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Mechanical Analysis and Design
ME 2104

Lecture 10

Concept Selection

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www.staff.city.ac.uk/~ra600/intro.htm

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Plan for today

- Review of concept generation (35 min)
  - » Evaluation - technical and economy aspects
- Team meeting (Evaluating concepts) (65 min)
- Q&A (10 min)
  - » Concept development and evaluation

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Concept generation and evaluation

A team of design students was asked to design a steam-powered machine shop kit that can be used to (1) develop hands-on skills in using machine shop tools for freshman engineering students, and (2) demonstrate the conversion of thermal energy into work, thus becoming a demonstration tool for an introduction to thermal science class. Stirling engine kits are being used in many engineering schools. The new kit must compete with the Stirling engine kit in its educational value and its cost. A Stirling engine kit is a kit containing the disassembled parts that compose a Stirling engine; a few of the parts require students to use the equipment in the workshop.

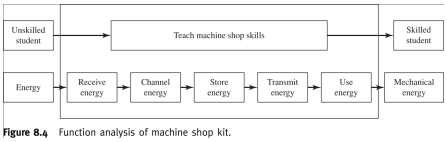

Figure 8.4 Function analysis of machine shop kit.

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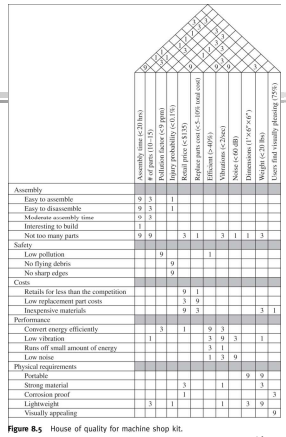
QFD



	Assembly time (<2h/hrs)	# of parts (10–15)	Pollution factor (<9 ppm)	Injury probability (<0.1%)	Retail price (<$150)	Profit margin (>5–10% total cost)	Efficient (>40%)	Vibrations (<2Sec)	Noise (<60 dB)	Dimension (7"×6"×6")	Weight (<20 lbs)	Users find it visually pleasing (75%)
Assembly												
Easy to assemble	9	3		1								
Easy to disassemble	9	3		1								
Moderate assembly time	9	3										
Interesting to build	1											
Not too many parts	9	9			3	1		3	1	1	3	
Safety												
Low pollution			9				1					
No flying debris				9								
No sharp edges				9								
Costs												
Retails for less than the competition					9	1						
Low replacement part costs					3	9						
Inexpensive materials					9	3					3	1
Performance												
Convert energy efficiently			3		1		9	3				
Low vibration		1					3	9	3		1	
Runs off small amount of energy							3	1				
Low noise							1	3	9			
Physical requirements												
Portable										9	9	
Strong material					3			1			3	
Corrosion proof					1							3
Lightweight		3		1				1		3	9	
Visually appealing												9

Figure 8.5 House of quality for machine shop kit.

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Morphological chart

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Receive	Open cylinder	Spring	Closed cylinder				
Channel	Funnel	Linkage	Shaft	Gear	Tube	Piston	
Store	Flywheel	Piston	Capacitor	Propeller	Shaft	Tube	
Transmit	Shaft	Belt	Gear	Steam wheel			
Use	Wheel & axle	Rod	Propeller	Linkage	Gear	Flywheel	Pulley

Figure 8.6 Morphological chart for machine shop kit.

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Concept variants

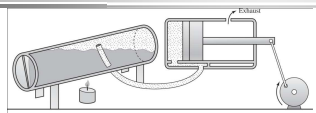

Figure 8.7 Concept I of machine shop kit: A tank full of water is heated to produce steam. The steam will travel through the tube and push the piston, which will turn the attached flywheel.

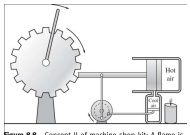

Figure 8.8 Concept II of machine shop kit: A flame is used to heat a piston, which will be pushed out to turn a gear. At the same time that the piston is pushed out, another piston is being pushed up, which will push the hot air piston back to its original position.

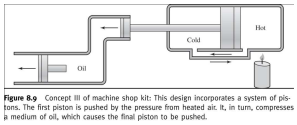

Figure 8.9 Concept III of machine shop kit: This design incorporates a system of pistons. The first piston is pushed by the pressure from heated air. It, in turn, compresses a medium of oil, which causes the final piston to be pushed.

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Concept variants

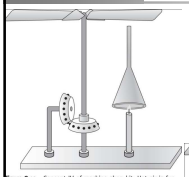

Figure 8.10 Concept IV of machine shop kit: Hot air is funneled to turn a propeller system. The propeller is connected to a central rod, which has a gear attached to it. The rotation of blades will cause the attached gear to rotate, which turns the other gear.

