Crib for 4C4 Design Methods 2024/2025

Version: JMC/4

Question 1

(a) marks 10% 2

From the notes, the United Nations Brundtland Commission defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs."

(b) marks 20% 4

A whole systems approach helps to understand the environmental, safety, economic, social, and sustainability dimensions of new technologies and processes.

The sustainability impacts and benefits (environmental, social and economic) for the bio-based plastic substitute are spread across the entire lifecycle of the product. A whole systems approach would consider these impacts at each stage. This might include the energy and material use, environmental and social impacts, and waste generation reduction for each stage: growing the straw, harvesting and processing the straw, converting the straw into the bio-base plastic, extruding the plastic piping, how the piping is used, recycling/disposing of the piping after use, and transportation for all stages.

(c) marks 50% 10

From the lecture notes, the six principles for sustainable systems thinking are:

Lifecycle thinking considering the sustainability impacts at every lifecycle stage of the product production. Care should be taken to include the impacts which our outside the companies immediate boundary, such as: the impacts from growing and harvesting the straw bio-feedstock; the expected lifetime of the piping systems in use; what will happen to the pipe after use (i.e. recycling, incineration, landfill).

Prioritising scale The scale of substitution and impacts should be considered to assess the commercial viability and sustainability of the bio-based plastic. For example, questions might be asked about: the amount of straw available (scale of supply); the volume and commercial value of the HDPE piping systems being replaced (scale of demand); the volumes of bio-based plastic to be produced and their impacts (scale of impact); how much waste will be produced, and when.

Accuracy and uncertainty The company should take account of the uncertainty in both the activities and the emissions factors for these activities. Care should be taken when using lifecycle assessment numbers from databases, to decide whether these numbers are appropriate for use, or whether primary data should be collected.

Setting boundaries Care should be taken when comparing impacts between the existing HDPE piping system and the new bio-based plastic product, to ensure an appropriate boundary is chosen, which reflects the major areas of impact and accounts for the differences in the products. For example, if the growing and harvesting of the straw is excluded fro the boundary, as there is no growing and harvesting for fossil fuel oil, this will give a more advantageous comparison for the bio-based plastic. Any impact results should be accompanied with a clear and transparent description of the boundary chosen.

Allocating impacts When preparing the sustainability impact assessment, the company should ensure that the impact grouping are mutually exclusive and collectively exhaustive, to avoid double counting or excessive truncation in the resulting impact assessment.

Metrics and weighting If a multi-criteria impact assessment is used, which compares the product across several impact categories, for example using a mix of environmental, social and economic indicators, care should be taken to ensure the weighting of the indicators does not bias one of the product systems. Assessments should be measured using appropriate metrics, which do not obscure the real impacts.

(d) marks 20% 4

The green-washing of products has become commonplace, whereby a company publicises sustainability assessments which hide or obscure the negative impacts of the product or overstate the positive sustainability benefit. For the example given, the company might:

- Stating that the bio-based plastic, made from straw, is inherently more sustainable because is it bio-based, without a proper assessment of the impacts of growing and harvesting the straw.
- Claiming the piping systems are bio-degradable, and therefore more green, when in fact a bio-degradable piping system for water or sewage would have no functional use.
- Failing to disclose that the piping system has a much shorter life than the standard HDPE piping system, meaning more pipes would be required overtime for the same service, and undermining the assessed sustainability benefit.
- Deliberately excluding impacts from some part of the lifecycle of the piping system, for example, the impacts of the straw growing and harvesting or a different disposal method for the new product.
- Focusing attention away from the sustainability impacts of the product (i.e. deforestation to provide land to grow the straw) and towards the positive benefits of the product (i.e. new jobs in the factory).
- Setting a boundary for the assessment which excludes the impacts from overseas (i.e. deforestation) to make the product look better.
- Claiming that the impact assessment of one product is better than another, or a competitors, without considering the uncertainty of the results. If the uncertainty is large for the assessment, which is the case for most life-cycle studies, then it may not be possible to say with confidence whether there is any difference between the two products.

Question 2

(a) marks 20%

A product life cycle is a model that describes why firms have to design new products as old products become obsolete. It has four phases:

Introduction low volume, little or no automation, losses

Growth higher volume, increased use of automation, some profits

Maturity very high volume, full use of automation, maximum profits

Decline decreasing volume, repair and spares, profit declining

(b) marks 20%

Examples of valid reasons include:

Market competition Competition leads to new front door products with superior performance or lower

Customer demands and market need Customers demand higher insulation due to heating bills or lower prices due to stretched budgets.

New materials or technologies New materials and manufacturing techniques enables say new laminate constructions with superior insulation at lower prices.

Changing regulation Government regulation on insulation standards demand additional insulation.

