



A Systems Engineering Approach to Redesigning the Alarm Clock

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1 Introduction

1.1 Systems Engineering

Systems engineering is an emerging process within all engineering sectors as a holistic approach to review ideas to improve the efficiency during the design process. The primary focus is a 'get it right first time' attitude which minimises cost for the supplier and the time taken to complete the process from customer demand to a final product. Systems engineering "considers all the life cycles of the systems" [1] and "favors synthetic thinking" [1]. The main difference is that systems engineering "defines problems before determining what disciplines are needed" [1] which allows for a critical review process based on customer highlighted functional and non-functional requirements.

1.2 System Breakdown

Systems engineering promotes the process of breaking down complex, complete systems into smaller sub-systems and components and aligning them with a specific function requirement. The manageable sub-systems are all subjected to the same systems evaluation process. Figure 1 demonstrates the sub-system breakdown of a car into manageable components.

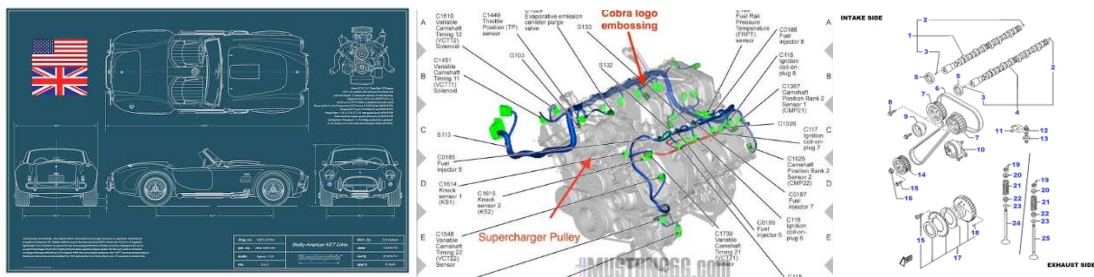


Figure 1 – Sub-system breakdown of a car

1.3 History of Systems Engineering

In World War II, the requirement for advancing complex systems became very apparent and the first instance of systems engineering was introduced to increase efficiency for both design and manufacture [2]. An example of its first use was by Bell Laboratories when designing radar systems where they learned to engineer how the entire system functioned from the start, rather than each individual component before assembling them into the final product without reviewing how it functions [3]. This holistic approach to engineering had not been used before and the Mk 56 Gun Fire Control System was the war's only successful effort to design a fully automated radar-controller firing system [3]. The technology at the time was far more advanced than had been seen before and it was due to the systems engineering approach to assess how the radar itself would function and be operated before attempting design, whereas previously, the main focus would have been where the radar

system would be fitted and then design it to cater to the gun system rather than as its own system entirely [3]. This sub-system breakdown of the gun system in total is what allowed the engineering of the radar to be successful.

Post World War II, systems engineering has proved to be a crucial method, especially in defence, as its integration into the design process has allowed for significant technological development [2].

1.4 Systems Engineering Method

Systems engineering looks at the entire lifecycle of a system [1] from requirement gathering and concept designing to manufacture and through to test and evaluation. The most common diagram to illustrate this is what's known as the V-diagram which is a graphical illustration of the lifecycle of a system in development.

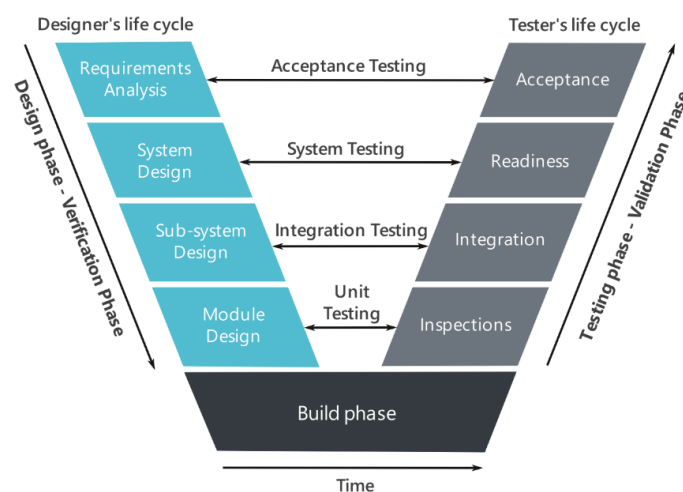


Figure 2 – V-diagram for lifecycle of a system

Figure 2 illustrates the V-diagram with time on the x-axis. The V-diagram provides a development path for systems engineers to follow during the design process, ensuring that the requirements are identified and met before moving on to the manufacturing process. The system requirements are identified initially, before the next sub-system is identified with its specific requirements which is repeated down the first diagonal of the V. By the time manufacture begins, all sub-systems and their relevant requirements should be identified, addressed and designed prior to any manufacture. This reduces the time required to develop and allows for the remaining time on contract to be utilised in the testing phase.