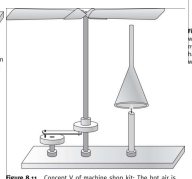

Figure 8.11 Concept V of machine shop kit: The hot air is channeled, which causes the propeller to rotate, which spins a flywheel. The flywheel is connected to a second flywheel by a connector link. Therefore, as the first flywheel turns, the second flywheel will also turn.

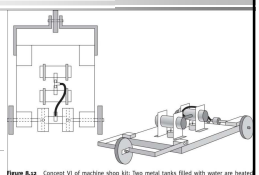

Figure 8.12 Concept VI of machine shop kit: Two metal tanks filled with water are heated with an alcohol burner. The heated water then generates steam that travels through a nylon tube to a steam tube. The steam tube is connected to two "steam wheels," which have holes drilled in them at 90° angles. The escaping steam will create rotation, which will turn the axles that turn the wheels and move the car.

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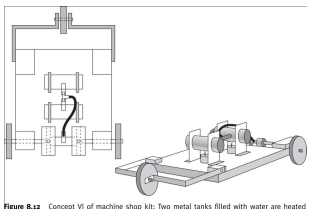

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Decision

Evaluation Chart

	Objective weight/10	Sketch 1	Sketch 2	Sketch 3	Sketch 4	Sketch 5	Sketch 6	D
Easy to assemble	7	0	0	0	+	0	+	A
Easy to disassemble	7	0	0	0	+	+	+	T
Safe for operator	10	0	0	0	0	0	0	U
Low vibration	5	+	–	+	0	0	0	M
Portable	4	–	0	0	0	0	+	
No sharp edges	6	+	0	+	–	–	0	
Retails for less than competition	9	+	+	+	+	+	+	
Convert energy efficiently	10	–	0	0	0	0	0	
No flying debris	8	0	0	0	0	0	0	
Low pollution	3	0	0	0	0	0	0	
Low replacement part cost	7	+	0	0	+	+	+	
Low noise	4	0	+	+	0	0	+	
Strong material	6	0	0	0	0	0	–	
Low energy dissipation	8	+	0	0	–	0	–	
Aesthetically appealing	5	–	0	–	0	0	+	
Total +		5	2	4	4	5	7	
Total –		3	1	1	2	1	2	
Overall total		2	1	3	2	4	5	
Weighted total		16	8	19	16	22	29	

Figure 8.13 Evaluation table for the machine shop kit

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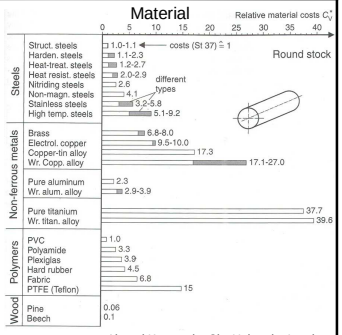
How to evaluate cost of concepts?

Relative costs

- Very useful for evaluation of concepts
- Related to the basic cost
- Do not change with time
- No problem with secrecy
- Help to achieve low-cost preliminary solution



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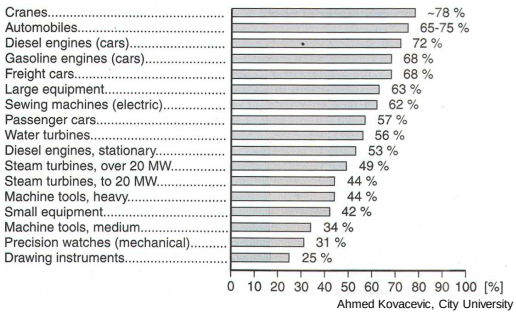
Relative costs

Cost of material as a percentage of the manufacturing costs



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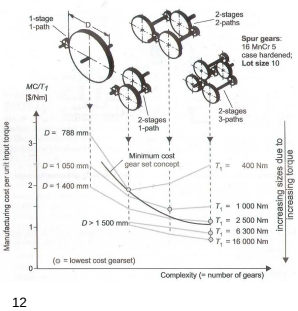
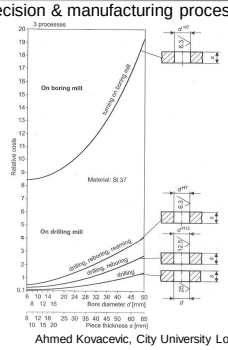
Relative costs

