DESIGN FOR TROUBLESHOOTING METHOD

This is a short overview taking you through the steps of how to perform the Design for Troubleshooting Method. This method is intended for designers who want to redesign a product to make it easier to diagnose and repair when if breaks.

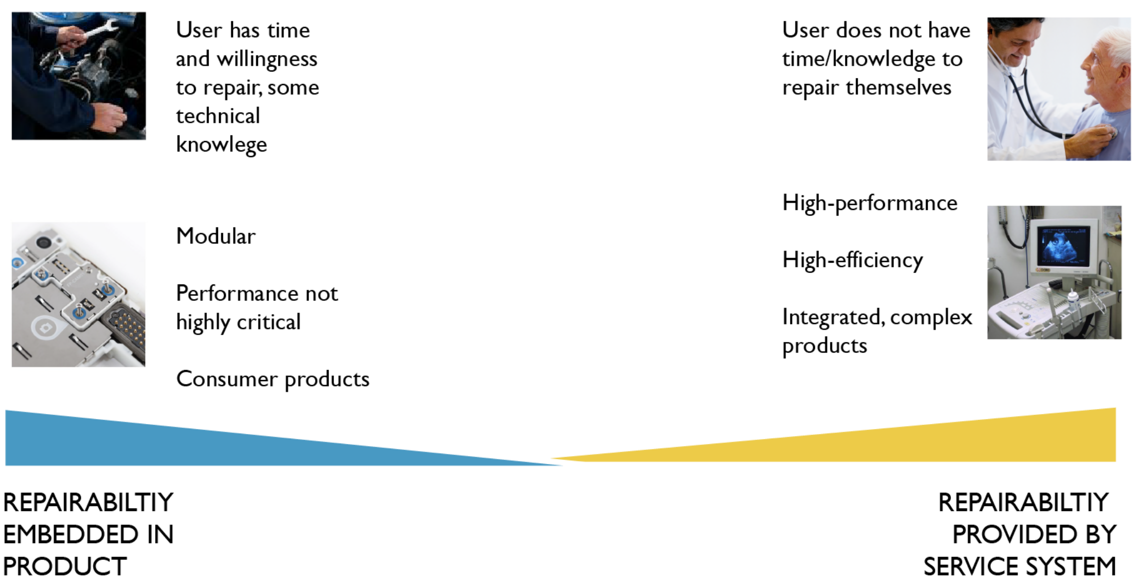
First, some key concepts relating to Design for Troubleshooting are explained, then the process is gone through step-by-step. Throughout the guide, the example of the repair of a hearing aid is used for representative examples.

1. KEY CONCEPTS

The following section describes the key concepts which underpin the Design for Troubleshooting process. These concepts have been used in the development of the method and are key to understanding the steps.

PRODUCT VS. SERVICE-SYSTEM

Making a product “repairable” doesn’t necessarily mean the user themselves should fix it. Products have a trade-off between modularity (which helps user repair) and performance efficiency. & quality. Some users may also be more willing and able than others to do repairs themselves. Therefore in many cases, a balance between user repair and serviced repair will be required.



TROUBLESHOOTING VS. REPAIR

Fixing a product is a long process in which actually repairing the problem may only be a small part. Especially for complex products, most of the time and effort involved is spent on finding the fault (or ‘’troubleshooting’) and actual repair is only a final step

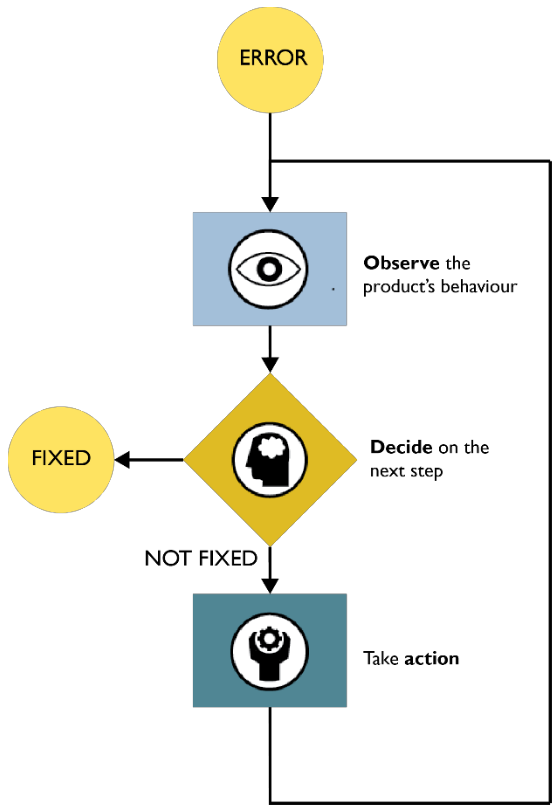
The troubleshooting process can be characterised by three activities:

Actions: the user interacts with the product

Observations: the user observes the product’s behaviour or gathers information about it

