Mechanical Analysis and Design
ME 2104

Lecture 10

Concept Selection

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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

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.

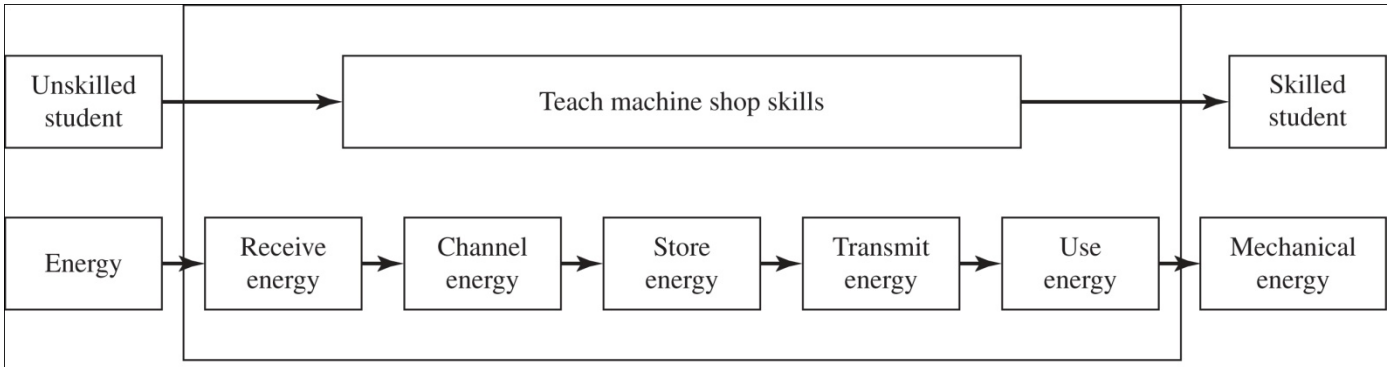
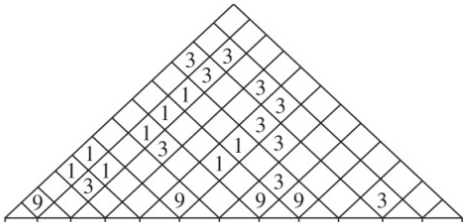


Figure 8.4 Function analysis of machine shop kit.

QFD



	Assembly time (<20 hrs)	# of parts (10–15)	Pollution factor (<9 ppm)	Injury probability (<0.1%)	Retail price (<$135)	Replace parts cost (<5–10% total cost)	Efficient (>40%)	Vibrations (<2/sec)	Noise (<60 dB)	Dimensions (1′×6″×6″)	Weight (<20 lbs)	Users find 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.

Morphological chart

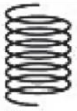
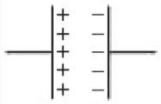
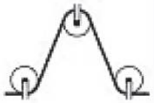
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Receive	 Open cylinder	 Spring	 Closed cylinder				
Channel	 Funnel	 Linkage	 Shaft	 Gear	 Tube	 Piston	
Store	 Flywheel	 Piston	 Capacitor	 Propeller	 Shaft	 Tube	
Transmit	 Shaft	 Belt	 Gear	 Steam wheel			
Use	 Wheel & axle	 Rod	 Propeller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

Figure 8.6 Morphological chart for machine shop kit.

Concept variants

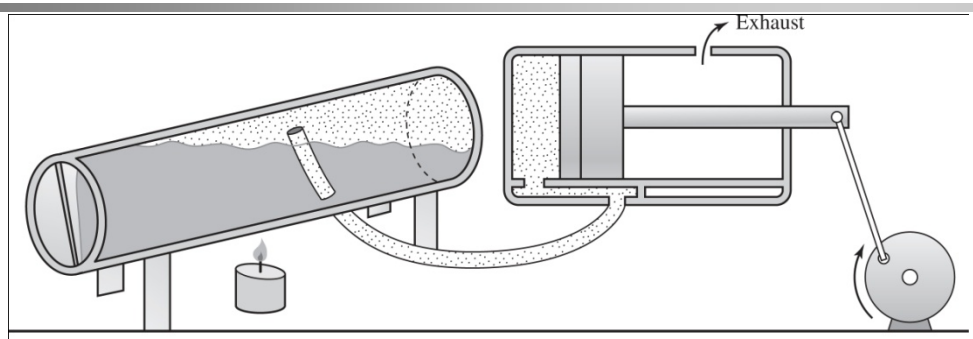


Figure 8.7 Concept I of machine shop kit: A tank full of water is heated to produce steam. The steam will travel through the tube and push the piston, which will turn the attached flywheel.

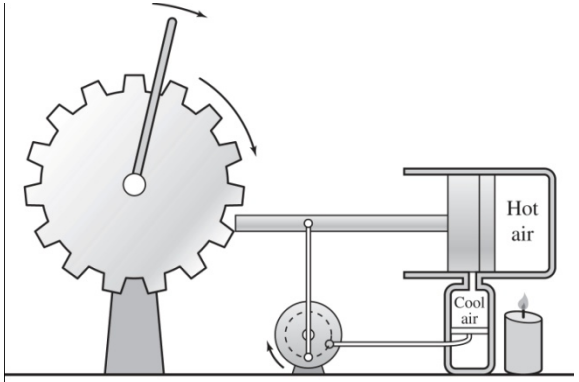


Figure 8.8 Concept II of machine shop kit: A flame is used to heat a piston, which will be pushed out to turn a gear. At the same time that the piston is pushed out, another piston is being pushed up, which will push the hot air piston back to its original position.

