Individual Research Paper

ENGN2225 Systems Engineering Design

Requirements for Larger People and Affordable Cardiovascular Conditioning

Josip Simunic
u5184799@anu.edu.au
Tutorial Group: W10A
Word Count: 1520

Abstract

Our group project is to design a cardiovascular machine for use by larger people (Specifically, a 2.3m, 210kg male). This paper will discuss not only what this machine should aim to do, but also technical specifications and outline a priority over them. This will help identify any aspects that need to be emphasized and possible compromises that need to be made. Pairwise analysis and a House of Quality will be used in order to determine and rank the system requirements. A software design process is used as an example 'requirements-creation' pathway, which can be taken to create a technical object, with a specific example (House of Quality demonstration) in computer security for small and medium enterprises. We strive to use a systems engineering approach with the requirements analysis in order to make a flexible concept that is safe and effective for the client.

Background

The chosen project is "Affordable exercise: a cardiovascular exercise machine for larger people." Our group will focus on developing something that the client can use to gain cardiovascular conditioning in a safe, convenient and affordable manner. The system will have a variety of requirements it must fulfil, such as being affordable. One aspect of developing a system that the client can use is prioritising the user's needs such as comfort, ease of use and, as stated, cost. This is where the topic of engineering requirements comes in.

Requirements engineering is an extremely fundamental part of any design process. Engineering requirements clearly define what the system is meant to achieve. It can be said that "the primary measure of success of a [software] system is the degree to which it meets the purpose for which it was intended." (Nuseibeh, Easterbrook, 2000). If a client specifies a system to perform X, Y and Z but the engineer creates it to achieve A, B and C, it's essentially a redundant system, which doesn't meet the requirements set by the client. It is important to achieve the requirements defined, or at the very least to attempt a compromise which achieves the best solution given compromises. The hierarchy of requirements will be determined using Pairwise Analysis and a "House of Quality." These methods will prioritise our system requirements and assist in determining if the design aligns with the client's needs.