Without a systems approach, time becomes the highest contributing factor to failure as the design phase will potentially overrun due to faults identified in the test phase because not all the sub-systems and requirements have been considered. Systems engineering reduces this factor by a significant amount, meaning the final design does not have to be redrawn and start the process over again.

2 Design Case

2.1 Key Customer Requirements

The customer has requested an improved design for an alarm clock as they have noted that their current model does not always complete its function. The customer's statement was that "an alarm clock should not only play a sound to wake up to but should also be more difficult to snooze whilst in bed. It should be easy to use and should always display the correct time". These requirements have come from failures the customer has experienced with their current model. The current model is a radio alarm clock with a digital time display, but the alarm must be set each day, which is a time-consuming process. The alarm clock also has an easily accessible snooze button that the customer can press whilst half asleep and they then go back to sleep, which causes a failure of the alarm clock to perform its desired function.

The input to the alarm clock is 230V from the mains through a 3-pin 13A plug and the output is sound from the internal speaker that is manually tuned using a dial to find the frequency of the desired FM radio station.

The other stakeholders within the house were questioned to define further requirements. The stakeholders requested that the alarm clock will not wake anyone but the user. By contacting the stakeholders, more requirements are generated that the user would not think about. With complex designs the customer's requirements are the primary concern with the stakeholder's requirements being the secondary consideration.

2.2 Requirement Comparison

The requirements outlined were put into a pairwise comparison to highlight the most important requirement to focus on. The results were plotted into a bar graph, in Figure 4, to easily identify the priority of the requirements.

		1	2	3	4	5	6	7	8	9	10	11
	Pairwise comparison of requirements 1 = No Preference, Reciprocal = 1 2 = Slight Preference, Reciprocal = 0.5 5 = Preference, Reciprocal = 0.2 9 = Strong preference = 0.11	provide stimulus to wake user	display correct time	the user requires that the alarm clock carry alarms to following day	the user requires that the alarm clock have a user friendly interface	the user requires that the alarm clock reapply stimulus if complete waking not detected	the user requires that the alarm clock apply stimulus at time set	the user requires that the alarm clock have multiple alarms set	the user requires that the alarm clock not wake entire house	Row Product	nth root of row product	Total Normalised
1	the user requires that the alarm clock provide stimulus to wake user	1	5	9	9	5	1	2	9	36450	3.72	29.1
2	the user requires that the alarm clock display correct time	0.2	1	5	5	5	1	9	9	2025	2.59	20.3
3	the user requires that the alarm clock carry alarms to following day	0.11	0.2	1	2	1	0.11	2	5	0.0484	0.68	5.36
4	the user requires that the alarm clock have a user friendly interface	0.2	0.2	0.2	1	2	0.11	2	2	0.00704	0.54	4.21
5	the user requires that the alarm clock reapply stimulus if complete waking not detected	0.2	0.2	1	0.5	1	0.11	5	5	0.055	0.7	5.45
6	the user requires that the alarm clock apply stimulus at time set	1	1	9	9	9	1	9	9	59049	3.95	30.9
7	the user requires that the alarm clock have multiple alarms set	0.11	0.11	0.5	0.5	0.2	0.11	1	0.2	1.331E-05	0.25	1.92
8	the user requires that the alarm clock not wake entire house	0.2	0.11	0.2	0.5	0.2	0.11	5	1	0.000242	0.35	2.76