Concept



Precision & manufacturing process



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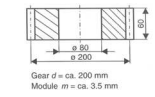
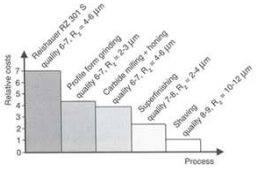
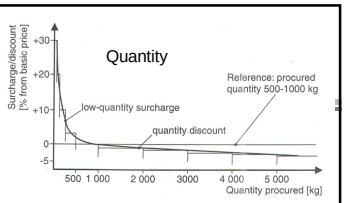
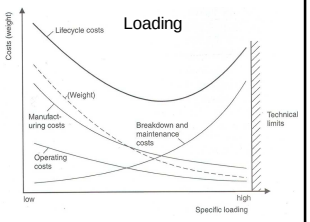
Relative costs

Manufacturing process









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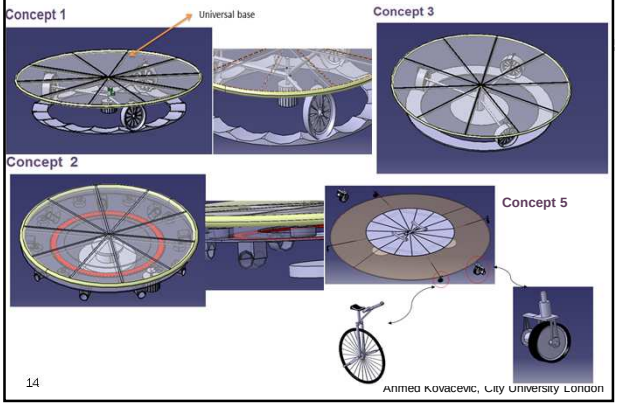
Concept Variants



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Cost analysis

Concept One (Bump)

Components	Number Of Parts	Material	Cost Of Each Material	Cost Total
Motor	1	Metal	£506.52	£506.52
Wheels	3	Rubber/Metal	£77.00	£231.00
Axles	3	Metal	£255.88	£767.64
Base	24	Wood	£119.60	£2,870.40
Cover	50	Plastics	£15.12	£756.00
Rods	8	Metal	£43.11	£344.88
		Total	£5,476.44	

Concept Two (Hydraulics)

Components	Number Of Parts	Material	Cost Of Each Material	Cost Total
Motor	1	Metal	£506.52	£506.52
Axles	3	Metal	£255.88	£767.64
Base	24	Wood	£119.60	£2,870.40
Hydraulics	2	Metal	£1,024.74	£2,049.48
Cover	50	Plastics	£15.12	£756.00
Wheels	3	Rubber/Metal	£77.00	£231.00
Gauge Pressure	2	Metal/Plastic	£240	£480.00
Rods	8	Metal	£43.11	£344.88
		Total	£8,095.92	

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Decision Matrix

Objectives			Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Maximum	
Level 2	Level 3	WF	RF	UV	RF	UV	RF	UV	RF	UV	RF	UV	RF	UV
Low Costs	Cost of Manuacturing	7	8.58	60.06	5	35	10	70	3.52	24.64	4.80	34.23	10	70
	Operational Costs	3	9	27	8	24	10	30	8	24	7	21	10	30
	Set up Costs	1	10	10	10	10	10	10	10	10	10	10	10	10
	Maintenance costs	1.5	9	13.5	8	12	10	15	8	12	8	12	10	15
		13	36.58	110.56	31	81	40	125	29.52	70.64	29.80	77.23	40	125
Low Weight	Weight of material	7	9	63	7	49	10	70	6	42	9.5	66.5	10	70
	Size	7	10	70	10	70	10	70	10	70	10	70	10	70
		14	19	133	17	119	20	140	16	112	19.5	136.5	20	140
High Safety	Safe for users	8	10	80	10	80	6	48	7	56	7	56	10	80
	Safe for Operator	4	10	40	10	40	6	24	7	28	7	28	10	40
	Structural safety	4	9.5	38	10	40	3.5	14	8	32	10	40	10	40
	Safe for Environment	2	8	16	7	14	10	20	7	14	9	18	10	20
	Meets regulations	4	10	40	10	40	10	40	10	40	10	40	10	40
	Safe against failure	3	10	30	10	30	3	9	10	30	9	27	10	30
		25	57.5	244	57	244	38.5	155	49	200	52	209	60	250
High value maintenance	Easy to maintain	3	9	27	8	24	10	30	7	21	8	24	10	30
	Parts easy to replace	1.5	9	13.5	8	12	10	15	8	12	8	12	10	15
	Long intervals	2.5	9	22.5	6	15	10	25	8	20	7	17.5	10	25
		7	27	63	22	51	30	70	23	53	23	53.5	30	70
Good Performance	Simple kinematics	6	9	54	8	48	3	18	8	48	10	60	10	60
	Low power required	2	9	18	8	16	2	4	9	18	10	20	10	20
		8	18	72	16	64	5	22	17	66	20	80	20	80
Aestheticaly appealing	Surface finish & texture	3	10	30	10	30	10	30	10	30	10	30	10	30
	Color and appearance	12	6	72	8	96	5	60	10	120	8	96	10	120
		15	16	102	18	126	15	90	20	150	18	126	20	150
Cheap to transport	Weight for transport	4	9.5	38	8	32	10	40	7.5	30	9	36	10	40
	Dimension of components	1	9.5	9.5	7	7	10	10	6	6	9	9	10	10
	Number of components	1	9.1	9.1	5.6	5.6	10	10	4.8	4.8	6.9	6.9	10	10
		6	28.1	56.6	20.6	44.6	30	60	18.3	40.8	24.9	51.9	30	60
High value assembly process	Easy to assemble	3	9.1	27.3	5.6	16.8	10	30	4.8	14.4	9.5	28.5	10	30
	Short time to assemble	2	9.1	18.2	5.6	11.2	10	20	4.8	9.6	9.5	19	10	20
	Required man power	2	10	20	10	20	10	20	10	20	10	20	10	20
	Instruction manual	1	10	10	10	10	10	10	10	10	10	10	10	10
		8	38.2	75.5	31.2	58	40	80	29.6	54	39	77.5	40	80