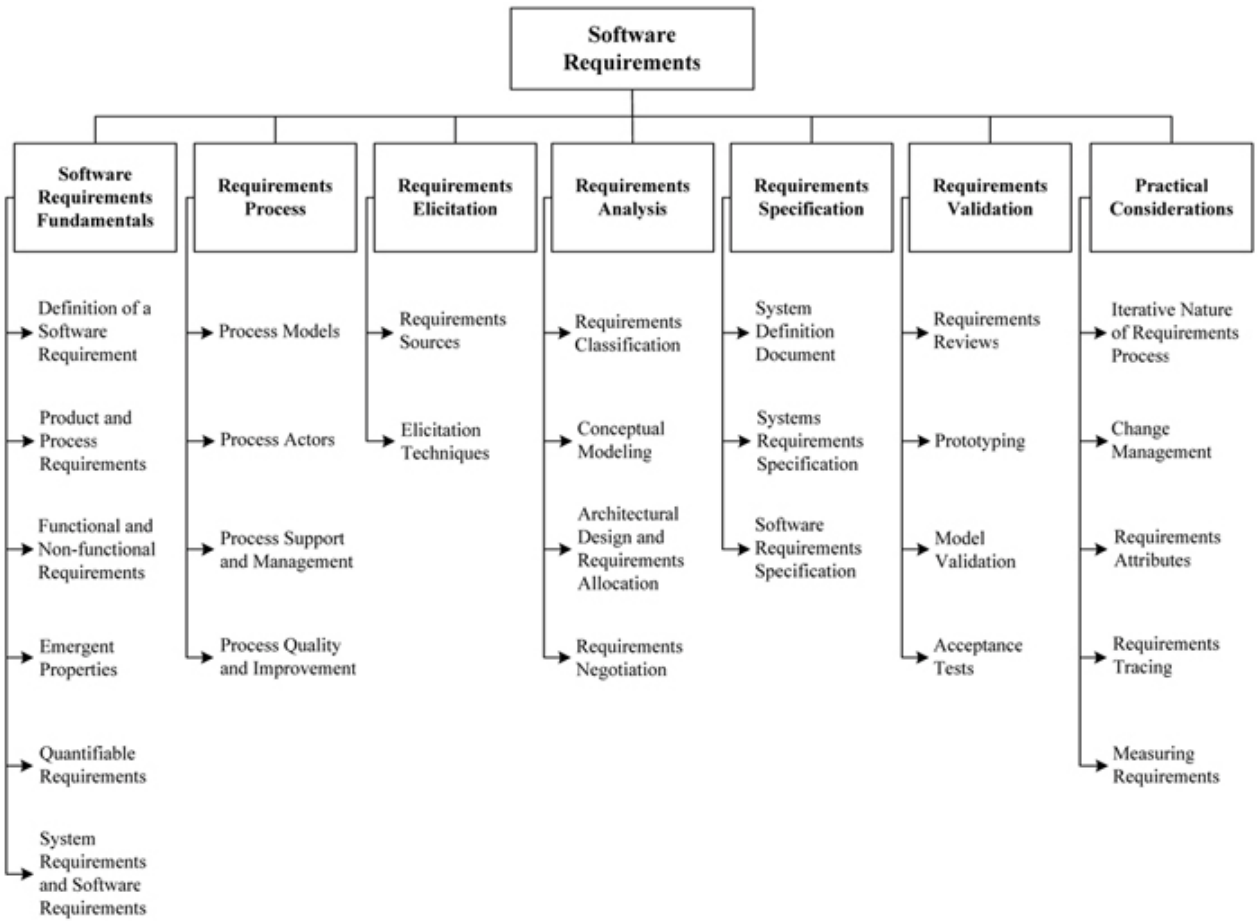

Figure 1 - Software Requirements - (Computer.org, 2014)

A prime example of the use of requirements is in the development of software. Figure 1 shows a breakdown of the software requirements topics. This branches into fundamentals, process, elicitation, analysis etc. As seen, it is a fairly detailed and extensive tree diagram, which highlights the importance of systematic development, modification and execution of systems engineering requirements (in the example of software). There are, in fact, entire bodies of standards in which deal with engineering topics such as requirements engineering and standardisation methods. To continue from the software example, the IEEE computer society (source of Figure 1) outlines detailed pages of documents describing different types of requirements such as those shown in Figure 1. For example, functional and non-functional requirements outlined in Figure 1 provide an instance of analysing different types of requirements in the system.

An example of a House of Quality in terms of software design requirements (as outlined in Figure 1) can be seen in Figure 2 to further detail the case study in the development of a computer security system.

