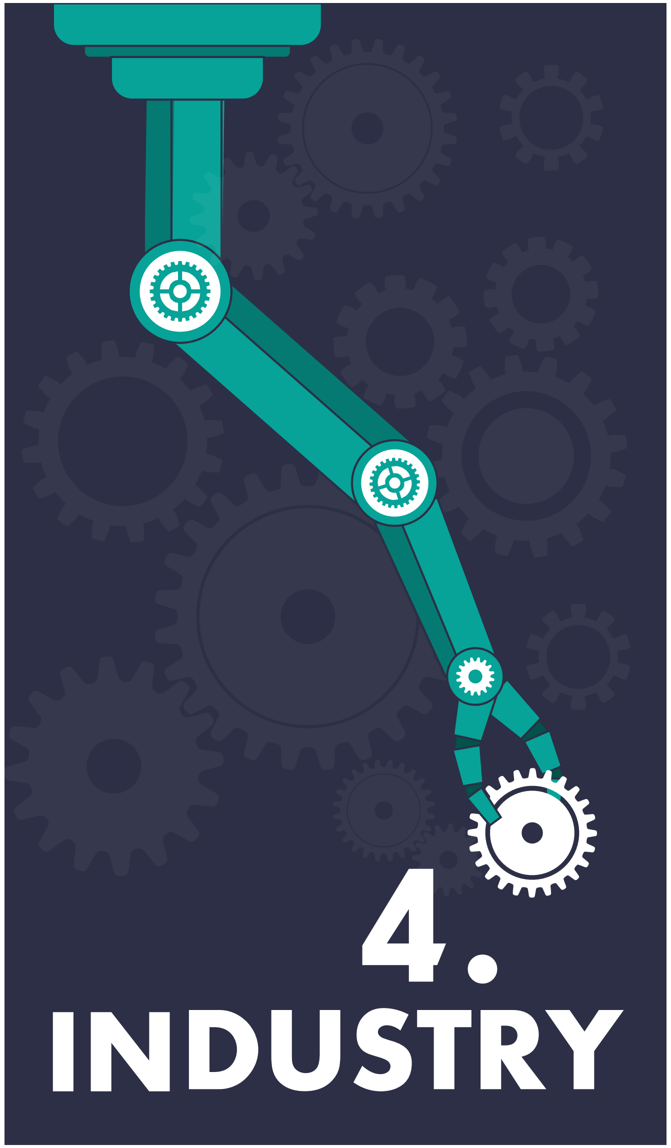


DECISION FRAMEWORK

Fab Expansion vs Fab Construction



3. Fab Expansion Analysis

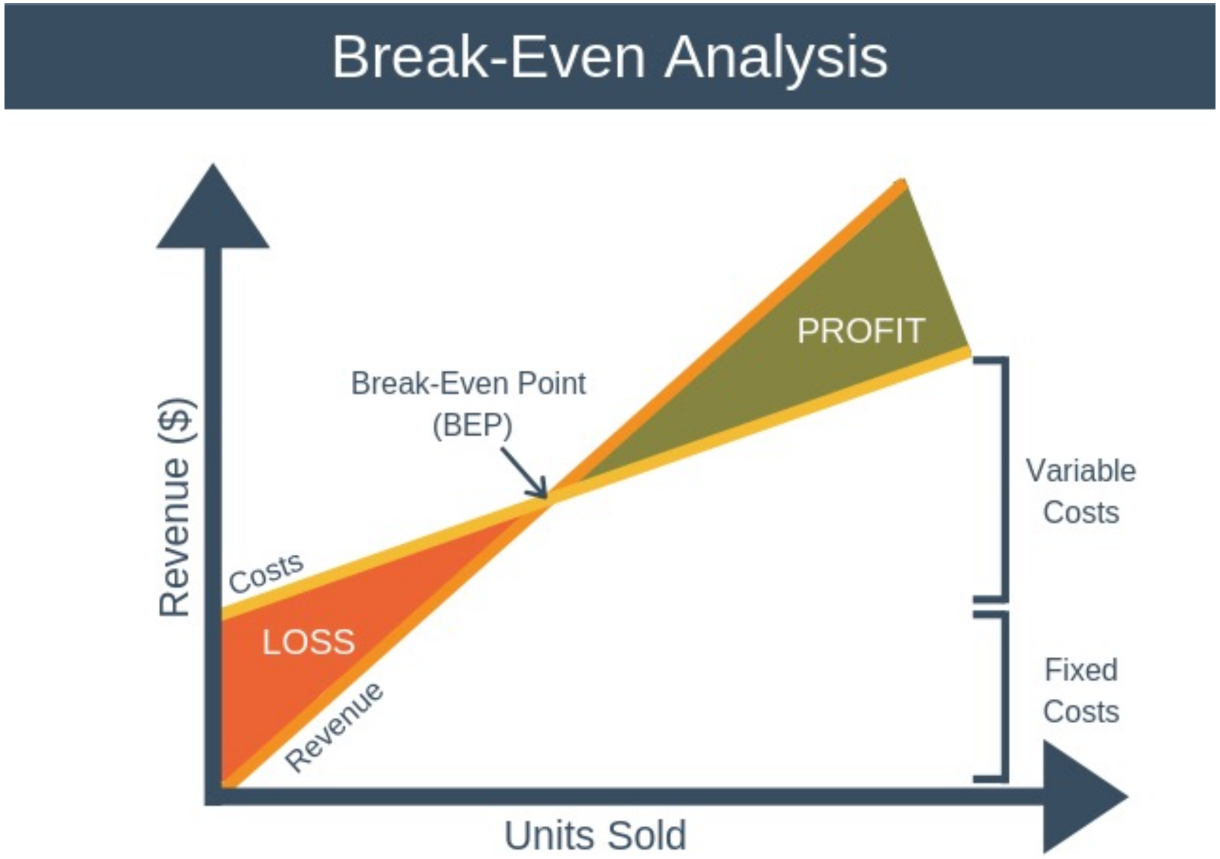


3. Fab Expansion Analysis

- Break-Even Analysis
- Demand Projection Forecast
- R&D: Technologies

EXPECTATION OF RETURNS

- Study the point where business' sale have generated enough revenue to cover all costs and expenses
- Using Break-even Analysis to determine if the production output will bring about revenue for company