Figure 3 – Pair-Wise comparison table

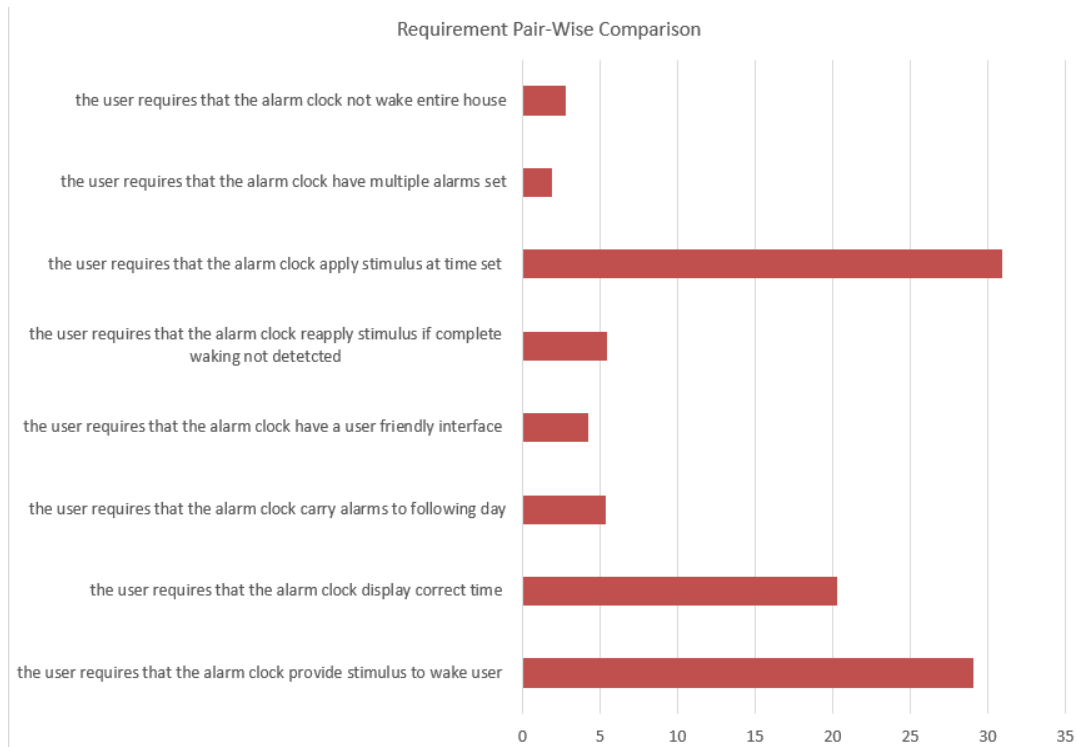


Figure 4 – Pair-Wise comparison bar graph

From the results, it is clear that the most vital requirement is that the alarm clock provide a stimulus at the time set (see Figure 4). The user stated when outlining their desired requirements that the alarm clock providing a stimulus to wake the user is the most important, however the pair-wise comparison ranks that second. This is an example of why a pair-wise comparison is a useful tool when ranking requirements as the user's belief was not the priority. Pair-wise comparison is not a fool-proof tool as it does not rank the stakeholders opinions in priority and is based solely on preference of the requirement not which of the stakeholders the requirement belongs to. It also fails to note how these requirements interact with each other. For example, the stimulus being provided at the time set incorporates both the alarm clock providing a stimulus and that it displays the correct time.

2.3 Operational Requirements

Following the pair-wise comparison, the operational requirements for the alarm clock must be identified. Operational requirements “define how a system will operate in its intended environment” [4], which are directly related to the user requirements. They are ‘how’ will the alarm clock satisfy the user requirements [4].

The operational requirements were identified as follows:

- Supply power
- Display current time
- Set alarm
- Produce stimulus
- Wake user
- Detect user has woken fully
- Re-apply stimulus if necessary
- Set alarm for following day

Although the operational requirements may seem similar to what the user defined previously, they are important to identify to compare during the design process in order to highlight which of the operational requirements are the most important based on how many user requirements it interacts with.

3 Quality Function Deployment (QFD) 1

3.1 QFD 1 Matrix

QFD is a crucial tool when applying a systems engineering approach as it provides a graphical methodology for finding out both stated and unstated customer expectations and desires [5].

QFD 1, sometimes known as ‘The House of Quality’ [6], is a tool used to demonstrate the relationship between what the customer wants and how the engineer will satisfy those wants [6]. The matrix that this tool provides makes a clear display of both how each user requirement is met and the level of which the operational requirement satisfies them. It also clearly highlights whether any user requirements have been neglected in the initial planning stages and can then be used to back track without having a large time impact later down the design and manufacture chain.

Key		How	Importance	Supply Power	Display Current Time	Set Alarm	Produce Stimulus	Wake User	Detect User Has Woken Fully	Re-Apply Stimulus if Necessary	Set Alarm for Following Day
	Strong Relationship										
	Medium Relationship										
	Mild Relationship										
	No Relationship										
Requirements											
the user requires that the alarm clock provide stimulus to wake user		29.101	9		3	9	9	9	9	9	3
the user requires that the alarm clock display correct time		20.277	9	9	3		1				3
the user requires that the alarm clock carry alarms to following day		5.3617	9	3	3						9
the user requires that the alarm clock have a user friendly interface		4.2135	3	9	9	3		9			9
the user requires that the alarm clock reapply stimulus if complete waking not detected		5.4481	9	1		9	9	9	9		
the user requires that the alarm clock apply stimulus at time set		30.91	9	9	9	9	9	3	3	9	
the user requires that the alarm clock have multiple alarms set		1.9241	9	3	9						9
the user requires that the alarm clock not wake entire house		2.7649	1			3	9	3	9		
			853	526	498	610	634	450	429	530	

Figure 5 – QFD 1 Table

These operational requirements are purposefully vague as it allows for more solutions to be generated further down the design process. For example, ‘Produce Stimulus’ has traditionally been noise, however, it could also be a physical stimulus to wake the user.