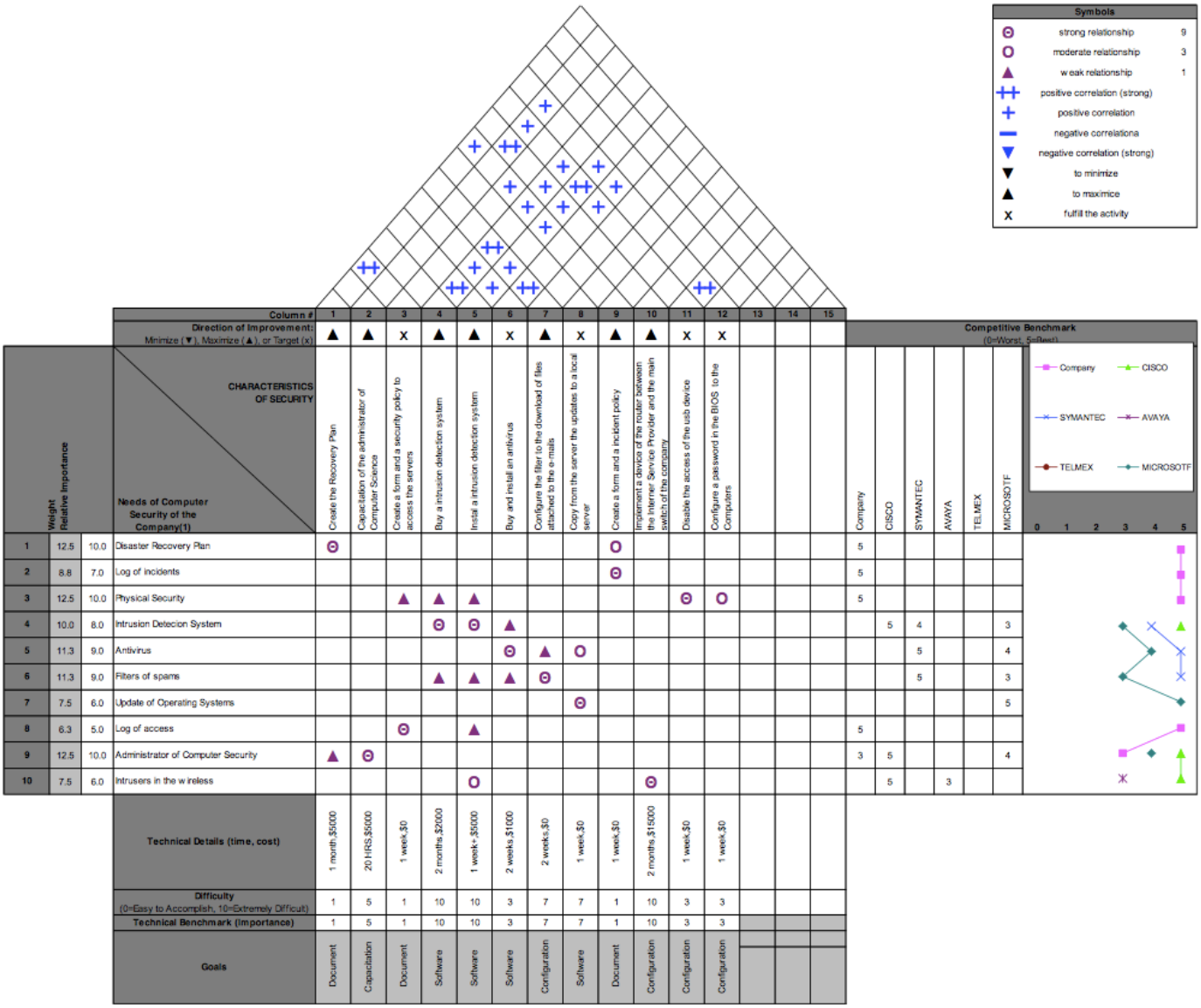

Figure 2 - HOQ for implementation in software example - (Ruiz-Vanoye and D\'\Iaz-Parra et al., 2013)

This is a direct example of a detailed House of Quality for a software system (security software). As shown, it compares different requirements of the company, includes relative importance, goals, technical benchmarks, technical details, relationship benchmarks, a relationship matrix, security characteristics, correlation matrix and a competitive benchmark. These are compared using the legend included in the figure. The column/row with most markings is the most involved aspect of the requirements/design characteristics respectively, which is used to assess weighting.

Application

The pairwise analysis (PA) and the House of Quality (HOQ) can be used together to assist our team to tailor a cardiovascular machine optimally for the client. The pairwise analysis will

compare certain design requirements, customer requirements and prioritise them. (Browne, 2013) This also allows a flexible method of introducing new requirements if the client decides to do so, which is great from a systems engineering perspective. This information is then used in a HOQ to determine the "relationship between customer requirements and technical characteristics… and over a long time frame iterations of the HOQ become a valuable tracking tool." (Browne, 2013)

It is important to apply these ideas to our project in order to determine what to focus on in design and approach. For example, there could be mutually exclusive requirements such as "low cost" and "solid gold frame". Will the client want a solid gold frame or a low cost device more? Procedures such as PA and HOQ will provide a platform to compare client needs and functional and achievable engineering requirements.

Table 1 shows a PA of some requirements of the group's project: a cardiovascular machine.