COST OF PROCESSING SEMICONDUCTORS

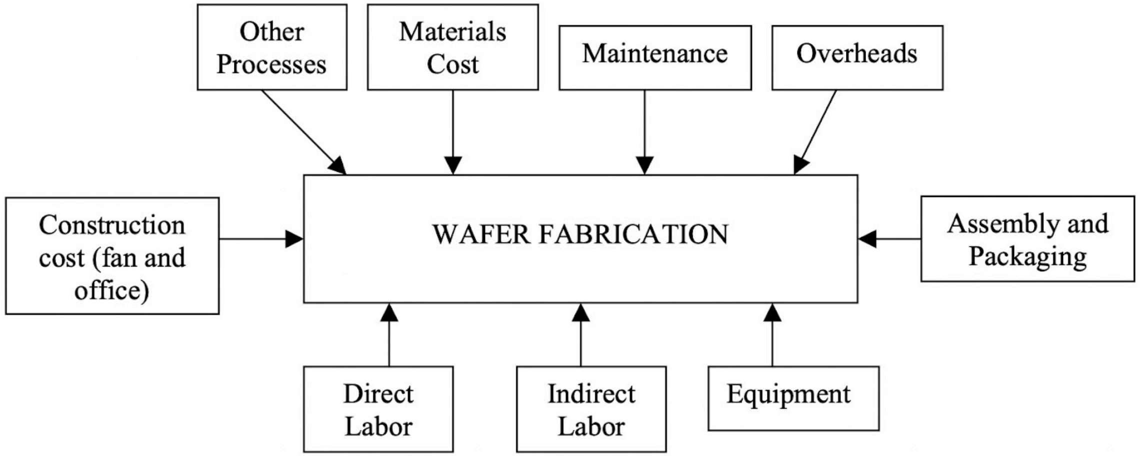


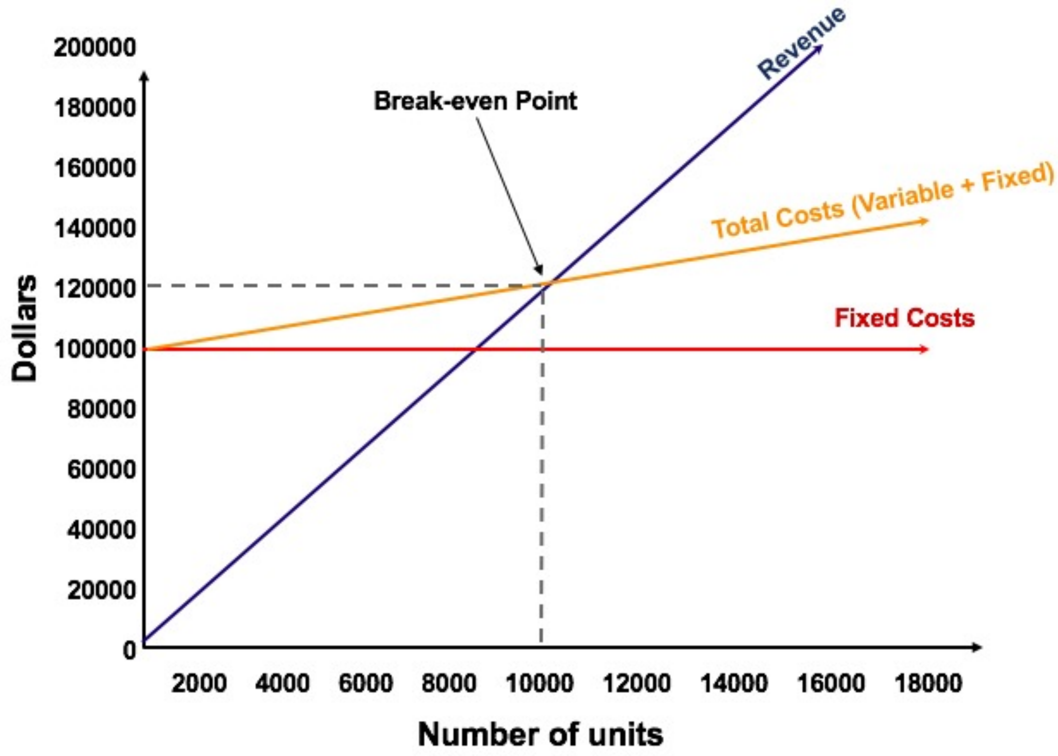
Figure 6: Cost associated with operating a wafer fab