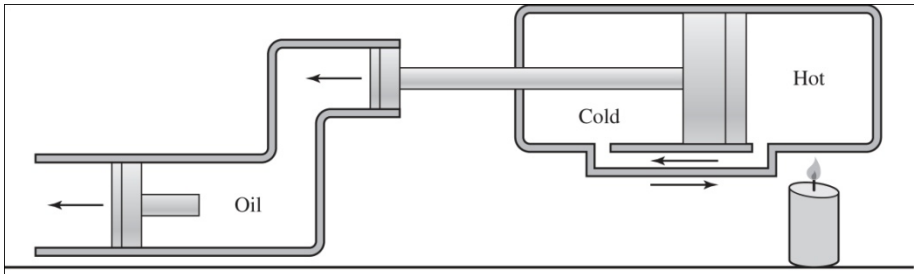


Figure 8.9 Concept III of machine shop kit: This design incorporates a system of pistons. The first piston is pushed by the pressure from heated air. It, in turn, compresses a medium of oil, which causes the final piston to be pushed.

Concept variants

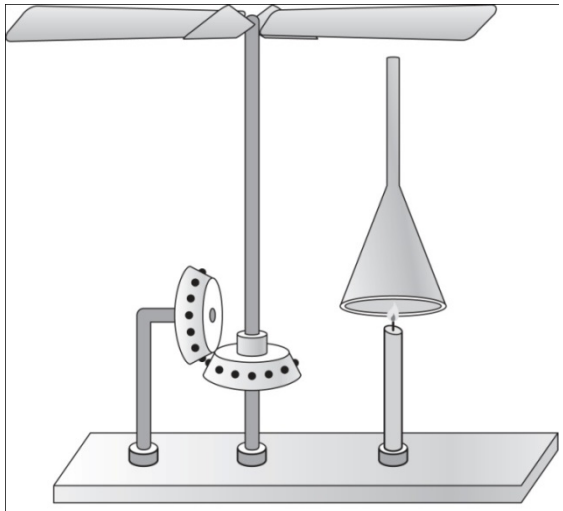


Figure 8.10 Concept IV of machine shop kit: Hot air is funneled to turn a propeller system. The propeller is connected to a central rod, which has a gear attached to it. The rotation of blades will cause the attached gear to rotate, which turns the other gear.

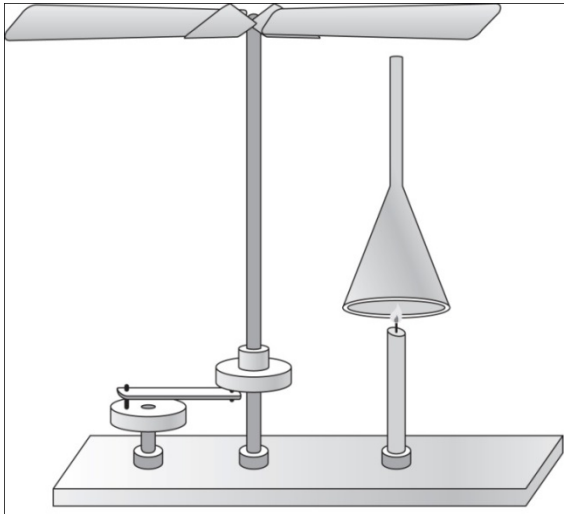


Figure 8.11 Concept V of machine shop kit: The hot air is channeled, which causes the propeller to rotate, which spins a flywheel. The flywheel is connected to a second flywheel by a connector link. Therefore, as the first flywheel turns, the second flywheel will also turn.

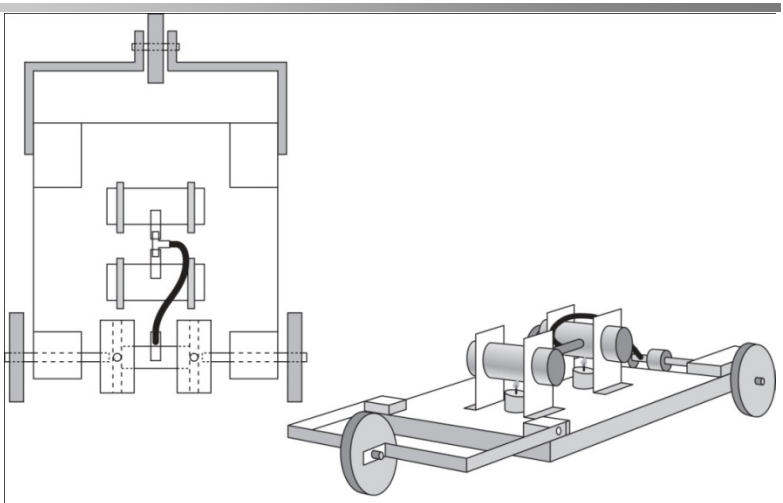


Figure 8.12 Concept VI of machine shop kit: Two metal tanks filled with water are heated with an alcohol burner. The heated water then generates steam that travels through a nylon tube to a steam tube. The steam tube is connected to two "steam wheels," which have holes drilled in them at 90° angles.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