Table 1 - The project Pairwise analysis

Pairwise Analysis for some Engineering Requirements

	Durable	Cheap	Easy To Use	Low Maintenance	Low Noise	Looks Good	Comfort	Ease of Access	Safety	**Score**	**Rank**
Durable	0	0	0	1	1	1	1	0	0	4	5
Cheap	1	0	1	1	1	1	1	1	0	7	1
Easy To Use	1	0	0	1	1	1	1	0	0	5	3
Low Maintenance	0	0	0	0	1	1	0	0	0	2	6
Low Noise	0	0	0	0	0	1	0	0	0	1	7
Looks Good	0	0	0	0	0	0	0	0	0	0	8
Comfortable	0	0	0	1	1	1	0	0	0	3	5
Ease of Access	1	0	1	1	1	1	1	0	0	6	2
Safety	1	1	1	1	1	1	1	1	1	9	1

As seen from the PA, cost, ease of access and ease of use are the primary requirements (apart from safety) that should be considered in the design of the cardiovascular machine. This will mean that group members will have to keep material cost, cost of manufacture as well as simplicity and usability of the design as main considerations. Low noise and looks seem to be the least

													x	Moving parts
												x		Number of Parts
											x	+	+	Installation time
										x		+	+	Production Cost
									x	-		+	+	Operational Noise Level
								x		-			+	Idle Noise Level
							x			+			-	Lifetime
Legend:	(+/-) = type of correlation					x								Weight
	1 = Weak relationship				x							+	+	Dimensions
	3 = Medium relationship			x				+						Power consumption
	9 = Strong relationship		x				+				+			Weatherproof
		x	+			+	+				+			toughness
		toughness	Weatherproof	Power consumption	Dimensions	Weight	Lifetime	Idle Noise Level	Operational Noise Level	Production Cost	Insallation time	Number of Parts	Moving Parts	
	Max or Minimise	+	+	-	+	-	+	-	-	-	-	-	-	
	Units	J/m3	Pa	kWh	m3	kg	years	dB	dB	$	Hours	Integer	Integer	
Durable	8	9	9	3	3	9	9			9				
Cheap	2	3	3	9			9			9		3	3	
Easy To Use	4				9	3					3	9	9	
Low Maintenance	10	3	9	1	1		3					9	9	
Low Noise	11			1				9	9				3	
Looks Good	12				3					9				
Comfortable	9	1	1		1			1	9	9		1	1	
Ease of Access	3				9	3				3		1	1	
Safety	1	1		3		3		1	3	9		1	3	
Adjustable Size	5				3	3				9	1	1	3	
Adjustable Resistance	7									9		3	3	
Metric Measurers	6		1	3						9	1	1		
	Rank													

Figure 3 - House of Quality for the cardiovascular machine

concerning topics to do with creating a cardiovascular machine for larger people.

The house of quality shows what variables interact with the others. For example, limiting production costs can negatively impact toughness, waterproofness and a lifetime of use. This valuable tool shows interconnections between aspects of the design and comparison of each aspect.

Figure 3 shows the HOQ for the group project. Understandably the HOQ identifies dimensions and cost as the characteristics that have the greatest impact on design requirements. These correlate highly with the requirements of ‘safe’ and ‘cheap’.

Environmental impact, while not a major concern, will be minimal, as the machine will most likely be made from cheap, recycled materials. The life cycle of the machine would be a similar priority for the group; the machine would be needed as long as the client would need to improve their health, approximately 0-5 years. It is important to include adjustable resistances to ensure variation in challenge as the client progresses through their weight loss and becomes fitter. Further details are explained in the discussion.

Discussion

As a group, we have created a selection of requirements as outlined in the Applications section. Initially, no communication with the client had been made, which was a concern as it made it difficult to prioritise/create requirements for this project. However, after a meeting with the client's representative it was made clear to us what was important for them. This fortunately paralleled with the group's existing requirements and only slight priority changes were to be made. They were also easily adapted into the PA and HOQ.