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Decision making

Technical		Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Maximum
Level 2	WF	UV	UV	UV	UV	UV	UV
Low Weight	14	133	119	140	112	136.5	140
High Safety	27	264	264	164	217	225	270
Good Performance	8	72	64	22	66	80	80
Aestheticaly appealing	15	102	126	90	150	126	150
Total	64	571	573	416	545	567.5	640
Normalised		89%	90%	65%	85%	89%	100%

Economy		Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Maximum
Level 2	WF	UV	UV	UV	UV	UV	UV
Low Costs	12.5	110.56	81	125	70.64	77.23	125
High value maintenance	7.5	67.5	55	75	57	57.5	75
Cheap to transport	7	66.1	51.6	70	46.8	60.9	70
High value assembly process	9	84.6	63.6	90	58.8	87	90
Total	36	328.76	251.2	360	233.24	282.63	360
Normalised		91%	70%	100%	65%	79%	100%

Overal Sum	100	90%	82%	78%	78%	85%	1000

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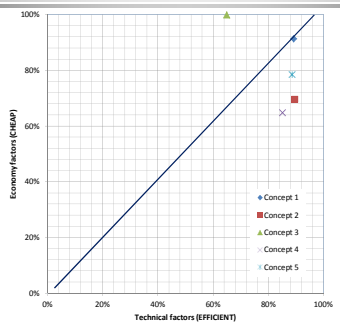
Technical – Economy Diagram



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Team meeting

» Second brainstorming of Morph chart
» Concepts
» Decide who is evaluating what and how

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Q & A

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Tasks for this week

Until Thursday:
» Make final sketches of concepts with clarity of operation principle
» Evaluate concepts (cost analysis + performance analysis) based on engineering characteristics

Meeting on Thursday:
» Review the analysis results
» Form Decision matrix

Until next Monday:
» Technical – Economy diagram
» Finish remaining documents from phase 1 and 2

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Content for 2nd Project Review

- Updated Objectives, Functional model, QFD, Requirements list
- Morphological chat
- At least three concept variants
- Evaluation of concepts (technical & economy)
- Decision matrix
- Technical-Economy Diagram
- Proposed concept – vision on what will it be!

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Report (10 Pages + Appendix) Due: Friday, 5th December 2014, 11:55 PM

- Introduction 5%
- Updated Objectives, Functional model, QFD, Requirements list (10%) (In appendices)
- Brain Storming and Morphological Chart 10%
- Concepts (5 to 7) 20%
- Analysis of Concepts 15%
- Decision Matrix 20%
- Technical vs Economical Chart 5%
- Selected 3 concepts with Ranking 5%
- Updated GANTT Chart and Plan 5%
- Summary 5%

% Indicates weighting of Marks

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Presentation (10 Slides, 15 mins + 10min Q's) Due: Friday, 5th December 2014, 11:55 PM

Presentation: 8th December 11:00 – 13:00, Room C302; G5-8
8th December 16:00 – 18:00, Room B307; G1-4

- Introduction (Team and Vision) 5%
- Updated Objectives, Functional model, QFD, Requirements list (10%)
- Brain Storming and Morphological Chart 10%
- Concepts (5 to 7) 20%
- Analysis of Concepts 15%
- Decision Matrix 20%
- Technical vs Economical Chart 5%
- Selected 3 concepts with Ranking 5%
- Updated GANTT Chart and Plan 5%
- Summary 5%

% Also indicates weighting of Marks