Concepts Evaluation – Machine Shop Kit

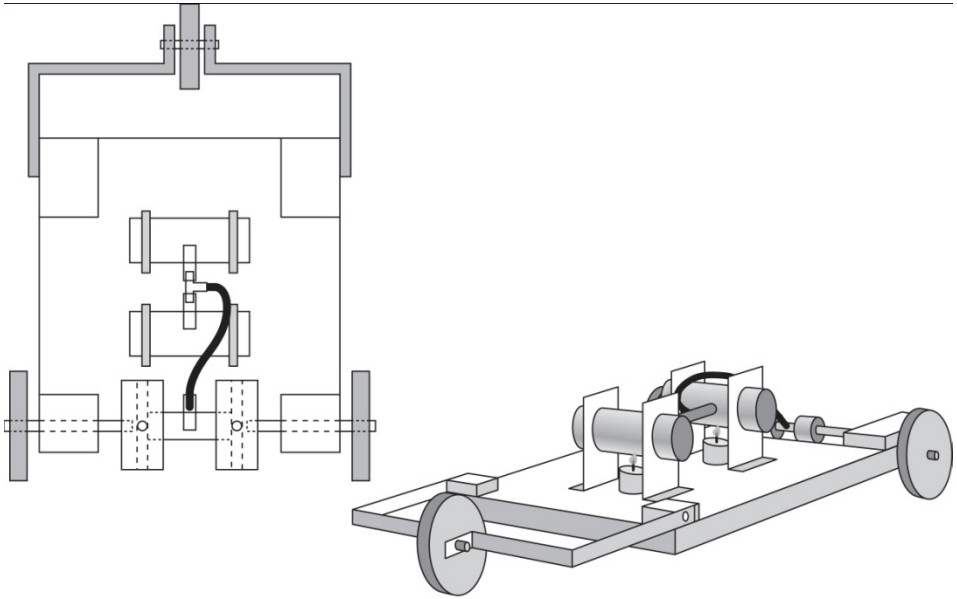


Figure 8.12 Concept VI of machine shop kit: Two metal tanks filled with water are heated with an alcohol burner. The heated water then generates steam that travels through a nylon tube to a steam tube. The steam tube is connected to two "steam wheels," which have holes drilled in them at 90° angles.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

Decision

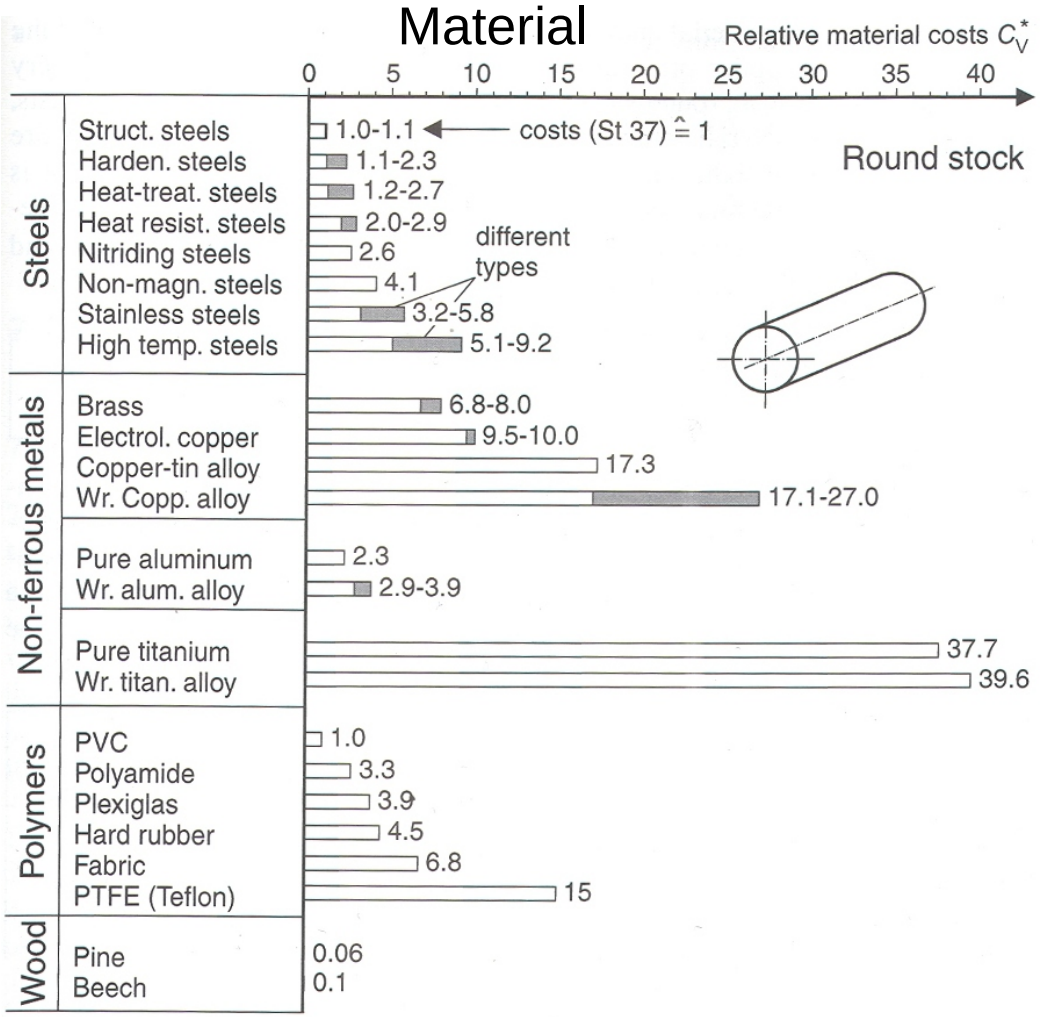
Evaluation Chart								
	Objective weight/10	Sketch 1	Sketch 2	Sketch 3	Sketch 4	Sketch 5	Sketch 6	D
Easy to assemble	7	0	0	0	+	0	+	A
Easy to disassemble	7	0	0	0	+	+	+	T
Safe for operator	10	0	0	0	0	0	0	U
Low vibration	5	+	–	+	0	0	0	M
Portable	4	–	0	0	0	0	+	
No sharp edges	6	+	0	+	–	–	0	
Retails for 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.