(c)(i) marks 20%

The function structure diagram should decompose the overall function (e.g. `Door and Monitoring`) into its key subfunctions, such as `Open Door`, `Close Door`, `Lock Door`, `Fix Door to Wall`, `Engage Monitoring`, `Disengage Monitoring`, `Transmit Monitoring` and `Supply Power`. Signals and flows of energy should be indicated in the diagram.

(c)(ii) marks 20%

This product does not leat itself to an archetypical product architecture, such as slot, bus, or sectional architecture. However, it can be modularised by inspecting its function structure diagram from (c)(i). Based on such a functional architecture we end up with a door itself, its fixings, its handle, the monitoring device, the power AC/DC transformer.

(c)(iii) marks 20%

The product architecture is likely to change over time and this can be understood by inspecting the technology s-curve, which plots technology performance through some indicator as a function of time. In the beginning, the product is new and focus is on innovation, which leads to no dominant architecture. As the product matures the customer and the designer know what they want and a dominant architecture emerges. When the product is mature the focus is on process, tackling reliability, consistency and reuse.

Question 3

(a) marks 20% 4

From the lecture notes:

- Risk management is the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimise, monitor, and control the probability and/or impact of unfortunate events.
- The strategies to manage risk include transferring the risk to another party, avoiding the risk, reducing the negative effect of the risk, and accepting some or all of the consequences of a particular risk.

(b) marks 10% 2

The risks should be selected from across the six risk types: The 10 risks should be spread across the different risk types (performance risk, management risk, external risk, development risk, support risk, commercial risk) and apply to different parts of the critical mineral supply chain (exploration, mining, refining, component manufacture, product manufacture). Examples might include:

- Insufficient investment in exploration activities (development risk)
- Disruptions to mining operations from conflict (external risk)
- Forced labour in mining operations (management risk)
- Environmental impact on communities from mining (legal risk, health risk)
- Disruption to transport routes (external risk)
- Delays in establishing mining or refining operations, due to social unrest (external risk)
- Price fluctuation for critical minerals (commercial risk)
- Variable production rates (management risk)
- Poor quality ores (performance risk)
- Contamination of refined critical minerals (performance risk)
- Change in demand for critical mineral, due to technology shift (commercial risk)
- Introduction of a trade tariff on critical mineral (commercial risk)
- Inadequate technical training for manufacture labour force (support risk)

c) marks 30% 6

For all systems, there is a possibility that a system will not perform as expected, leading to some undesirable behaviour, where: Risk = Likelihood x Impact.

Score	Likelihood
1 - low	Event likely to occur less than once in 10 years
2 -	Event likely to occur once in 10 years
3 - medium	Event likely to occur once in 3 years
4 -	Event likely to occur once a year
5 - high	Event likely to occur more than once a year

Score	Financial loss	Delay	
1 - low	<£100k	1 week	
2 -	£100k to £500k	1 week to 1 month	
3 - medium	£500k to £1m	1 month to 1 year	
4 -	£1m to £5m	1 year to 5 years	
5 - high	£5m plus	<20	> 5 years plus

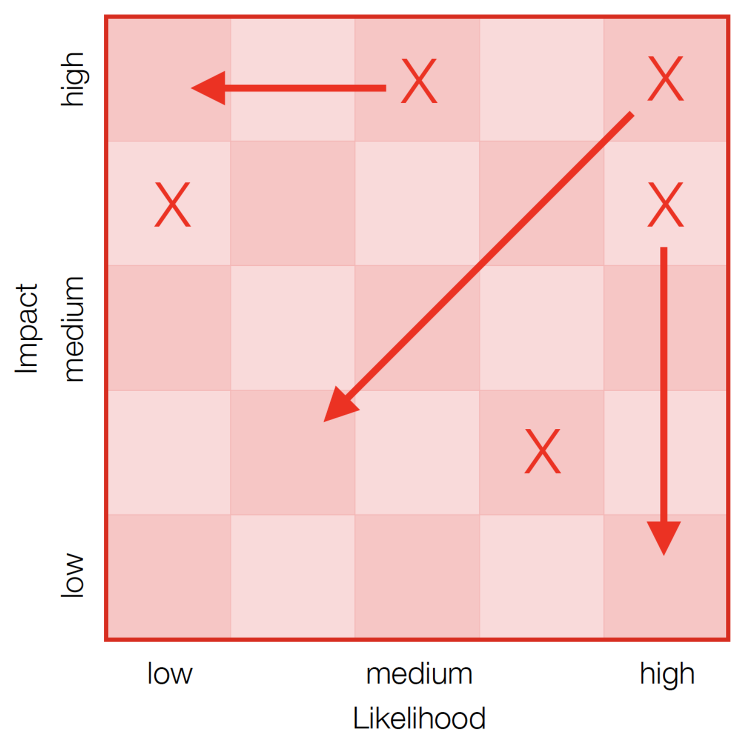
Students should assign likelihood and impact scores to each risk identified, and multiply the likelihood and impact to get final risk scores. The risks should be ranked according to these scores. The likelihood and impact scores chosen will be arbitrary, so marks are only given to the process.

