Making Future-Proofing Design Decision under Uncertainty

Capability Systems Centre

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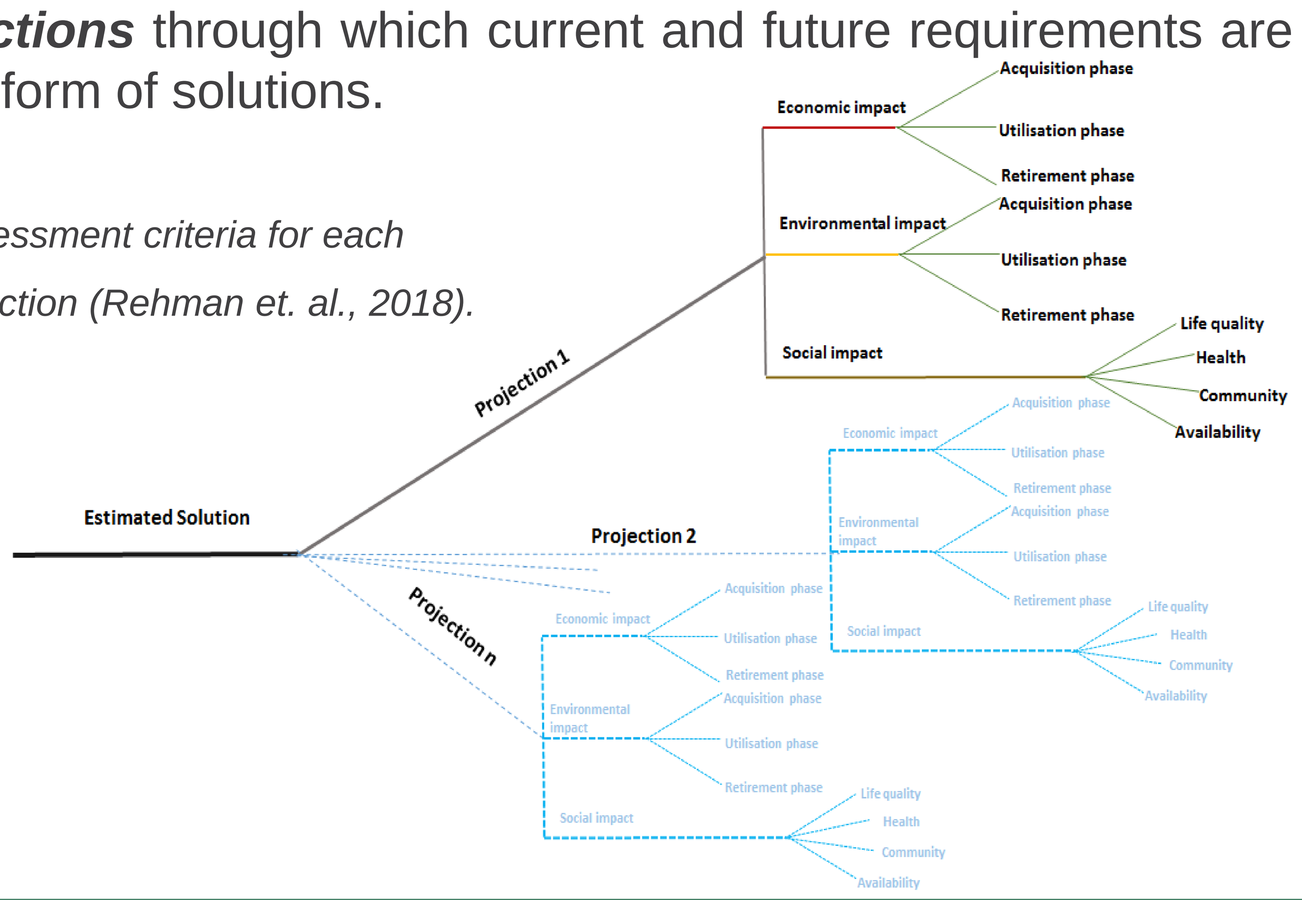
OBJECTIVE

- A main element of sustainable future-proof design is to assess the impact of the sustainability elements on the available solution.
- However at the beginning of system design detailed design data is not always available.
- We present a novel future-proof design selection methodology which incorporates the data uncertainties and fuzziness in a systematic and an effective way.
- The methodology[1] is based on the analytic hierarchy process (AHP) which is modified to include a stochastic process to address data uncertainties and fuzziness in the future-proofing decision-making process.
- The proposed methodology provides a useful tool for the future-proof system designer to visualize the impact of uncertainty and fuzziness in the data to make an effective future-proofing decision.