How to evaluate cost of concepts?

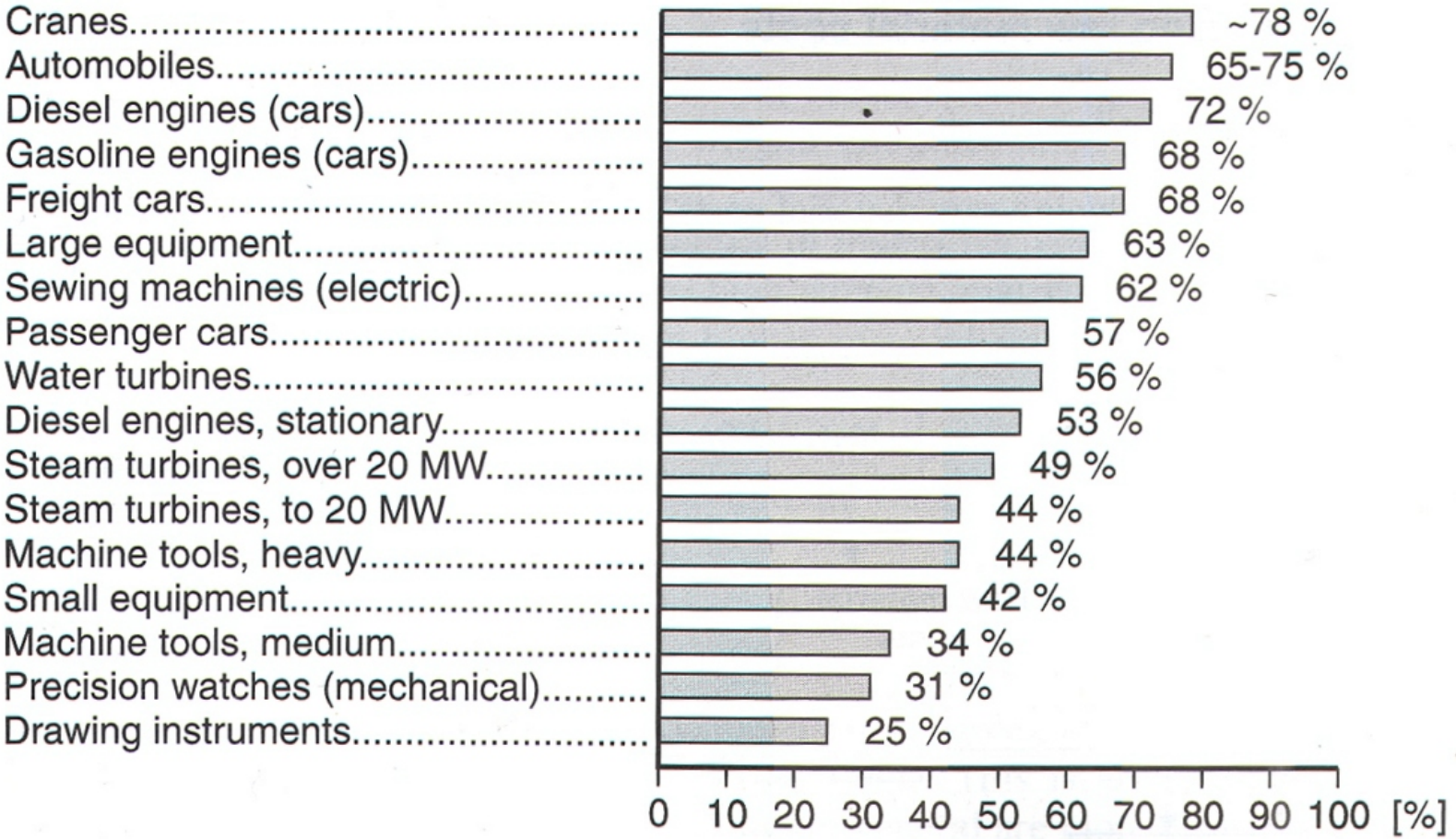
Relative costs

- 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



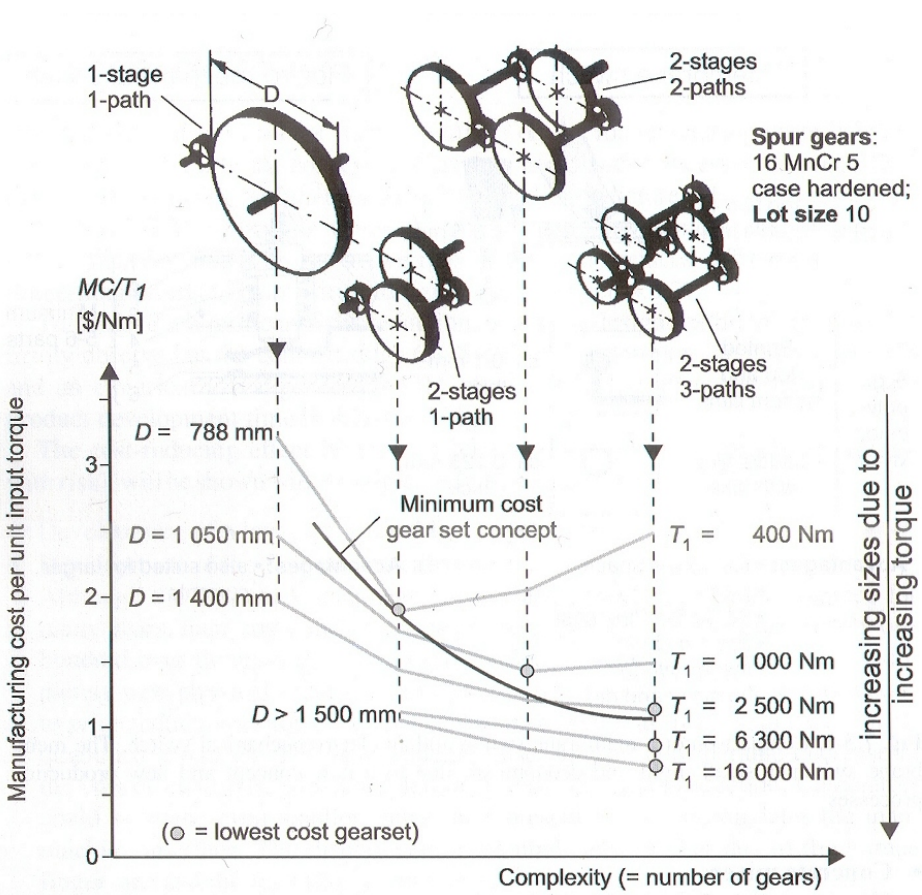
Relative costs

Cost of material as a percentage of the manufacturing costs

