Requirements engineering on noise reduction system

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Abstract

Requirements engineering is generally considered as one of the most important techniques which can be used to determine whether a design satisfied the customer requirements. This report has illustrated the three main concepts of the requirements engineering in terms of Pairwise analysis, technical performances measures and quality function development and also applied these theories to the group project which was the noise reduction system. Based on these analysis, the design requirements, engineering characteristics and their inter-relationships of the silencing system can be determined, therefore, the team can have a clear idea of the requirements of the silencing system and develop system functions and detailed design in the following weeks. Also, some parts of the house of quality matrix were filled in based on the analyses.

Background

Technical performances measures

The technical performance measures (TPMs) are the measurements that used in determining if the system exceeds the design requirements. TPMs are considered as the main requirements drivers of the customers and also specify assessments of the product and the process in terms of design, implementation and test. TPMs can include, but not limited to, the project performances, range, accuracy, weight, size, power output, timing etc. (Roedler et.al, 2005).

One of the examples of the technical performances measures is the notional scenario for satellite development. As can be seen in the Figure 1, propulsion capacity, battery cycles and solar cell life are three key factors that will affect the service life of the satellite. Also the engineering characteristics, which can be used to describe the performance of the propulsion can be determined as volume allocated to propellant, satellite mass, thruster efficiency and propellant energy/volume. Therefore, the metric of these ECs can be determined as the units of these parameters (Roedler et.al, 2005).

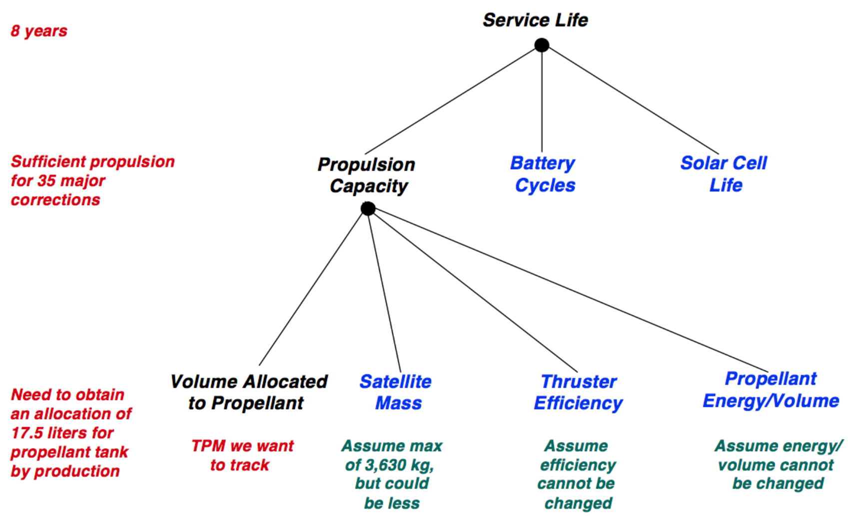


Figure 1 Technical performance measures of the satellite system (Roedler et.al, 2005).

Quality function development

The quality function development is considered as a system approach that defines customer requirements and then transfers them into specific design and manufacturing plans which will help the manufacturing of the product. The structure of basic representation of QFD (usually referred as the house of quality matrix) can be seen in figure 1 below. The customer requirements is used to describe the stated and unstated needs from customer which can be obtained from discussion, interview, questionnaires, customer specifications, etc. (Vatthanakul et.al, 2010). The technical requirements are also referred as engineering characteristics which describes all the measurable characteristics of the product. The purpose of the inter-relationship is to transfer customer requirements to technical requirements and the roof is aimed to identify whether the technical requirements that characterize the product, support or impede another (Lowe, 2001).

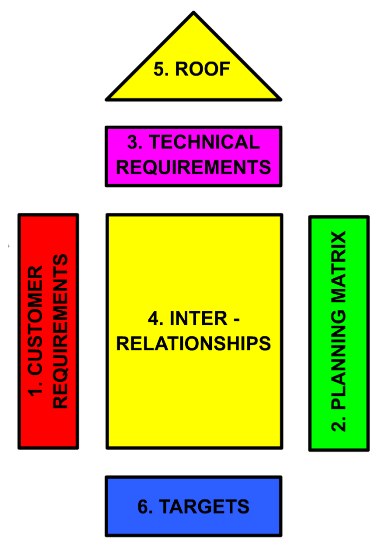


Figure 2 QFD diagram (Lowe, 2001).