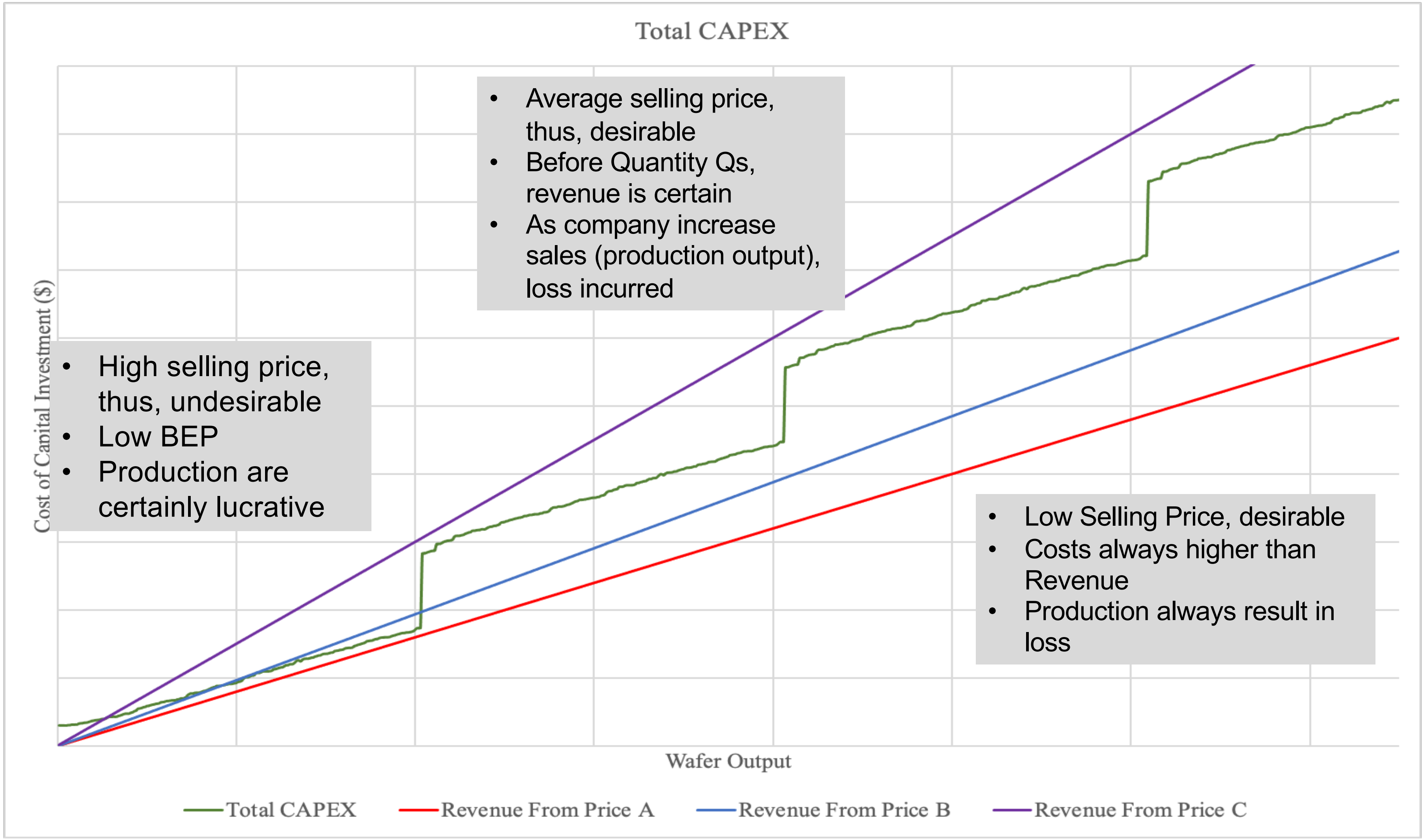
BREAK-EVEN POINT

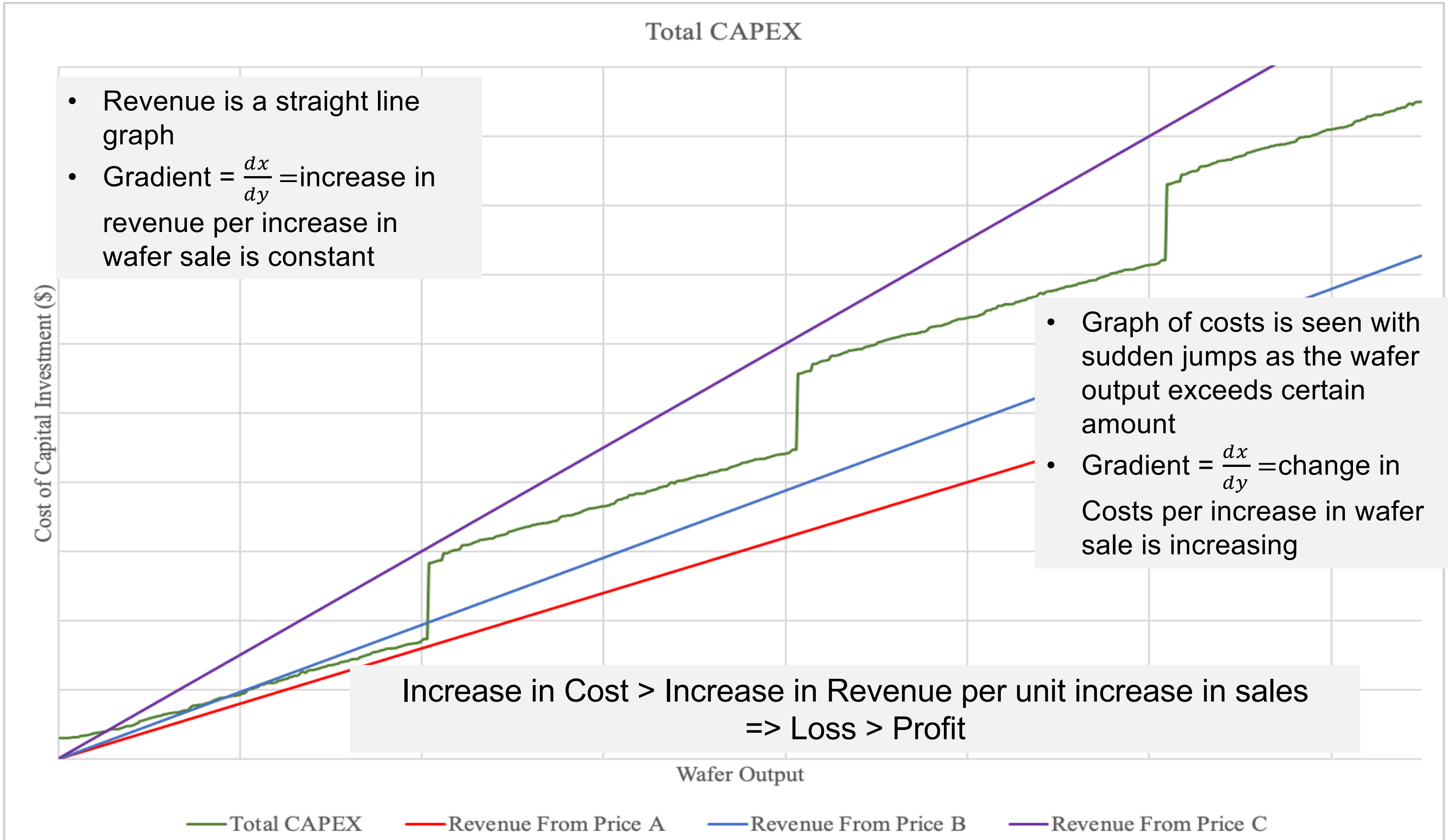
- Revenue = Sales x Price per unit
- Total costs = Fixed Costs + Variable Costs
- Break-even Point: where revenue from sales are sufficient to cover total costs
- Break even Point:

Revenue = Total Costs

- **Lower BEP is desired**




Total CAPEX
• Average selling price, thus, desirable
• Before Quantity Qs, revenue is certain
• As company increase sales (production output), loss incurred
• High selling price, thus, undesirable
• Low BEP
• Production are certainly lucrative
• Low Selling Price, desirable
• Costs always higher than Revenue
• Production always result in loss
Cost of Capital Investment ($)
Wafer Output
Total CAPEX
Revenue From Price A
Revenue From Price B
Revenue From Price C