The client's representative had specified that the client would like a bike-like machine. As the client also has a form of knee arthritis, this low/no-impact cardio machine would be appropriate (as opposed to brain-stormed ideas like treadmills) as to not aggravate the condition. As a 2.3m, 210kg man, sheer sizing and dimensions of the machine itself, as stated, are of utmost importance for (comfortable) operation, as well as mounting and dismounting the machine. It was also stressed to the team that the client would like a machine to develop their cardiovascular endurance and reduce their body weight.

Safety should be especially important as combining cardiovascular conditioning with larger users could create possible complications in terms of heart rates. The client has underlying health conditions so it is vital to maintain a safe environment. Systems like built-in heart-rate monitors and sturdy bases will keep the user in a safe level of operation of the machine. Cost is a top-ranking requirement because it was specified in the project brief. Ease of access is a close second as we think larger people obviously need more space to operate cardio equipment and this obviously is a main design concern (getting on the machine, moving around, getting off, etc). Possible joint problems and physical disabilities or hindrances should also be at the forefront. This requirement is why the topic exists in the first place, as large people cannot use conventional cardio equipment.

Conclusions/Recommendations/Summary

Ranking the system requirements through requirements engineering has helped influence further design by synthesising the customer's needs and engineering capabilities. The approaches outlined in the report such as Pairwise Analysis and House of Quality provide systematic and flexible tools

to aid our team in making, modifying and executing engineering requirements while grappling with concerns such as trade-offs in the domain of systems engineering. The meeting with the client's representative was extremely informative and assisted the team in guiding the requirements into the right direction. Analysis has identified safety, cost and ease of access as the major focuses of the cardiovascular machine design.

Bibliography

Nuseibeh, B. and Easterbrook, S. 2000. Requirements engineering: a roadmap. pp. 1-2.

IEEE Computer Society, Computer.org. 2014. *Software Requirements*. [online] Available at: http://www.computer.org/portal/web/swebok/html/ch2 [Accessed: 16 Mar 2014].

Browne, C. 2013. *ENGN2225 OC - House of Quality*. [online] Available at: http://www.youtube.com/watch?v=nME24qo5kPY&feature=share&list=PL2hygCecjFiXEDTXwBOgWlAFVZL06gnSA [Accessed: 16 Mar 2014].

Browne, C. 2013. *ENGN2225 OC - Pairwise Analysis*. [online] Available at: http://www.youtube.com/watch?v=dhv6o9ubHC0&list=PL2hygCecjFiXEDTXwBOgWlAFVZL06gnSA&index=4 [Accessed: 16 Mar 2014].

Ruiz-Vanoye, J. A., D\'\Iaz-Parra, O., Nolazco-Flores, J. A., Saenz, A. C., Hern\', Ez, V. H. and Gongora, H. M. 2013. Quality Function Deployment (QFD) House of Quality for Strategic Planning of Computer Security of SMEs. *International Journal of Combinatorial Optimization Problems & Informatics,* 4 (1).

Peer Review Critique

In response to aspect 1 of the peer review, I've researched and included a specific example of a usage of HOQ in a software design example (security creation). I believe this fulfills the concerns raised for aspect 1. The second reviewer raised a concern in aspect 2 that I didn't include environmental impact or life-cycle concerns. I have since included some information about this in the body of the report and hope that it additionally contributes to a systems engineering perspective. Other than this concern, aspect 2 was satisfactory for all parties. Reviewer 1 raised issues about the actual theory of HOQ. I have since corrected this and made clear what a HOQ does and how it does it in a basic way. The second reviewer commented on using HOQ or PA for the case study, which, as stated, was also included after feedback was received. For aspect 4, the

first reviewer raised a point that it would be good to assume a situation and apply techniques to it. However, it was deliberately done like this to ensure flexibility in the future. Reviewer 2 commented on difficulty reading the HOQ, which was slightly corrected. (Unsure if the figure was unclear or the concept of HOQ [which was corrected anyway]). The reviewers were happy with the bibliography and so it was left untouched (With further sources added.)