Takes the logistics customer service as an example, lead time, flexibility, reliability, accuracy, fill rate and frequency were considered as customer requirements and just in time, information technology, order picking optimization, quality of services customer relationship management were determined as technical requirements. These performance factors were summarized in Appendix A and the House of quality matrix can also be seen in Appendix A (Liao and Kao, 2014).

Project background introduction

The group project was selected as the silencing system that could minimize noise in the noisy house to help clients with hearing acids. The team was aiming to install some devices in the house in order to minimize the noise inside the house, there were several options have been considered such as using a number of noise absorption materials that can be stuck on the wall (noise barriers) and installing speakers that could produce a anti noise to cancel the disturbance (active noise cancellation). The system functions and the specific design plan will be developed based on the engineering requirements topic.

Application

First of all, the customer requirements of the silencing system were determined as durable, low cost, looks good, easy to use, last long, reduce noise and sustainability based on brainstorming by the team and also the information given by the clients. By applying Pairwise analysis (can be seen in Appendix B) on the customer requirements, the reduce noise, durable, easy to use, sustainable and low cost were selected and analyzed in the following section based on their high rankings. In order to determine the design requirements and engineering characteristics of the noise reduction system, the technical performance measures were firstly applied on the silencing system. After that, the relationship between design requirements and engineering characteristics and the correlations of engineering characteristics were discussed using quality function development.

Technical performances measures

After the customer requirements were determined, the design requirements and engineering characteristics were discussed and all the detailed requirements can be seen in table 1. The symbol "-", "+" and "•" represent the direction of improvements which means whether the characteristic need to be minimized, maximized or optimized at a certain value.

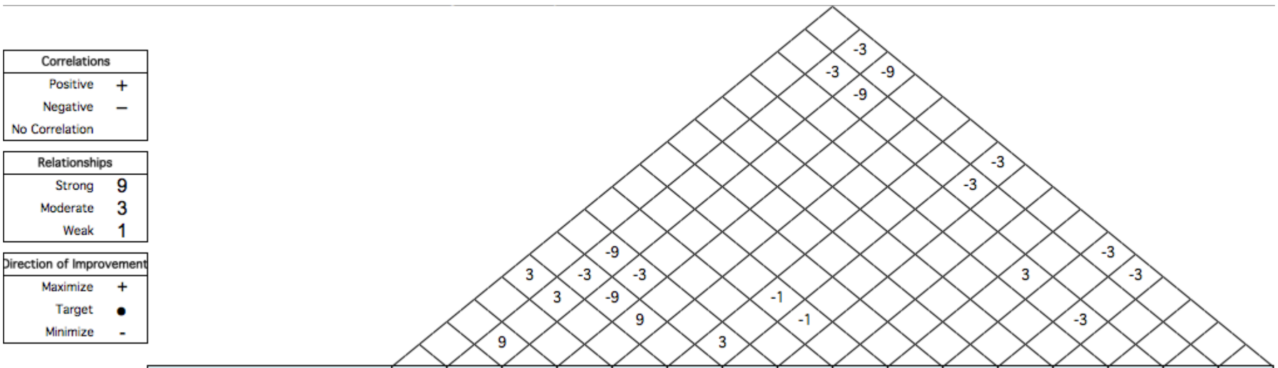
Take the customer requirements ‘reducing noise’ as an example, the ability of reducing noise inside of the house can be transferred to design requirements as catches noise appropriately and effective noise absorption. In order to assess whether the system satisfies ‘catches noise appropriately’, the range of frequency of the sound that can be absorbed and the distance from the source of the noise and the material can be measured. The range of frequency is supposed to be an optimized value since the system are required to absorb noise like cooking sound and television instead of human voice. Also, the absorption distance is supposed to be minimized value due to the fact that the silencing system can receive more noise if the absorption distance becomes smaller. On the other hand, the number of the absorption material (speakers), set up time of the system, effective area that can be covered by the system and the material and the noise level after installing the system can be determined to evaluate the efficiency of the noise absorption system.