Total CAPEX
Cost of Capital Investment ($)
Wafer Output
Total CAPEX
Revenue From Price A
Revenue From Price B
Revenue From Price C
• Revenue is a straight line graph
• Gradient = $\frac{dx}{dy}$ =increase in revenue per increase in wafer sale is constant
• Graph of costs is seen with sudden jumps as the wafer output exceeds certain amount
• Gradient = $\frac{dx}{dy}$ =change in Costs per increase in wafer sale is increasing
Increase in Cost > Increase in Revenue per unit increase in sales
=> Loss > Profit

3.1 Break-even Analysis

- Provision of manufacturing & production data

Micron

Production Quantity

Costs

Pricing

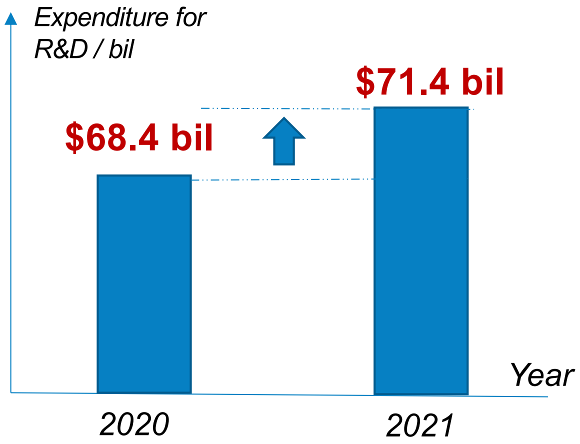
BREAK-EVEN ANALYSIS

- Accurate, Predictive Quantiative Analysis

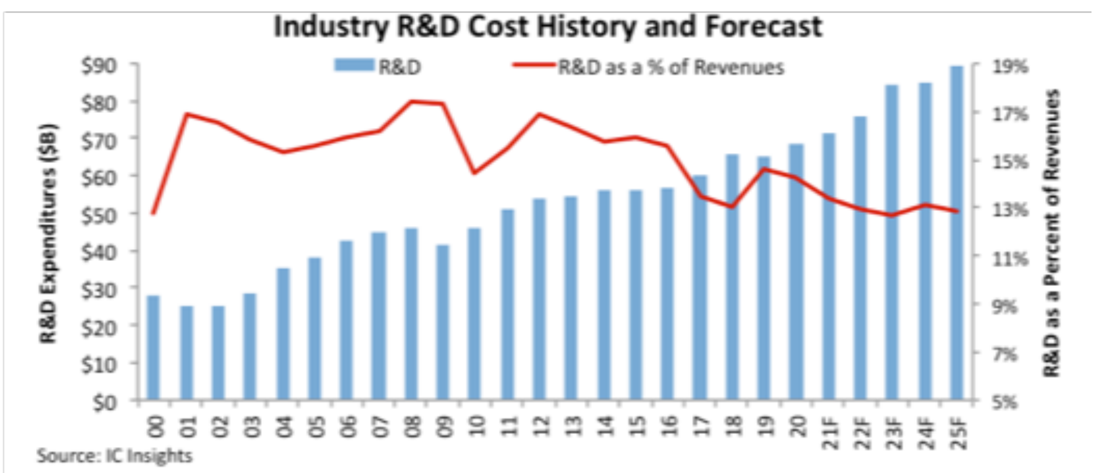
Whether the increase in production from Expansion of Fab is profitable

3.3 R&D: Technologies

- Technologies play an essential role in any semiconductor companies
- R&D spending by semiconductor companies worldwide is forecast to grow 4% in 2021 to $71.4 billion after rising 5% in 2020 to a record high of $68.4 billion
- Yet, a decreasing trend in the values of R&D as a percentage of Revenues



Increase in R&D spending



Decreasing R&D per Revenue

3.3 R&D: Technologies

- 5-nanometer plus, or N5P takes at least three months.
- The companies still need to keep up with the production of the previous technologies
- iPhone 12's A14 chip requires a 5 nm chip, a 7nm chip is still required for iPhone 11’s A13 chip and iPhone XS’s A12 chip
- To mass-produce 5 nm chip by 2024, TSMC build a $12 billion chip plant

iPhone XS

iPhone 11

iPhone 12

3.3 R&D: Technologies

- Micron, one of the major suppliers of DRAM and NAND memory
- Needs to produce advanced 3D Nand flash memory chips used to produce solid-state drives that are used in smartphones, tablets and computer