METHODS

- The requirements are categorized into three phases of the lifecycle i.e. ***Acquisition, Utilisation and Retirement phases.***
- The mechanisms to achieve future-proofing are called ***solution projections*** through which current and future requirements are satisfied in the form of solutions.

Impact assessment criteria for each future projection (Rehman et. al., 2018).



EXAMPLE

Requirements for Acquisition Phase for House building

Current Requirements	Future requirements	Estimated solution projection
Standard building material with reasonable life, standard utility connections, landscaping.	1. Fibre network for smart appliances computer connection.	Prj 1. Use standard connections. Prj 2. Provision for fibre connection. Prj 3. Complete installation of the fibre connection.
	1. Low maintenance garden.	Prj 1. Standard garden with grass and vegie patch. Prj 2. Garden with pavers, synthetic turf, and a small vegie patch with irrigation system.

Fuzzy impact assessment for acquisition phase

Future Requirements	Future Projection	Economic Impact			Environmental impact			Social Impact			
		AP	UP	RP	AP	UP	RP	Life Quality	Health	community	Availability
1	Prj 1	N-SL	N-L	M-VH	L-M	L-M	M-VH	M-H	N-L	N-SL	M-VH
	Prj 2	L-M	N-M	L-H	L-M	L-H	L-H	L-M	N-H	N-M	L-M
	Prj 3	H-VH	L-M	SL-H	SL-M	N-L	N-SL	N-M	N-M	N-M	N-L
2	Prj 1	L-M	H-VH	L-M	N-H	N-SL	N-SL	M-H	M-H	N-L	M-H
	Prj 2	H-VH	L-SL	H-VH	H-VH	L-M	M-H	N-L	L-SL	L-SL	N-SL

AP: Acquisition phase. UP: Utilisation phase. RP: Retirement phase. Prj: Solution projection. N: nil. L: low. SL: Slightly low. M: Moderate. H: High. VH: Very high.

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Weights assignment for requirement 1 in acquisition phase.

Prj	A (0.07)			B (0.22)			C (0.71)			
	a_1 (0.76)	a_2 (0.07)	a_3 (0.22)	b_1 (0.76)	b_2 (0.07)	b_3 (0.22)	c_1 (0.22)	c_2 (0.05)	c_3 (0.62)	c_4 (0.1)
Prj 1	a_{11} {0.48, 0.13}	a_{21} {0.48, 0.24}	a_{31} {0.07, 0.03}	b_{11} {0.24, 0.07}	b_{21} {0.24, 0.07}	b_{31} {0.07, 0.03}	c_{11} {0.07, 0.05}	c_{21} {0.48, 0.24}	c_{31} {0.48, 0.13}	c_{41} {0.07, 0.03}
Prj 2	a_{12} {0.24, 0.07}	a_{22} {0.48, 0.07}	a_{32} {0.24, 0.05}	b_{12} {0.24, 0.07}	b_{22} {0.24, 0.05}	b_{32} {0.24, 0.05}	c_{11} {0.24, 0.07}	c_{21} {0.48, 0.05}	c_{31} {0.48, 0.07}	c_{41} {0.24, 0.07}
Prj 3	a_{13} {0.05, 0.03}	a_{23} {0.24, 0.07}	a_{33} {0.13, 0.05}	b_{13} {0.13, 0.07}	b_{23} {0.48, 0.24}	b_{33} {0.48, 0.13}	c_{13} {0.48, 0.07}	c_{23} {0.48, 0.07}	c_{33} {0.48, 0.07}	c_{43} {0.48, 0.24}

Prj: Solution projection.

