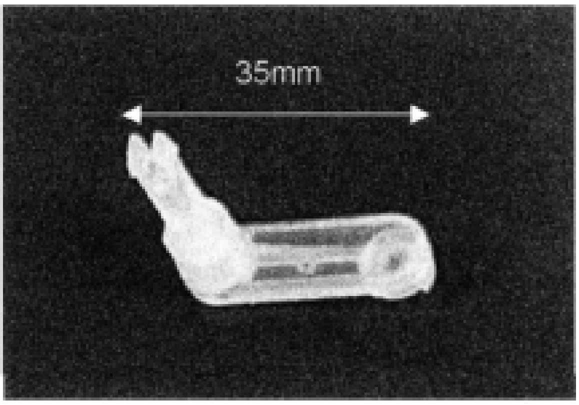
Case Study (Using Hopkinson and Dickens Cost model)

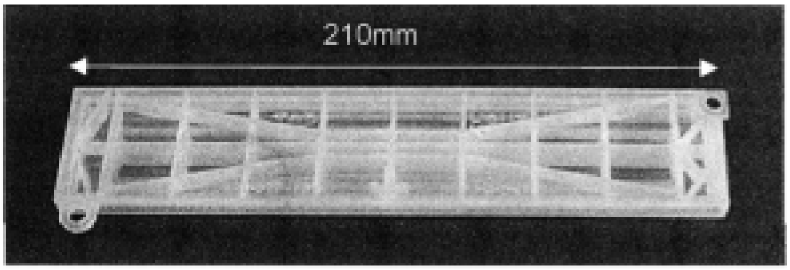
Goal of the case study: Perform cost estimation to compare a traditional manufacturing route **(injection molding**) with layer manufacturing processes (**Stereolithography SL**, **Fused deposition modelling FDM** and **Laser sintering LS**) in terms of the unit cost for parts made in various quantities.

The main purpose is to provide a direct comparison between the AM different processes/ technologies and Injection molding. For Two different parts, and quantity:

Part.1 (Lever)



Part.2 (Cover part)



Assumptions:

- The machine ***depreciation for AM machines is 8 years***, same for Injection molding. - The capacity utilization for AM machines and injection molding ***is 90% that means (7884 h per year***).
- The costs of Injection molding will be provided in this case study.
- The estimation of Overheads costs is not included in this case study.
- The costs of AM processes will include machine setup, machine output, and post processing (which are labor activity), and Machine build. Thus, the costs for AM processes are broken down into:
    - ***Machine costs***
    - ***Labor costs***
    - ***Material costs***
- The costs of producing parts by AM are calculated by assuming that a machine produces one part consistently for 1 year.

The cost model equations:

Calculation of Machine costs, that estimate the total machine cost for one part, by each of the AM process.

	Variable	Obtained by
Number per platform	N	Maximum possible in one build
Platform build time	T	Hours
Production rate per hour	R	N/T
Hours per year in operation	HY	$365 \times 24 \times 90\% = 7884$
Production volume total per year	V	$R \times 7884$
Machine costs		
Machine and ancillary equipment	E	Machine purchase cost
Equipment depreciation per year	D	$E/8$
Machine maintenance per year	M	Most comprehensive package
Total machine cost per year	MC	$D + M$
Machine cost per part	MCP	MC/V

Calculation of Labor cost, to formulate the labor costs per part for each AM process used. The operator (for machine setup, and post processing) hourly rate (€/h) cost is **5.30 euros per hour**.

	Variable	Obtained by
Number per platform	N	Maximum possible in one build
Platform build time	T	Hours
Production rate per hour	R	N/T
Hours per year in operation	HY	$365 \times 24 \times 90\% = 7884$
Production volume total per year	V	$R \times$ HY
Labour costs		
Machine operator cost per hour	Op	Minimum wage 5.30 euros
Set-up time to control machine	Set	Timed
Post-processing time per build	Post	Timed
Labour cost per build	L	Op $\times$ (Set + Post)
Labour cost per part	LCP	L/N

Calculating material costs, however, the different nature of AM processes employed necessitated the use of different means for calculating material costs.

For SL it was sufficient to weight completed parts with supports in order to calculate the cost.

For FDM it was sufficient to weight parts and support separately and then to multiply these by the associated material costs to find the material cost.

For LS a more complex formula is required to estimate the material cost. It also assumed that no material was to be recycled to ensure the consistent part quality, only new material. The mass of material used was calculated in terms of sintered material (by weighing parts) and un-sintered material (by calculating the volume of unused material and multiplying this by its un-sintered density).