The user requirements and the operational requirements were integrated into a QFD 1 matrix, as shown in Figure 5. The colour coordination displays the level of relationship between both requirement sets in order to define the impact of the operational requirements on the user requirements. A ‘9’ demonstrates a strong relationship between the requirement pairing and a blank means no relationship, with the ‘3’ and ‘1’ being between the two extremes.

The data taken from Figure 5 highlights that all of the operational requirements serve a purpose and that all the user requirements have been met without going into specifics of how the alarm clock will perform these functions.

3.2 Functional Importances

The results from Figure 5 were plotted into a bar graph (Figure 6) of functional importances to quantify which of the operational requirements is the most important based on ranking between the strength and amount of user requirements it interacts with.

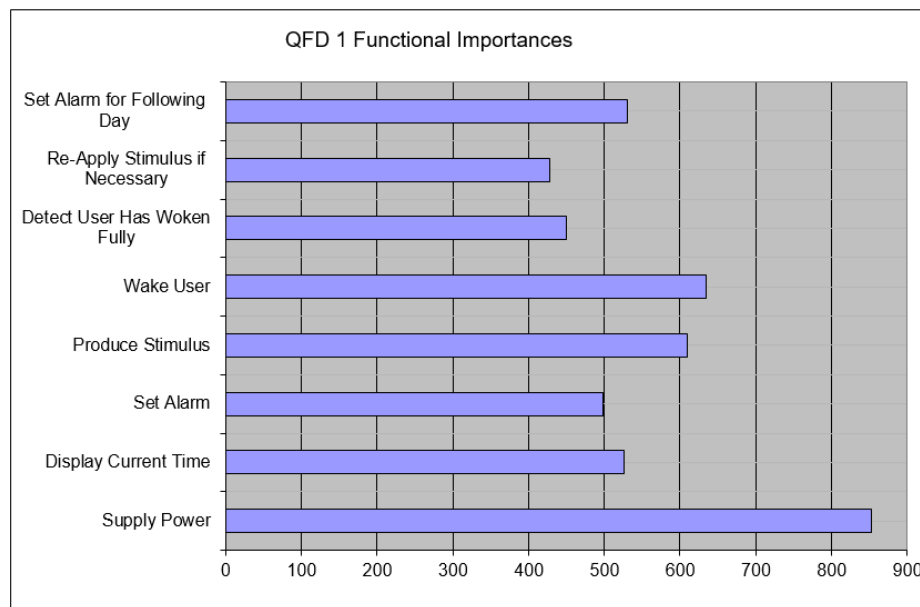


Figure 6 – QFD 1 Functional Importances Graph

From Figure 6, it is observable that supplying power to the alarm clock is the most important requirement followed by waking the user and producing a stimulus. Although those requirements are very similar in regards to the function of an alarm clock, it is important to highlight that they are two separate actions that the alarm clock undertakes to produce the overall result and must be considered individually.

3.3 Functional Metrics

Functional metrics are important within the systems engineering approach as they allow for evaluation of how well the system performs its desired functions. As before, the system is broken down into subsystems tests which are then compared to the original user requirements to assess their need to be adopted into the final design [7].

Key		Function:- Provide Stimulus to Wake User									
		Test method and relationship to requirements									
		Importance	Stimulus Operational Test	Set Alarm Test	Trigger Alarm Test	Stop Alarm Test	24-Hour Format Test	Daylight Saving Time Test	Multiple Alarms Test	Stimulus Duration Test	
Requirements											
	Strong Relationship	the user requires that the alarm clock provide stimulus to wake user	29.101	9	9	9	3	1	1	3	9
	Medium Relationship	the user requires that the alarm clock display correct time	20.277	1	3	1	1	9	9	1	1
	Mild Relationship	the user requires that the alarm clock carry alarms to following day	5.3617	1	3	3	1	9	9	9	1
	No Relationship	the user requires that the alarm clock have a user friendly interface	4.2135	3	9	9	9	9	9	9	9
		the user requires that the alarm clock reapply stimulus if complete waking not detected	5.4481	9	1	9	3	1	1	3	9
		the user requires that the alarm clock apply stimulus at time set	30.91	9	9	9	1	9	9	9	3
		the user requires that the alarm clock have multiple alarms set	1.9241	3	3	3	3	3	9	9	3
		the user requires that the alarm clock not wake entire house	2.7649	3	1	1	9	1	1	3	9
				641	669	672	229	590	601	514	498

Figure 7 – Functional Metrics Table

Figure 7 is the comparison table for subsystem tests in regards to the user requirements stated previously. The table colour coordination is the same as in Figure 5. From the data, it is clear that most of the functional metrics tests had strong relationships to the user requirements, and so they were plotted into a bar graph (Figure 8) to clearly identify which test is the most crucial to satisfying the customer's needs.