Customer requirements	Design requirements	Engineering characteristics	Metric
Reducing noise	Catches noise appropriately	• The range of frequency	Hz (frequency)
		- Absorption distance	M (distance)
	Effective noise absorption	+ Number of noise barriers / speakers	No.
		+ Effective area	M^2 (area)
		+ Set up time	S (seconds)
		- Noise level after installation	dB (decibels)
Durable	Minimize incidental damage	+ Maximized pressure that the structure can stand	Pa
	High quality of parts	+ Meet quality standard	Yes/No
	Long life cycle of parts	+ Life cycle of parts	Years
Easy to use	Minimised size	- Size	M^3 (volume)
	Exfoliation of the barriers	• Viscosity between parts and wall	m*Pa*s
Sustainability	Sustainable and recyclable materials	+ Recyclability of material	Yes/No
	Minimised embodied energy	- Embodied energy of the material	J (joules)
		- Carbon emission throughout manufacturing process	Kg
Low cost	Low capital cost	- Minimized capital cost	AUD
	Low maintenance cost	- Minimized maintenance cost	AUD

Table 1 Engineering characteristics and metric of the silencing system

Quality function development

After all the design requirements and the engineering characteristics of the noise reduction system were determined, the inter – relationship between them and the correlations of ECs and these parameters were presented in the HoQ matrix which can be seen in Figure 3. The ranking of all the design requirements was analyzed using Pairwise analysis and the detailed ranking table can be seen in Appendix C, the direction of improvements was determined before and listed in the matrix using "-", "+" and "•". The inter-relationships between design requirements and engineering characteristics were indicated using 1 (weak), 3 (moderate) and 9 (strong) respectively (the empty space means there is no direct connection between two requirements). The correlations between each engineering characteristics were also represented by 1 (weak), 3 (moderate) and 9 (strong), the "+" and '-' sign indicated whether the two characteristics were support or impede each other.



Row #	Customer Importance	Design Requirements \ Engineering Characteristics	Maximum pressure	Effective area	Number of noise barriers/speaker	Absorption distance	Set up time	Noise level after installation	Size	Viscosity between arts and wall	The range of frequency	Carbon emission	Meet quality standard	Life cycle of parts	Recyclability of materials	Embodied energy of the material	Minimized capital cost	Minimized maintenance cost
		Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		Direction of Improvement	+	+	+	-	+	-	-	●	●	-	+	+	+	-	-	-
1	1	Catches noise appropriately		3	9	9	1	9	3		9		3				1	
2	2	Effective noise absorption	3	9	9	9	3	9	3		9		3				1	
3	10	Minimize incidental damage	9						3	3			9				1	3
4	4	High quality of parts	3	1				1					9	3			3	9
5	10	Minimise size	3	9	3			3	9	1	1	3				3	3	9
6	7	Long life cycle of parts	3						3				9	9			3	9
7	5	Sustainable and recyclable material										3		9	9	3		
8	8	Minimise embodied energy			3				3			9		3	3	9		
10	5	Low capital cost		3	3		3		3	1			3	3			9	1
11	8	Low maintenance cost	3	1	9			1	3	3			9	3			1	9
12	3	Exfoliation of the barriers	1						3	9			3				1	1
14		TPMs	Pa	m^2	No.	m	m	dB	m^3	m*Pa*s	Hz	Kg	Yes/No	Years	Yes/No	J	AUD	AUD

Figure 3 HoQ matrix

Take ‘catches noise approropriately’ as an example, it has strong related to number of speakers or noise barriers (more speakers or barriers can absorb more noise), absrption distance from the source to the system boundaries, noise level after install the silencing system and the range of frequency that the system can absorb (ensure the system can catch noise instead of human voice). In terms of the correlations between engineering characteristics, for example, the effective area of the system has a strong positve relation wiht the number of speakers or barriers since the effective area will become mmuch larger if more speakers or barriers are installed.

Discussion

First of all, the team has considered two basic approaches in terms of noise barriers and active noise cancellation but did not decide which approach will be used to construct the silencing system. Therefore, some of the design requirements and engineering characteristics were not accurate, for example, the noise barriers did not need a setup time since they were expected to operate throughout their lifetime and the active noise cancellation did not need to be stuck on the wall which meant exfoliation won’t need take into consideration in this case. However, after the team finalizes the noise reduction approach, some of the design requirements and engineering characteristics may be adjusted to suit the silencing system.

Also, it was hard to distinguish the inter-relationships between DRs and ECs since there were no district boundaries between ‘weak’, ‘medium’ and ‘strong’. All the decisions were made based on discussions within the team which means the results did not have a high level of accuracy. In terms of the correlations between each ECs, it can be seen in Figure 3, some EAs were independent and were not related to other ECs such as meet quality standard, life cycle of parts and the recyclability of the materials.