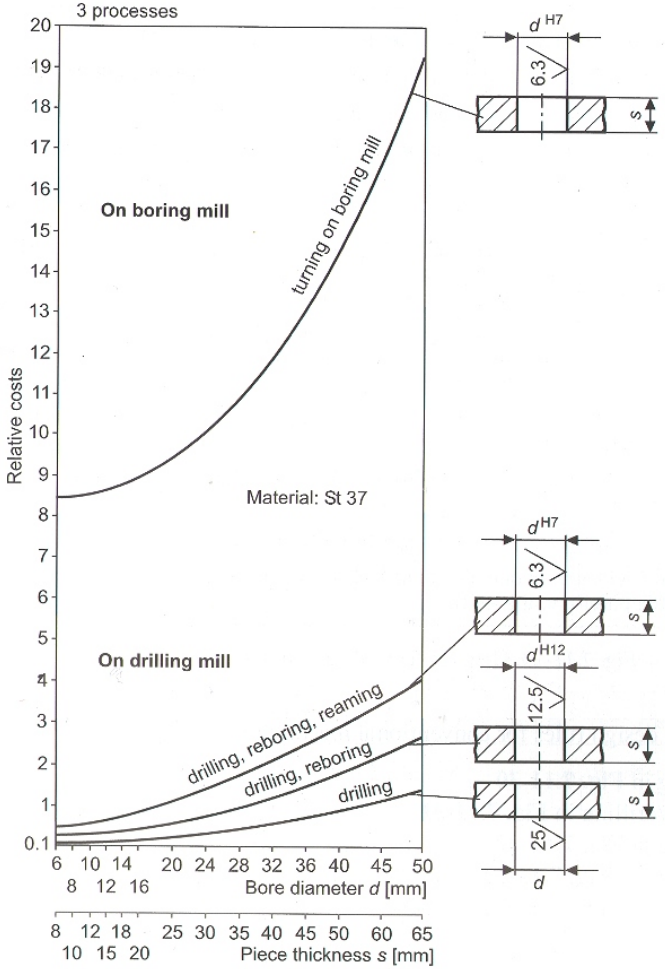


Relative costs

Concept

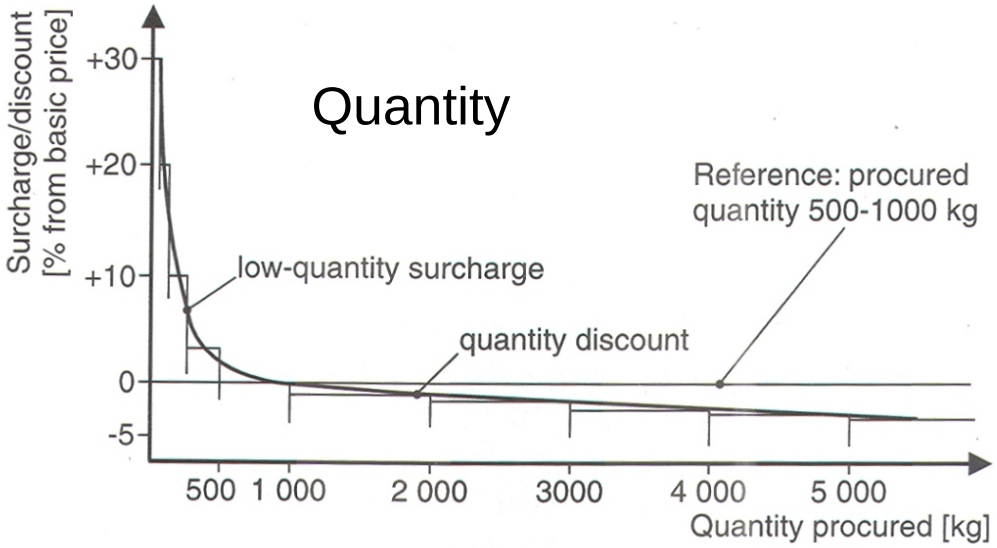


Precision & manufacturing process

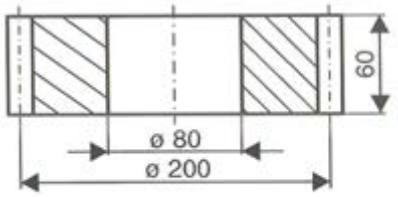


Relative costs

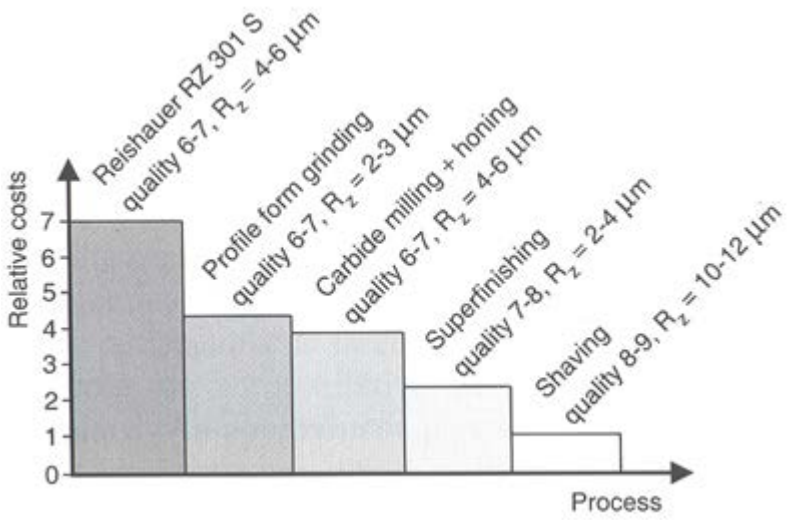