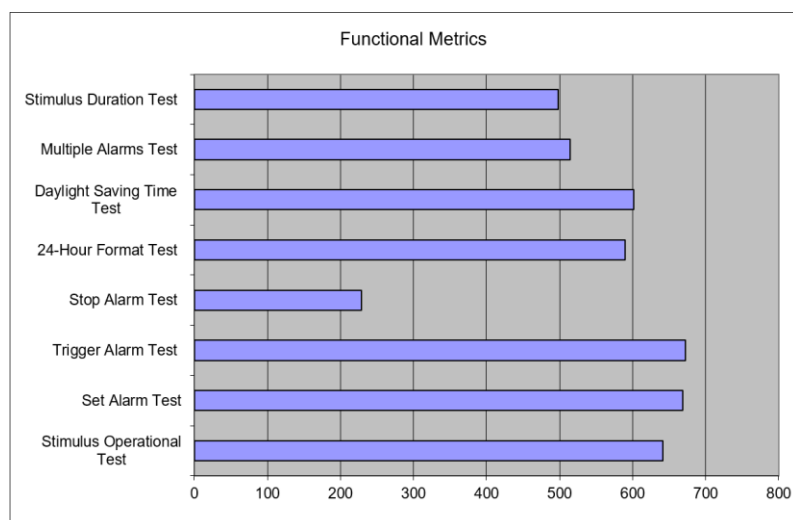


Figure 8 – Functional Metrics Graph

From the bar graph, the trigger alarm test and the set alarm test are the most important with the stop alarm test being the least important. However, this does not mean that the stop test is not valuable to the system, only that when compared to the user requirements it is not the priority as opposed to the other tests.

3.4 Failure Modes and Effects Analysis (FMEA)

Analysis of failure modes is a vital part of the design process when using the systems engineering approach as it allows thought into the impact that can be caused due to system failure. It is futile to believe that a system will not fail at all, although it can be designed so that the failures are kept to a minimum in both quantity and potential outcome [8].

Within the system of an alarm clock, no matter the design, there are 5 key subsystems that need to be considered for failure modes. These are:

1. Timekeeping Subsystem
2. Alarm Activation Subsystem
3. Power Distribution Subsystem
4. User Interface Subsystem
5. Stimulus Delivery Subsystem

By completing an FMEA on the system as a whole, the potential failures can be identified, with measures incorporated to reduce the impact on the user.

The failure modes have been put into a table (Figure 10) with possible mitigations corresponding to each one. They have all been numbered based on probability of occurrence (O), seriousness of occurrence (S) and probability of detection (D) [8].

Scale	1	2	3	4	5	6	7	8	9	10
S	Not severe							Extremely severe		
O	Very unlikely to occur							Very likely to occur		
D	Certain to detect							Cannot detect		

Figure 9 – O, S & D scale key

Figure 9 is a summary of the failure mode rating categories which has been used in the table Figure 10. The FMEA is a “relative and subjective analysis” [8] and so is ranked by the systems engineer based on their opinion. However, the ranking of the failure modes is likely to be the same irrespective of the person(s) conducting the analysis [8].

Subsystem	Failure Mode	Cause	Impact	O	S	D	Possible Mitigation
Timekeeping	Clock inaccuracy	Software malfunction	Alarm trigger is wrong	5	7	2	Use a RTC in the circuit
Timekeeping & Power Distribution	Time resets on power loss	No battery backup	Alarms fail and time has to be reset	8	4	1	Use a RTC in the circuit
Alarm Activation	Alarm fails to trigger at desired time	Incorrect alarm time set	User does not wake on time	3	9	1	Display the time for when the alarm has been set clearly
Alarm Activation & User Interface	Alarm can not be turned off	User Interface frozen or Button stuck	Continuous stimulus - may wake entire house	5	8	1	Include a failsafe so the stimulus runs for a maximum set time
Power Distribution	Short circuit or overheating	Manufacture / design issue	Alarm clock breaks permanently	3	9	6	All components isolated with an earth return and thermal cutoff included
User Interface	Display frozen	Software malfunction / overheating	User sees alarm is set when it is not	2	8	8	Alarm set indicator on separate circuit to screen eg a bulb that turns on and off
Stimulus Delivery	Stimulus does not wake user	Stimulus not powerful enough	User does not wake on time	6	9	4	Include adjustable stimulus strength control or automated by measuring level of sleep

Figure 10 – FMEA Table

From Figure 10, it is evident that most of the failure modes have a high severity if they were to occur. However, the possible mitigations identified should resolve or reduce the frequency of occurrence and should be incorporated into the design. Performing the FMEA has diagnosed issues that may not have been previously considered and therefore has been a valuable step within the design process.