PRIORITY CALCULATION

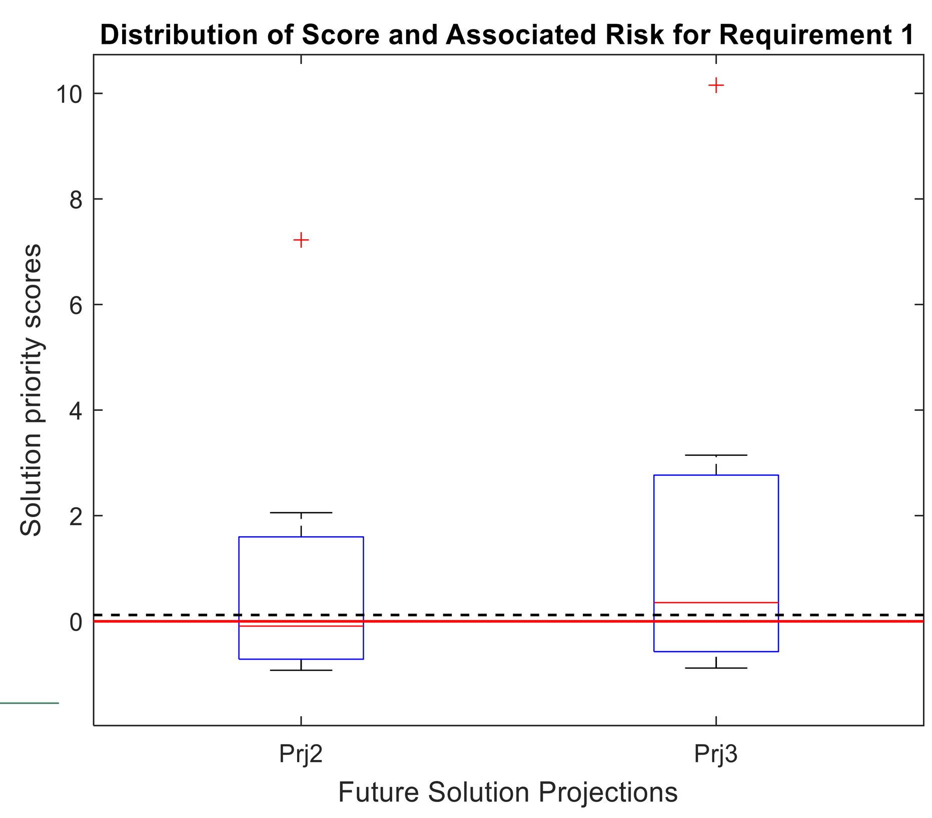
Expected maximum priority score for i^{th} projection= $\left[\left(\frac{\max(a_{1i})}{\min(a_{11})}\times a_1+\frac{\max(a_{2i})}{\min(a_{21})}\times a_2+\frac{\max(a_{3i})}{\min(a_{31})}\times a_3\right)\times A+\left(\frac{\max(b_{1i})}{\min(b_{11})}\times b_1+\frac{\max(b_{2i})}{\min(b_{21})}\times b_2+\frac{\max(b_{3i})}{\min(b_{31})}\times b_3\right)\times B+\left(\frac{\max(c_{1i})}{\min(c_{11})}\times c_1+\frac{\max(c_{2i})}{\min(c_{21})}\times c_2+\frac{\max(c_{3i})}{\min(c_{31})}\times c_3+\frac{\max(c_{4i})}{\min(c_{41})}\times c_4\right)\times C\right]\times \max(p_f)$.