Quantity



Manufacturing process



Gear d = ca. 200 mm
Module m = ca. 3.5 mm



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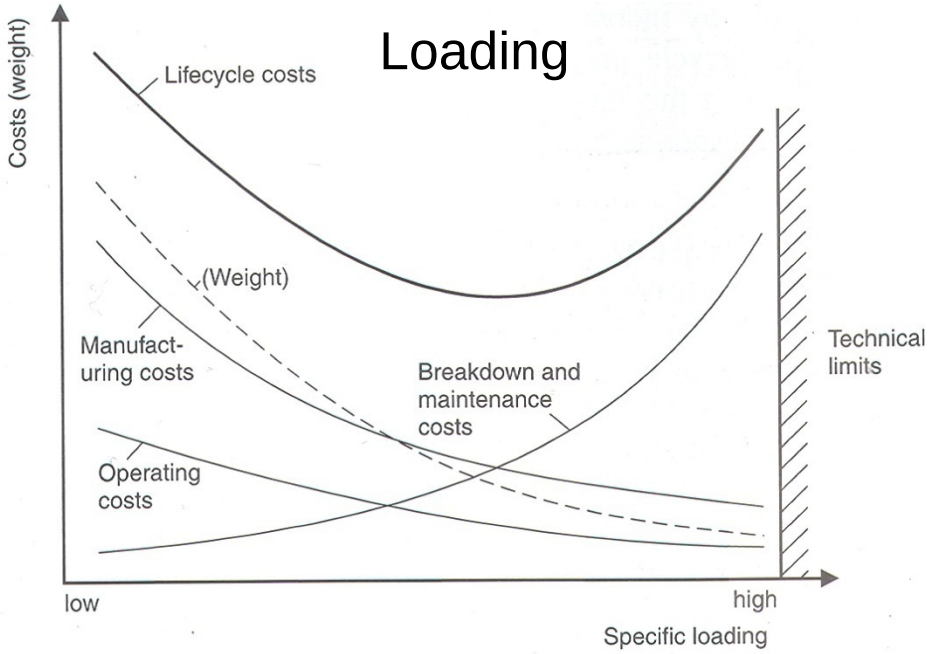
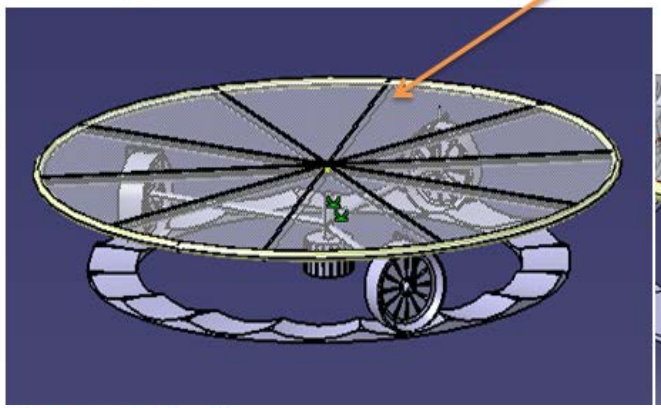
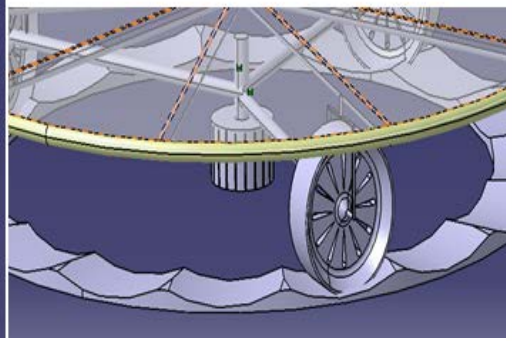