4 Quality Function Deployment (QFD) 2

4.1 Function Mean Analysis

A function means analysis is an approach used to generate methods of completing operational requirements [9]. This method also helps to breakdown the system into components that satisfy the user requirements which can then be ranked further in QFD 2. As the operational requirements are purposefully vague, it allows for this process to become more open so that idea generation is not limited by the desired outcome.

Due to systems getting more complex, designing them right first time has become more of a challenge for engineers [9]. The function means analysis permits the design process to be transparent and traceable, which assists those who support the process in understanding how the progression has developed [9].

Function	Means				
Supply Power	230 V Mains	Internal Battery	Solar Powered		
Display Current Time	LED Display	E-ink Display	Magnetic Fluid	Holographic Display	
Set Alarm	Physical Buttons	Touchscreen User Interface	Voice Command	Neuro Interface (Thought Control)	
Produce Stimulus	Speaker Noise	Flashing Lights	Hydraulic Struts within Bed		
Wake User	Sound Alarm	Intense Flashing LED	Roll User out of Bed		
Detect User Has Woken Fully	Snooze Button Placed Away from Bed	Synced via Bluetooth to Smart Watch	In Built IR Camera with Motion Detection		
Re-Apply Stimulus if Necessary	Speaker Noise	Flashing Lights	Hydraulic Struts within Bed		
Set Alarm for Following Day	Microcontroller Internal Memory Store	Calendar Linked Scheduling	Weather Predicted Adjustment	AI Learned Routine	

Figure 11 – Function Means Analysis Table

Figure 11 is the functions means analysis for an alarm clock. Based on the operational requirements, ideas were input for ways to achieve those requirements functionally. The green represents existing designs, the yellow represents slightly more advanced designs and the red being new designs that have not yet been commercially used. The “if it is not broken do not fix it” motto does need to be a focal point during this design process, however, that does not mean that improvements cannot be made to reduce the user input to make the system easier to use.

By implementing some of the yellow and red colour coded ideas, it is possible to make the alarm clock system more automated, thus reducing the risk of user input error. Unfortunately, this would make the alarm clock more expensive due to the internal components needing significant development and also being expensive for the manufacturer to import in order to assemble the product.

With this in mind, discussions need to be had between the engineering, manufacturing and procurement team to decide on whether the more complex and futuristic components have an impact that justifies the expense. It is also important to return back to the customer and discover their price budget in order to conform with their ideals so it can remain accessible to them.

4.2 System Pugh Analysis

The system Pugh analysis is a comparison tool used to rank new designs to the original model and compare them to determine which design improves the most from the customer's original product [10]. They are all ranked based on how well they achieve the user requirements, with the original product being the baseline [10].

In this case, the original product is the customer's digital radio alarm clock which sets the baseline as 0 for all requirements. A positive number signifies an improvement on meeting that user requirement compared to the original product with the higher numbers representing a bigger improvement. The negative numbers signify the reciprocal of that, with the higher numbers representing a counterproductive change in regards to the original product. If there has been no change then a 0 has been input.

A system Pugh matrix has been completed (Figure 12) to compare three new designs to the original product. The numerical rankings are subjective to the engineer completing the matrix.

The new designs are listed below:

1. Automatic Syncing (AS) Alarm Clock

An alarm clock that is powered by 230V mains with an inbuilt real-time clock (RTC) module that maintains time even if the power is disconnected [11]. It syncs via Bluetooth to the user's mobile phone to integrate their calendar to automatically set alarms in the morning based on the user's schedule. It also gathers traffic and weather data from the internet in the morning to adjust the alarms based on the user's route to work. The stimulus used is noise which is emitted from the inbuilt speaker system, with an adjustable dial to control the noise output. It features an LED display for the time in a 24-hour format, with a smaller led to the side of the screen to indicate if an alarm has been set or not. The stop alarm button is a remote control that can be attached to a wall or surface away from the alarm clock with a range of 10 metres.