Additionally, there were several observations and recommendations based on the requirements engineering analysis above. First of all, the design requirements ‘catches noise appropriately’, ‘effective noise absorption’ and ‘size’ were related to most of the characteristics which meant they were more essential compared with other requirements, therefore, the team should focus more on these parameters in the future. Secondly, all the trade offs of characteristics ‘minimized capital cost’ and ‘minimized maintenance cost’ were negative (impede with other characteristics), which meant the cost was highly dependent on the performance of the system and in order to minimized the cost and maintain a high level of performance, the team needs to focus more on balancing the relationships between cost and other characteristics.

Conclusions/Recommendations/Summary

This paper introduced the main concepts of requirements engineering in terms of technical performances measures and quality function development and also applied these theories into the noise reduction system. The main outcomes of this report were the determination of the design requirements, technical requirements (ECs) and their correlations. Based on these requirements analysis, the team will gain more understanding on engineering characteristics of the noise reduction system, therefore, system functions and some detailed design such as size and structure of the silencing system in the following week.

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Peer Review Critique

> Peer Review 01:
> Try to stick to the page limits (4-5pages). Check your spelling.
> One recommendation is that in House of Quality, it's better to use (1,3,9) to show the weak to strong relationship rather than triangles and circles. The reason for that is that numbers can show the relationships clearer than shapes.
> Personally, I think that stable structure and simple manufacturing process do not count as engineering characteristics but are design requirements instead. I think that engineering characteristics are supposed to be measurable.

I changed triangles and circles to (1,3,9) in order to describe the inter-relationship between design requirements and engineering characteristics based on the feedback from the first peer review since numbers are clearer than shapes and also they were more consistent with the version that Chris taught in the online classroom. Also, I changed 'stable structure' to 'maximized pressure that the structure can stand' and 'simple manufacturing process' to 'carbon emission throughout the manufacturing process' due to the fact that 'stable structure' and 'simple manufacturing process' were not measureable parameters and could not count as engineering characteristics strictly. Therefore, I think the first peer review provided really good advices and helped in improving my paper.

> Peer Review 02:
> There were a few errors in spelling and grammar, but they did not affect comprehension. In the Quality Function Development section, the incorrect figure was referenced. In the Discussion section, you have listed 'Strong', 'Medium', and 'Strong'.
> There was some discussion of the design outcomes, but it was difficult to see where any improvement was made by applying systems theory.

I added some more recommendations to the project design based on the second peer review since it was really hard to provide improvements since the team did not even have a design.

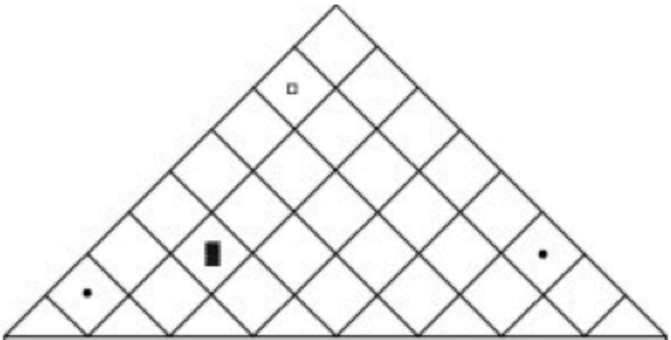
> Peer Review 03:
> In the background of this paper, the author introduce the technical performance measure& quality function development, but the pairwise analysis also can get some introduce in the background it will let the reader know how to rank the customer requirement.
> Most of the system theory is introduced in the paper. But in the technical performances measures this paragraph the customer needs reduce noise should change to reduce noise and sound proofing, this is more suitable for the customers need.
> In the customer needs "easy to use" is not only the minimize size but also the material is easy to clean and sound control windows is easy to open. The engineering characteristics of "the range of frequency" is not suit in this case, it should change to "the most loudest noise can reduce below 50dB, metric should be dB.

The reason I did not include background information on Pairwise analysis was because this topic was considered as assumed knowledge from ENGN 1211. Also, I did not really understand why I should put 'reduce noise and sound proofing' instead of 'reduce noise' since they have similar meaning to me. In term of the design requirement 'easy to use', I added 'exfoliation of the material' since we need to make sure the materials we sticked on the wall won't drop off by themselves and I also add 'sound control window is easy to open' as 'set up time' in the design requirements of effective noise absorption. Additionally, there were several misunderstandings in the third peer review: 'the range of frequency' represents what level of frequency the system can absorb and 'the most loudest noise can reduce below 50dB' was written as 'the noise level after installation' in the draft paper. I added some more explanations in the noise reduction part in order to let other readers understand the meaning of these characteristics.