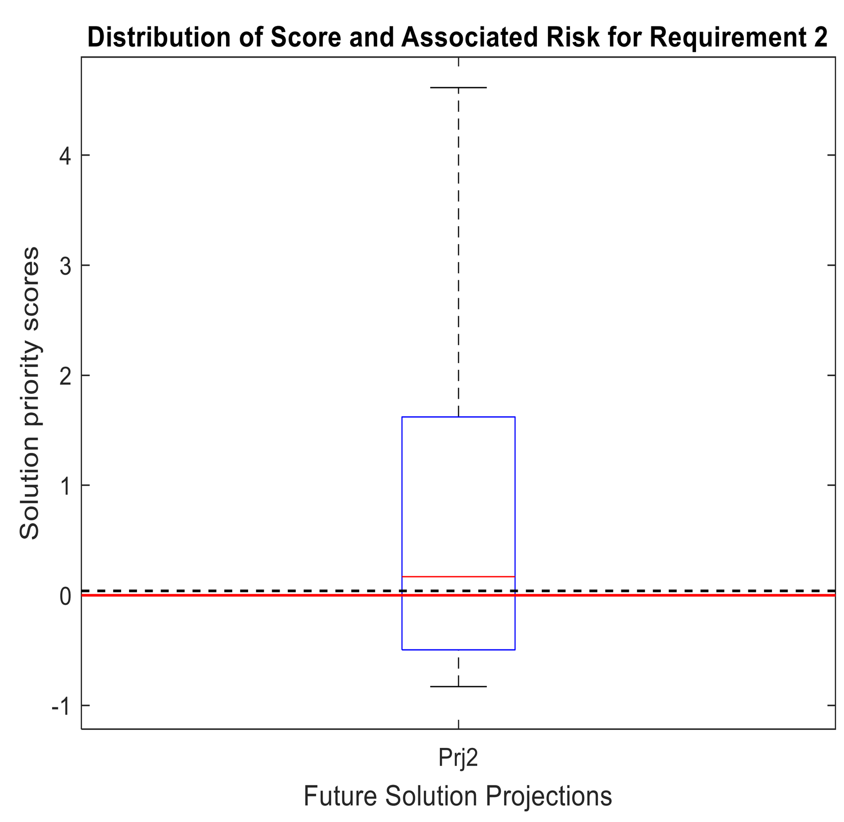
Expected mean priority score for i^{th} projection= $\left[\left(\frac{\text{Avg}(a_{1i})}{\text{Avg}(a_{11})}\times a_1+\frac{\text{Avg}(a_{2i})}{\text{Avg}(a_{21})}\times a_2+\frac{\text{Avg}(a_{3i})}{\text{Avg}(a_{31})}\times a_3\right)\times A+\left(\frac{\text{Avg}(b_{1i})}{\text{Avg}(b_{11})}\times b_1+\frac{\text{Avg}(b_{2i})}{\text{Avg}(b_{21})}\times b_2+\frac{\text{Avg}(b_{3i})}{\text{Avg}(b_{31})}\times b_3\right)\times B+\left(\frac{\text{Avg}(c_{1i})}{\text{Avg}(c_{11})}\times c_1+\frac{\text{Avg}(c_{2i})}{\text{Avg}(c_{21})}\times c_2+\frac{\text{Avg}(c_{3i})}{\text{Avg}(c_{31})}\times c_3+\frac{\text{Avg}(c_{4i})}{\text{Avg}(c_{41})}\times c_4\right)\times C\right]\times \text{Avg}(p_f)$.

Expected minimum priority score for i^{th} projection= $\left[\left(\frac{\min(a_{1i})}{\max(a_{11})}\times a_1+\frac{\min(a_{2i})}{\max(a_{21})}\times a_2+\frac{\min(a_{3i})}{\max(a_{31})}\times a_3\right)\times A+\left(\frac{\min(b_{1i})}{\max(b_{11})}\times b_1+\frac{\min(b_{2i})}{\max(b_{21})}\times b_2+\frac{\min(b_{3i})}{\max(b_{31})}\times b_3\right)\times B+\left(\frac{\min(c_{1i})}{\max(c_{11})}\times c_1+\frac{\min(c_{2i})}{\max(c_{21})}\times c_2+\frac{\min(c_{3i})}{\max(c_{31})}\times c_3+\frac{\min(c_{4i})}{\max(c_{41})}\times c_4\right)\times C\right]\times \min(p_f)$.

$$Relative\ normalised\ priority\ score = \frac{score(Prj\ i)-score(Prj\ 1)}{score(Prj\ 1)}$$

RESULTS





- Both Prj 2 and the Prj 3 for requirement 1 may provide sustainable future-proofing solutions (large part of the box is in the positive region).
- The Prj 3 is the best solution as the median (red line inside the box) lies in the positive region (above red solid line) and also above the line of risk probability (black dashed line) i.e. $p_r = 0.12$.
- For requirement 2 Prj 2 is the best solution.

CONCLUSIONS

- A method to select a sustainable future-proofing solution projection for a system is proposed.
- It provides an analytical and systematic decision-making process by incorporating qualitative assessment of sustainable elements.
- The method is easy to use and provide a visual tool for a system designer to explore the impact of the associated uncertainty in the future-proofing decision.

REFERENCES

[1] Rehman, O. U., Ryan, M. J., 2018, '*A framework for design for sustainable future-proofing*', Journal of Cleaner Production, 170, 715-726.