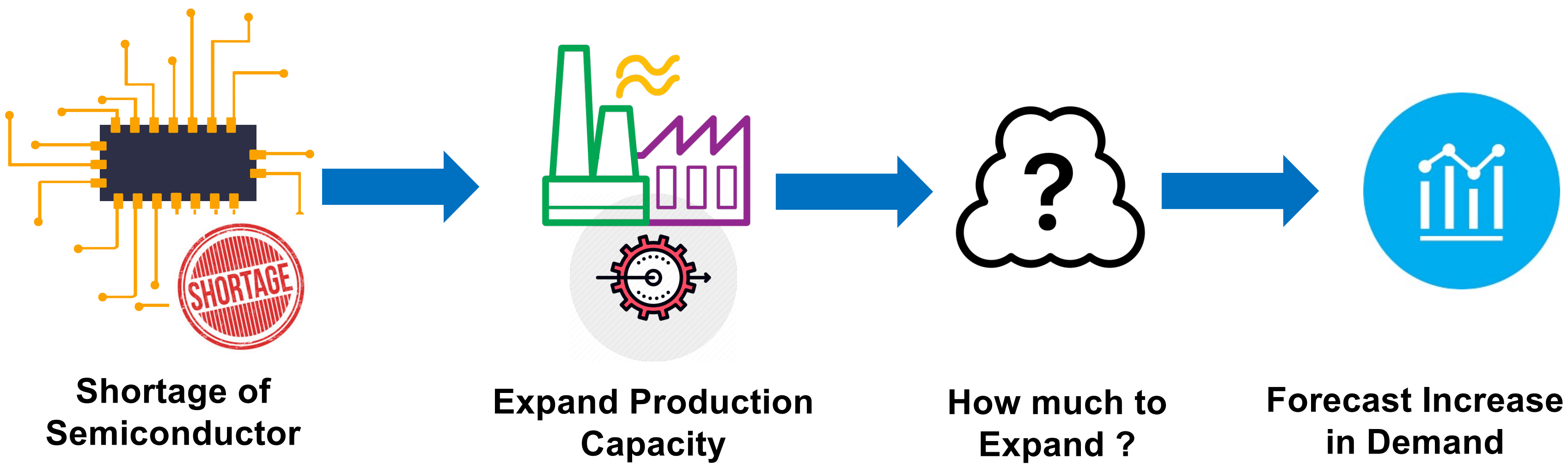
DRAM

NAND

Micron is a GOOD candidate for expansion

3.2 Demand Projection Forecast

- The shortage of chips and semiconductors in the market will prompt companies to expand their capacity for production
- Hence, the ability to forecast demand plays an important role in a fabrication plant expansion, thus, determine capital investment for capacity planning



3.2 Demand Projection Forecast

- Demand forecast is complex and difficult as there are many factors to consider
- Thus, leading to demand uncertainty and increasing risks of capacity shortage and/or surplus in the demand forecast.