Appendix A: Case Study on logistics customer service

Service requirements ("**WHATs**")	Description
Lead-time	Time period passing from customer's order until receipt
Flexibility	Capability to modify orders in terms of due date and quantity when required by customers
Reliability	Capability to deliver orders within the due date
Regularity	The dispersion around the mean value of the delivered lead-time
Completeness	Capability to deliver full orders when required by customers
Accuracy	Avoidance of mistakes and damages in orders delivered process
Fill rate	The percentage of units available when requested by customers
Correctness	Avoidance of mistakes in orders delivered
Harmfulness	Avoidance of damages in orders delivered process
Productivity	Number of item produced in a given time period
Frequency	Number of deliveries accomplished in a given time period
Organization accessibility	Customer's opportunity to establish a contact with firm's staff
Complaints management	Process subsequent to the recognition of some errors in service provided, that allows service quality standards to be reestablished

Operation requirements ("**HOWs**")	Description
Just-in-time	The provision of right materials at the right price, of the right quality, in right quantity, at the right time and from the right source
Forecasting methods	The process of using models to generate predictions for future demands based on known past events
Information technology	Generic term used to include software, hardware and networking technologies
Information sharing and trust	Mutual trust-based information sharing between the customer and the provider
Service quality	Various aspects including on-time delivery, accuracy of order fulfillment, frequency/cost of loss and damage, promptness in attending customers' complaints, and commitment to continuous improvement
Long-term trade relationship	The relationship involves shared risks/rewards and cooperation between customers and providers
Order picking performance	Performance concerning the activity by which a number of goods are retrieved from a warehousing system to satisfy a number of customer orders
Warehouses lay-out performance	Performance concerning the assignment of items to storage locations, the arrangement of the functional areas of the warehouse, the number and location of docks and input/output points, the number of aisles, etc.
Customer relationship management	A generic term which encompasses methodologies, software, and Internet capabilities that help the firm to manage customer relationships in an organized way
Risk management	The capability of the provider to address any unforeseen problem and to ensure the continuity of the services
Customer relationship management	CRM is a generic term which include method software, and Internet technology that help the firm to manage customer relationships action



Customer service requirements (CSRs)	Relative weights (w_j)	Just-in time (JIT)	Information technology (IT)	Order picking optimization (OPO)	Demand forecasting methods (DFM)	Quality services (QS)	Customer relationship management (CRM)	Warehouses lay-out optimization (WLO)	Information sharing and mutual trust (IST)
		Logistics operation requirements (LORs)							
Lead-time	0.218	•	•	▲				▲	
Accuracy	0.211	□	□			▲			•
Fill rate	0.179		□		□		▲		
Flexibility	0.153	•	□				□		
Reliability	0.135	□	□		▲				□
Frequency	0.103	□	▲	□		•		□	

Appendix B: Pairwise analysis on customer requirements

	Durable	Low cost	Long lasting	Aesthetic	Reduce noise	Recyclability	Easy to use	Score	Ranking
Durable		1	1	1	0	1	0	4	3
Low cost	0	1	0	1	0	0	0	2	5
Long lasting	0	1		1	0	0	0	2	5
Aesthetic	0	0	0		0	0	0	0	6
Reduce noise	1	1	1	1		1	1	7	1
Recyclability	1	1	1	1	0		0	4	3
Easy to use	1	1	1	1	0	1		5	2

Appendix C: Pairwise analysis on design requirements

	Catches noise appropriately	Effective noise absorption	Minimize incidental damage	High quality of parts	Minimize size	Long life cycle of parts	Sustainable and recyclable materials	Minimize embodied energy	Low capital cost	Low maintenance cost	Exfoliation	Score	Ranking
Catches noise appropriately		1	1	1	1	1	1	1	1	1	1	10	1
Effective noise absorption	0		1	1	1	1	1	1	1	1	1	9	2
Minimize incidental damage	0	0		0	0	0	0	0	0	1	0	1	10
High quality of parts	0	0	1		1	1	1	1	1	1	0	7	4
Minimize size	0	0	1	0		0	0	0	0	0	0	1	10
Long life cycle of parts	0	0	1	0	1		0	0	1	1	0	4	7
Sustainable and recyclable materials	0	0	1	0	1	1		1	1	0	0	5	5
Minimize embodied energy	0	0	1	0	1	1	0		0	0	0	3	8
Low capital cost	0	0	1	0	1	0	0	1		1	1	5	5
Low maintenance cost	0	0	0	0	1	0	1	1	0		0	3	8
Exfoliation	0	0	1	1	1	1	1	1	1	1		8	3