2. Hydraulic Strut (HS) Alarm Clock

An alarm clock that has a wired hydraulic system that tilts the bed lengthways to remove the user if the user has not left the bed after 5 minutes of snoozing the alarm. The hydraulic system is universal and can be fitted to any bed except for an ottoman style. The alarm is set via voice command and uses the internal microcontroller memory store to save the alarm data set for the following day if specified by the user. It features a magnetic fluid display with a 24-hour format with an alarm bell icon forming in the corner to signify an alarm set. It also has a noise output alarm from the built in speakers that will trigger initially before triggering the hydraulic system if the user has not left the bed. This is controlled using a balance that relays to the alarm clock the mass of the bed without the user which sends a pulse if that mass exceeds 10kg after 5 minutes of the noise alarm being shut off.

3. Artificial Intelligence (AI) Alarm Clock

An alarm clock that uses an AI interface to adjust and set alarms. It is powered by 230V mains and features an infrared motion detection camera to determine if the user has left the bed. It uses a neuro interface to set the alarms and to determine the state of sleep of the user, to tailor the stimulus to wake the user. It features both a noise and light stimulus output and must be wired to the room light fitting. It features a holographic clock display, with a 12 or 24-hour format that has its own internal battery and can be placed anywhere in the room. The stimulus can only be shut off by the user leaving the bed and will automatically increase in strength if there is no response from the user.

Key 0 = Baseline; -1 = Worse; 1 = Better		Relative Importance Equal	Relative Importance Weighted	Digital Radio Alarm Clock	AS Alarm Clock	HS Alarm Clock	AI Alarm Clock
Customer Requirements							
the user requires that the alarm clock provide stimulus to wake user		5	29.101	0	0	1	1
the user requires that the alarm clock display correct time		5	20.277	0	1	0	1
the user requires that the alarm clock carry alarms to following day		5	5.3617	0	2	-1	1
the user requires that the alarm clock have a user friendly interface		5	4.2135	0	1	1	2
the user requires that the alarm clock reapply stimulus if complete waking not detected		5	5.4481	0	1	2	1
the user requires that the alarm clock apply stimulus at time set		5	30.91	0	2	0	1
the user requires that the alarm clock have multiple alarms set		5	1.9241	0	2	-1	0
the user requires that the alarm clock not wake entire house		5	2.7649	0	1	1	-2
				0	50	15	25
				0	109.095	39.6898	93.9949
Ranking		100		0	-59.095	-24.69	-68.995

Figure 12 – System Pugh Matrix

From the rankings in Figure 12, the analysis displays that the 'Automatic Syncing Alarm Clock' is the better design as it is the only one that exceeds the baseline. It is also precedent that the 'Hydraulic Strut Alarm Clock' is the worst design as it is ranked at 39.6/100 when compared to the baseline.

4.3 QFD 2 Matrix

Following the system Pugh matrix, the 'Automatic Syncing Alarm Clock' design have been input into a QFD 2 matrix to compare its features to the operational requirements and then rank them.

The QFD 2 matrix works similarly to that in QFD 1 with the change being on what is being compared. QFD 1 focuses on the user requirement to analyse what the system needs to achieve and QFD 2 focuses on how to deploy these functions using components within the system.

Key		Design feature	Importance	230v Mains Power	RTC Module	Calendar Alarm Syncing	Traffic and Weather Data Collection	Volume Adjustable Noise Stimulus	LED Clock Display	Remote Stop Controller
	Strong Relationship									
	Medium Relationship									
	Mild Relationship									
	No Relationship									
		Functionality								
		Supply Power	85	9						1
		Display Current Time	53	9	9	1	1	1	9	
		Set Alarm	50	9	3	9	9	1	3	
		Produce Stimulus	61	9	1	9	3	9		3
		Wake User	63	3		3	9	9	3	9
		Detect User Has Woken Fully	45	3			3	9		9
		Re-Apply Stimulus if Necessary	43	9	3	3	3	9	3	3
		Set Alarm for Following Day	53	9	9	9	3		9	
				3425	1289	1845	1677	2013	1418	1373

Figure 13 –QFD 2 Matrix

Figure 13 is the QFD 2 matrix completed for the 'Automatic Syncing Alarm Clock' with its specific features being ranked with the 230V mains power input being the most crucial feature.

To more clearly highlight the component rankings, they have been put into a bar graph in Figure 14.