For example: Disruptions to mining operations from conflict (external risk), might be given a likelihood of 3 – once every 3 years and an impact of 3 – medium 1 month to 1 year. This gives a risk score of 3 x 3 = 9

d) marks 30%

6

The top five ranked risks will have mitigated actions to reduce the risk score. For example, Disruptions to mining operations from conflict (external risk), could be reduced to impact to 2 – 1 week to 1 month, and the overall risk score to 3x 2 = 6, by creating a contingency plan to increase security in the event of a local conflict. The new risk scores are added to the risk matrix in (c).
The risk matrix will be of the form shown, with the ten risks plotted with a suitable key.



e) marks 10%

2

Risks are distributed across the supply chain, and different risks are borne by different actors. For example, the development risk of *Insufficient investment in exploration activities*, poses a risk to the country where the mining is taking place, if no new mines are found, then no revenue can be earned from mining. Or, the commercial risk of *Price fluctuation for critical minerals* poses a risk to a component manufacturing company, as the increase price might undermine their profit margin. Or, an *Environmental impact on communities from mining* is both a legal risk to the company and an health risk to the community members.

Question 4

(a) marks 10%

A solution-neutral problem statement can be arrived at of the form "Devise a means of assisting the driver of a tractor to optimise crop yield". This statement can be lowered one level of abstraction to encompass the design problem: "Devise a means of assisting the driver of a tractor to optimise crop yield by providing coordinated sensor-driven opportune information".

(b) marks 20%

The system boundary delineates our concerns and makes risk assessment and system mapping tractable. As such, it must encompass all relevant entities, which for this design problem are: (1) the tractor, (2) the display system; (3) the sensor system; (4) the online connectivity; (5) the online data and recommendation services; (6) the driver; (7) the fields; (8) the crops; and (9) applicable regulation.

(c) marks 30%

The system is complex due to:

Complexity Its complexity itself, which relies on a both the driver, the tractor, the field, the crops, weather systems, and online systems, which in turn relies on sensor data which is subject to uncertainty. There is need for several subsystems to work with other systems and some of these subsystems, such as sensor readings, soil characteristics, and weather patterns are inherently stochastic.

Tight coupling The tractor itself is decoupled from the online advice but the online advice is tightly coupled to both its online service and the sensor information gathered from the tractor. As any of these subsystems change, there are changes required in the corresponding subsystems.

Emerging properties The system is only successful is the advice is (1) accurate; (2) useful, in that it can be acted upon; and (3) the driver of the tractor acts on the advice. There advice itself is emergent from sensor readings, weather patterns, and soil characteristics, while the efficacy of the advice is contingent upon the interactivity between the driver and the system, which is also emergent.

A strategy for mapping the system is to describe the process and the actors using a swimlane diagram. A system diagram can describe how data is transformed through the processes of the system. A FAST-diagram can help enumerate all functions that have to be achieved in the system. Alternatively, a function structure diagram can help elucidate the flows of signals, materials, and energy through the key functions in the system.

(d) marks 20%

Requirements must be testable and verifiable. Examples of key requirements include:

1. There must be a mechanism that alerts the driver if a sensor failed. Source: technical team. Verification method: test.
2. The system must provide recommendations in a way that does not distract the driver. Source: human factors team. Verification method: user studies.
3. The system must indicate to the driver that the online services are connected to the system. Source: technical team. Verification method: test.
4. The system must explain its recommendations to the driver when prompted by the driver in a way that is understandable to the driver. Source: user research. Verification method: user studies.

(e) marks 20%

While the verification ensures requirements have been met, validation examines whether the system is fit for purpose. A validation strategy for a complex system such as this will need to ensure the system is (1) adopted by drivers; (2) allows appropriation in situations where the drivers must engage in workarounds to achieve their goals; and (3) operates in a safe manner; and (4) is effective and efficient. One validation strategy is the following. As the system is complex there is high risk and as such frequent validation efforts at both modular and system-level minimises validation failure. Another principle is triangulation—the use of several validation methods in recognition that no single validation method will be fully accurate. This strategy can be implemented by modularising the system into the tractor, the weather service provider, the online database, the set of sensors on the tractor, and the user interface. These modules can be validated through frequent pilot deployments both in isolation and as connected to a system in representative deployment environments with study participants sampled from the target audience. This will require both direct and indirect studies of effectiveness, efficiency, accuracy, safety, and appropriation moves. This can be achieved by combining data logging, technical testing, interviews, observations, and frequent surveys, such as the experience-sampling method.