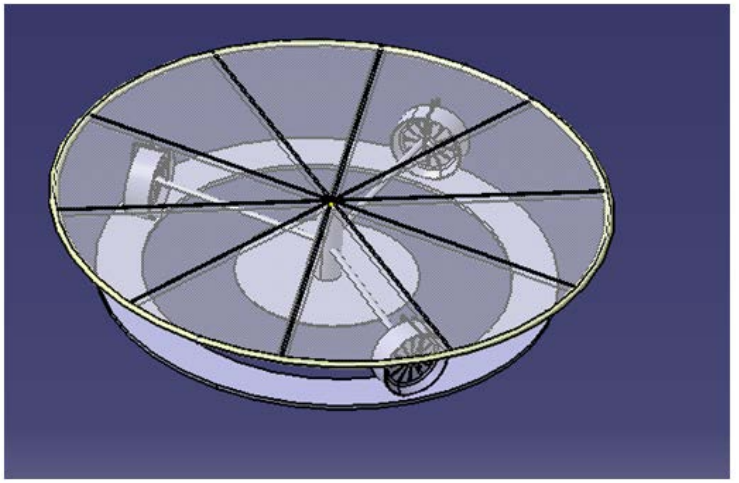
Concept Variants

Concept 1

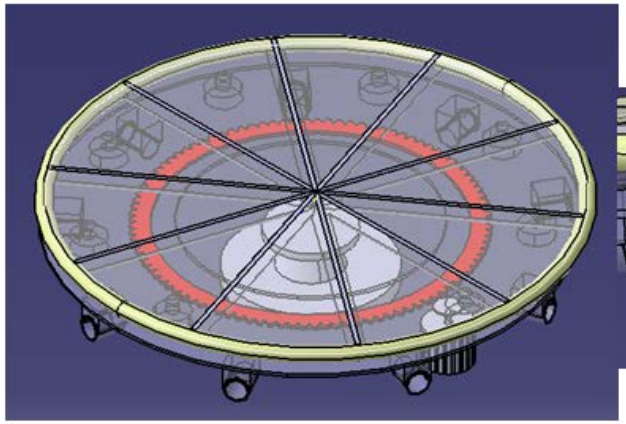


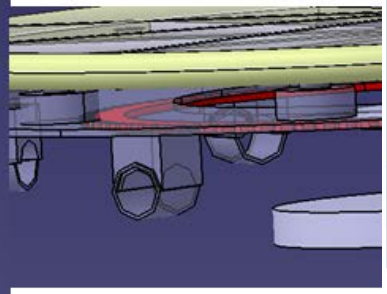


Concept 3

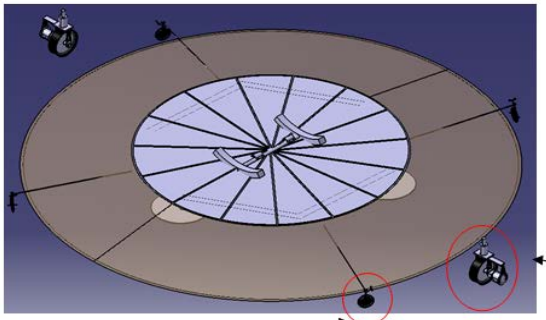


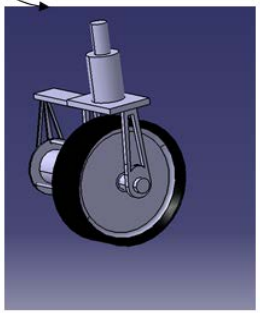
Concept 2





Concept 5





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	£8,005.92	

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	4.89	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**	29.89	**77.23**	40	**125**
Low Weight	Weight of materal	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 finsih & texture	3	10	30	10	30	10	30	10	30	10	30	10	30
	Color and apearance	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**