Overestimated Demand forecasting

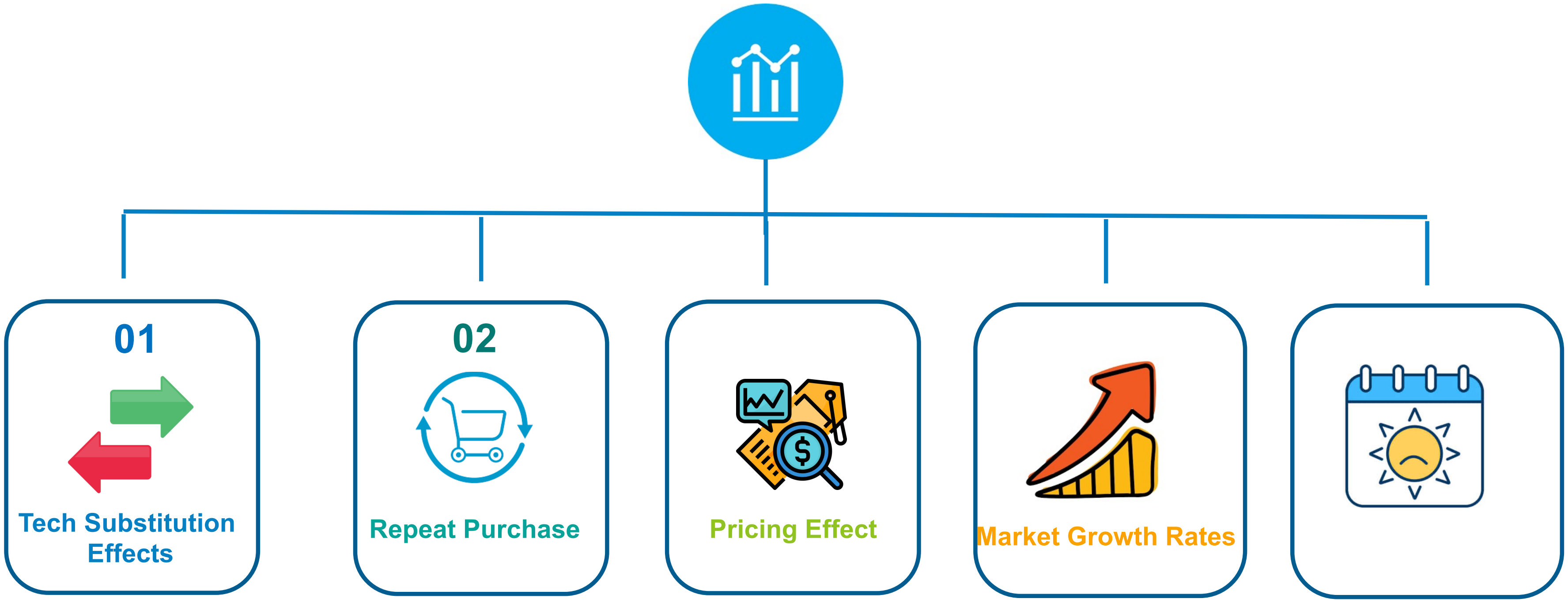
➡ Inefficiently utilized Capacity

Underestimated Demand forecasting

➡ Insufficient Capacity to meet demand

3.2 Demand Projection Forecast

- **SMPRT demand forecasting model**
- **Developed by Norton and Bass in 1987**



3.2 Demand Projection Forecast

01
Tech Substitution Effects

Moore's Law refers to **Moore's** perception that the number of transistors on a microchip doubles every two years, though the cost of computers is halved.

02
Repeat Purchase

Measures the degree of loyalty of customers and whether they would repurchase the goods in the future

Pricing Effect

- ↑↓ prices & Qty Demanded
- Expectation of Future Price to rise/fall
- Current demand
- Future demand

Market Growth Rates

- When growth rate is rising , the demand might increase

Seasonal Factors

3.2 Demand Projection Forecast - Micron

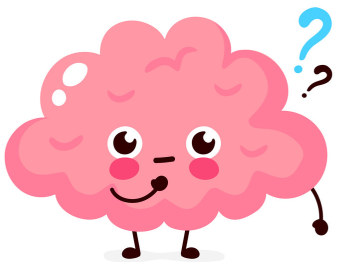
The search for new types of semiconductor is ongoing, in not only Singapore but also in the whole world

Computers and electronic devices are necessities during this time. Price effects become negligible

Increase in revenue and demand of semiconductors in recent year → market growth rate is increasing

Covid -> causes a surge in demand for PC and electronic devices

Thank you!



QUESTIONS & ANSWERS