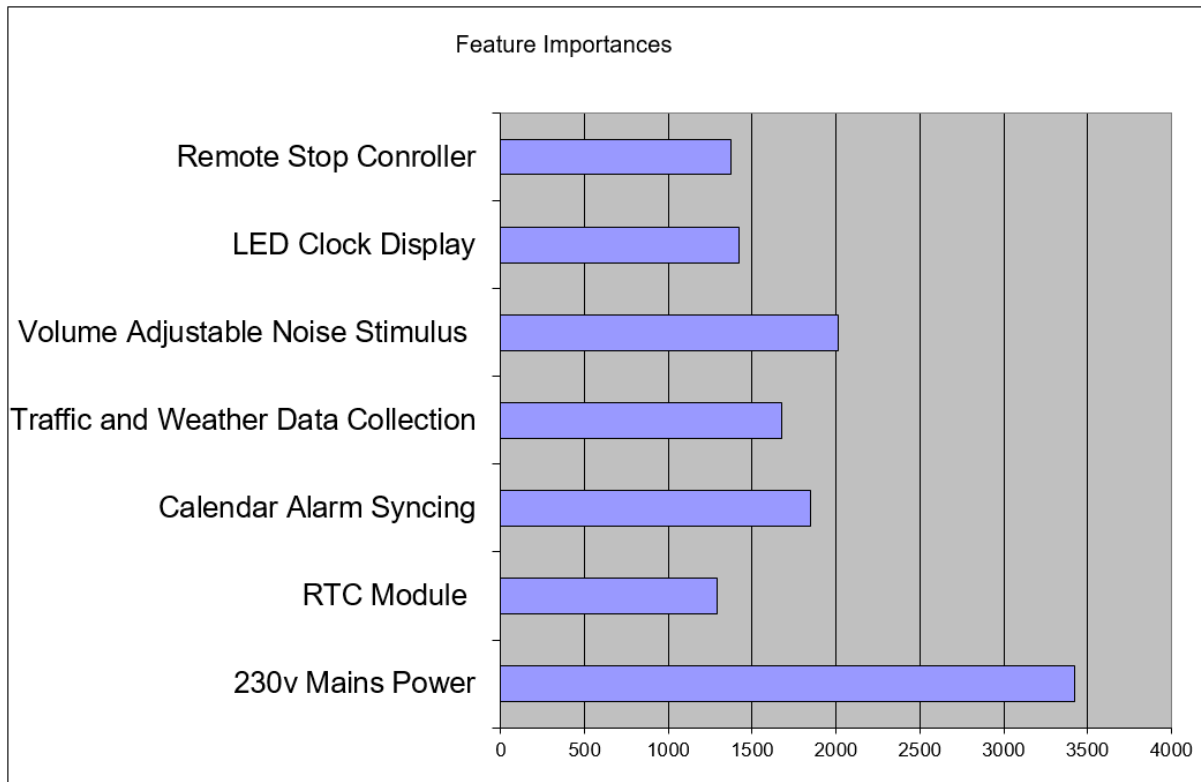


Figure 14 – QFD 2 Bar

This component ranking allows the engineer to visually assess which of the components within the system require the most attention and therefore investment into developing as they are the most critical to satisfying the customer. Each of the means in Figure 14 are important and some are easier to develop than others, as seen in the function means analysis.

As the first two in the hierarchy of means are 230V mains power input and volume adjustable noise stimulus, the engineer can quickly see that the calendar alarm syncing is therefore the primary focus, being that the two above it are already implemented in the majority of alarm clocks.

So despite the top two being ranked where they are, due to the systems engineering approach, it has already been deciphered that they will not require the focus that would be expected from their ranking position.

This is why QFD 2 is important as it clearly indicates which of the means are important in comparison to the others, leaving it to the engineer's discretion as to whether or not the lower ranked means are incorporated into the final design or are re-thought to better meet the operational requirements.

5 Conclusion

In this report, the systems engineering approach has been adopted for the generation of ideas to redesign an alarm clock. The tools used have aided the analysis of the system as a whole before breaking it down into the subsystems and components. This allows for the entire design process to remain fluid and holistic.

The QFD process highlighted the functions the alarm clock needed to satisfy the user requirements before breaking them down further to identify specific components within the subsystems to complete these requirements, as well as minimising the frequency of failure.

Following the systems approach requires the user's opinion and demands and keeps a strong focus on them rather than getting set on an idea that does not meet the demand. Within engineering, this is crucial as customer satisfaction is the priority, yet often it is the case that customer requirements get lost in the design process. The systems engineering approach ensures that this does not happen.

Following this structure, the optimal design generated was the Automatic Syncing Alarm Clock, which adheres to all of the user requirements. It also provides a product that is superior to the user's original alarm clock without it being over-engineered and too technologically advanced that cannot be listed for a reasonable price.

The most important tool used is the FMEA as it ascertains components and features that make the product more reliable and less likely to fail. Although there is still possibility, aspects such as a thermal cut off minimise the risk of a failure mode to occur. It also helps to specify the key subsystems within the overarching system and focuses on them individually to encourage an in depth consideration and analysis.

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