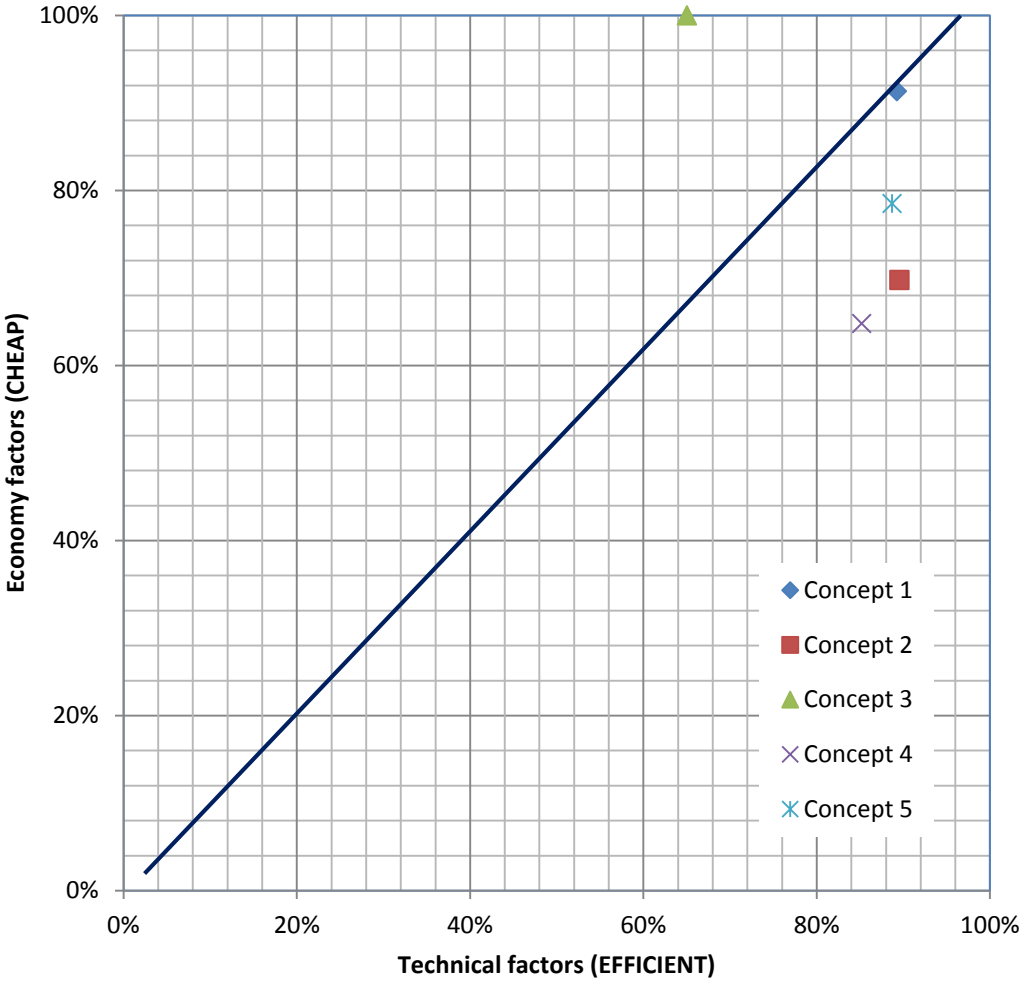
Decision making

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

Technical – Economy Diagram



Team meeting

» Second brainstorming of Morph chart

» Concepts

» Decide who is evaluating what and how

Q & A

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

Content for 2nd Project Review

- Updated Objectives, Functional model, QFD1 and QFD2, Revised Requirements list
- Updated Projectile Motion Calculation
- Updated Pressure Calculation
- 3 to 5 concept variants; Evaluation of concepts (technical & economy); Decision matrix, Technical-Economy Diagram
- Selection of gear and belts
- 3D CAD model embodying the selected concept

Report (10 Pages + Appendix)
Due: Sunday, 3rd Dec 2017, 11:55 PM

- Introduction 5%
- Updated Objectives, Simplified Functional model, Simplified QFD, QFD2, Revised Requirements list (10%) (In appendices)
- Updated Projectile Motion Calculation (10%)
- Updated Pressure Calculation (10%)
- 3 to 5 concept variants; Evaluation of concepts (technical & economy); Decision matrix, Technical-Economy Diagram (20%)
- Selected concept 5%
- Selection (calculation) of gear and belts (10%)
- 3D CAD model embodying the selected concept (20%)
- Updated GANTT Chart and Plan 5%
- Summary 5%

% Indicates weighting of Marks

Presentations (Max 10 Slides, 10 mins + 10min Q's)
Due: Sunday, 3rd December 2017, 11:55 PM

Presentations:	4th December	11:00 – 12,50, Room AG21;	G5-9
	8th December	10:00 – 11:50, Room ELG01;	G1-4

- Introduction (Team and Vision) 5%

Findings from:

- Updated Objectives, Simplified Functional model, Simplified QFD, QFD2, Revised Requirements list (10%) (In appendices)
- Updated Projectile Motion Calculation (10%)
- Updated Pressure Calculation (10%)
- 3 to 5 concept variants; Evaluation of concepts (technical & economy); Decision matrix, Technical-Economy Diagram (20%)
- Selected concept 5%
- Selection (calculation) of gear and belts (10%)
- 3D CAD model embodying the selected concept (20%)

- Updated GANTT Chart and Plan 5%
- Summary 5%

% Also indicates weighting of Marks