	Variable	Obtained by
Number per platform	N	Maximum possible in one build
Material costs for SL		
Material per part including support (kg)	SLMass	Weighing finished parts
Material cost per kg	SLcost	Quote = 275.20 euros
Material cost per SL part	SLMCP	SLMAss × SLcost
Material costs for FDM		
Material per part (kg)	FDMPM	Weighing finished parts
Support material per part (kg)	FDMSM	Weighing finished supports
Build material cost per kg	FDMPC	Quote = 400.00 euros
Support material cost per kg	FDMSC	Quote = 216.00 euros
Material cost per FDM part		(FDMPM × FDMPC) + (FDMSM × FDMSC)
Material costs for LS		
Material cost per kg	LSC	Quote = 54.00 euros
Mass of each part	LSM	Weighing finished parts
Volume of each part	VP	Found with Magics software
Total build volume	TBV	34 × 34 × 60 cm^3
Mass of sintered material per build	LSMS	N × LSM
Mass of unsintered material per build	LSMU	(TBV − N × VP) × 0.475*
Cost of material used in one build	LSMC	(LSMU + LSMS) × LSC
Material cost per LS part	LSMCP	LSMC/N

* Published density of unsintered LS powder is 0.45–0.5 g/cm^3

The costs using Injecting molding

	Part name	
	Lever	Cover
Tool cost (euro)	27 360	32 100
Unit cost (euro)	0.23	0.21

Requirement for the cost estimation:

For SL:

Both parts were build using ***Epoxy material*** on ***SLA7000 machine***.

Number per platform: Lever: 190, Cover: 22
Platform build time (h): Lever: 26.8, Cover: 24.73
Machine and support equipment (€): 1040000
Machine maintenance (€/year): 89000
Machine setup time (min): Lever: 33, Cover: 30

Post-processing time per build (min): Lever; 49, Cover:68
Material per part including support (Kg): Lever; 0.0047, Cover: 0.0551
Material cost (€/kg): 275.20

For FDM:

Both parts were build using **ABS material**, on **FDM 2000 machine**.

Number per platform: Lever: 75, Cover: 4
Platform build time(h): Lever: 67.27, Cover: 31.40
Machine and support equipment (€): 101280
Machine maintenance (€/year): 10560
Machine setup time (min): Lever: 10, Cover: 10
Post-processing time per build (min): Lever:60, Cover:5
Material per part (kg): Lever: 0.0035, Cover: 0.04
Support material per part (kg): Lever: 0.0016, Cover: 0.027
Build material cost (€): 400
Support material cost per part (€): 216

For LS:

Is only used to fabricate the **Lever** part only. Using **Nylon material** on **EOSP360 machine**.

Number per platform: Lever: 1056
Platform build time(h): Lever: 59.78
Machine and support equipment (€): 340000
Machine maintenance (€/year): 30450
Machine setup time (min): Lever: 120
Post-processing time per build (min): Lever:360
Material cost (€/kg): 54
Mass of each part (Kg): 0.0036
Volume of each part (cm3): 4.3

Question:

Compare the different AM process costs with the Injection molding costs, for each part. And select the best process to adopt for each part. Write a short summary satisfying which process is more effective to adopt or use to manufacture each part (Lever, Cover).

Try to propose tables for the solutions, as it shown at the beginning of this case study ***(calculation of machine costs, labor costs, and material costs***), by the finding the required parameters for the estimation for both parts costs.

Question Case 2:

Using the same cost model equations, we need to estimate the cost **using LS** for other part, using different machine, and different material. In this case we will use two different machines ***EOS M290, and EOS M400-4.*** And ***316L Stainless Steel*** material. Then compare the cost for a single part using these different machines, and write a summary which machine is more cost effective to use/ buy to manufacture the part, and why?

Also, what will happen if we exclude the **cost of un-sintered powder**? For the case that this powder will be used again for other purpose. That is mean only including the cost **of sintered powder** for the material used cost, does it affect the decision of which machine to select or use? And in your opinion, why? if this affect the decision?

Requirement for the estimation:

For LS using EOS M290 machine:

Number per platform: 15
Platform build time(h): 26.1
Machine and support equipment (€): 480000
Machine maintenance (€/year): 48000
Machine utilization rate is the same 90%, that means (7884 h) hours per year operation
Machine depreciation: changed to (6 years)
Machine setup time (min): 18 min
Post-processing time per build (min): 45 min
Operator hourly rate (€/h): is changed to **39**, required more skilled operator
Material Type: 316L Stainless Steel
Material cost (€/kg): 40
Total build volume (cm3): 25 x 25 x 35
Mass of each part (Kg): 0.182
Volume of each part (cm3): 23.1
Un-sintered density (g/cm3): 4.74 (0.00474 kg/cm3)

For LS using EOS M400-4 machine:

Number per platform: 40
Platform build time(h): 21.7
Machine and support equipment (€): 1420000
Machine maintenance (€/year): 142000
Machine utilization rate is the same 90%, that means (7884 h) hours per year operation
Machine depreciation: changed to (6 years)
Machine setup time (min): 48
Post-processing time per build (min): 120
Operator hourly rate (€/h): is changed to **39**, required more skilled operator
Material Type: 316L Stainless Steel
Material cost (€/kg): 40
Total build volume (cm3): 40 x 40 x 40
Mass of each part (Kg): 0.182
Volume of each part (cm3): 23.1
Unstinted density (g/cm3): 4.74 (0.00474 kg/cm3)