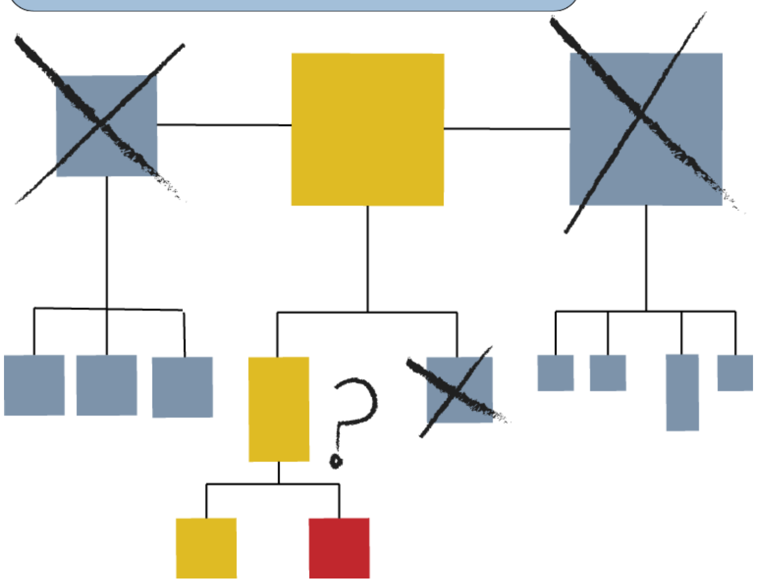
Decisions: the user decides on a next step

These three activities are important to consider in design for troubleshooting.



EXAMPLE:

A user attempting to fix a hearing aid first **observes** that the device is not working. They **decide** to change the tube, (an **action**) since this has worked in the past. They then observe the results - the device is still broken. They **decide** instead that the problem might be in the battery, so take further **action**



FAULT-FINDING

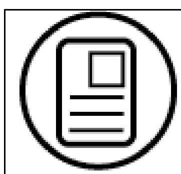
Troubleshooting proceeds by a process of elimination. Parts which are definitely not the cause of the error are eliminated, narrowing down the number of potential sources of the error.

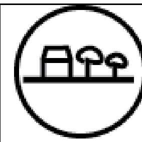
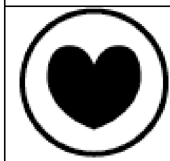
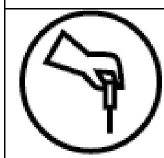
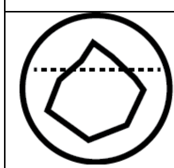
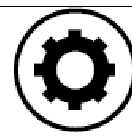
EXAMPLE:

The user changed the hearing aid battery, and observed no improvement. This means that the problem might not be in the battery. The user checks the battery in another hearing aid, and it works, thus eliminating the battery from the liste of possible broken parts.

TROUBLESHOOTING ENABLERS

Each activity in the troubleshooting process (Actions, Observations and Decisions) is enabled by the presence or absence of a certain technical, social or organizational factor, called here ‘Troubleshooting Enablers’.

	**Legality & IP** Some troubleshooting actions are constrained by laws (e.g. who is allowed to repair high-voltage power lines). Others are constrained by company policy which aims to shield the workings of the machine from competitors.		Codified Knowledge Explicit knowledge that can easily be written down, explained and transferred between people (e.g. user instruction manuals, system architecture diagram of a machine)

	**Risk** The safety or functional risk caused by taking the troubleshooting step. This could be either 1) a safety risk to the person carrying out the action 2) the risk of damaging the product itself while carrying out the action. The size of a risk can be estimated by considering both how likely it is to happen and its severity.		**Environment** Requirements of the environment around the machine. This could be a special place (e.g. workshop, cleanroom) or a particular state (e.g. clear workers from area for enough time to fix)
	**Emotion** Emotional state or attitude which affects repair. For example, having the self-confidence to replace a part, or being too stressed to stop normal workflow and fix a non-critical error.		**Senses** Information gained by a user observing the machine through sight, sound, touch or smell (e.g. warmth from an overheated motor, hearing a squeaky wheel, seeing an on-screen error message)
	**Skills** Ability to perform a task related to repair and maintenance (e.g. knowing how to use a voltmeter, or read a log file)		**Data** Quantitative readings from the machine or its environment (e.g. temperature, humidity, voltage)
	**Tacit Knowledge** 'Expert' knowledge gained from repeated experiences, which allows problem-solving and analysis (e.g. skilled mechanic able to guess what might be wrong with an engine)		**Parts/Tools** Tools are artifacts which help in the troubleshooting process, and parts are existing product components which can be replaced as part of troubleshooting.

EXAMPLE:

Fixing a hearing aid requires **skills** (physical dexterity), **senses** (to hear when the device is working), **tools** (a pin) and **spare parts** (a new battery) and the **emotional** desire to try to fix it. It requires no **risk, legality, data** or **special environment,** and little **tacit knowledge**.

2. ANALYSIS & NEED FINDING

The first step in finding out how to make a product more repairable and ''troubleshootable'' is figuring out how it fails and how it is fixed. There are two stages in the process:

1. A Technical Analysis of the product, through which you can understand how it works and how it is ''suppose'' to fail and be fixed

2. A User Observation study, to see how the product actually fails and is repaired in real life.

Technical Analysis

Resources:

For information on how the product functions: look for service manuals or technical documentation and if possible talk to experts on the product. If these are not available, a product teardown can be performed in order to figure out how the product is constructed.

For information on troubleshooting and failures: ask manufacturers for lists of frequent errors or customer complaints. Look through service and user manuals to see if any troubleshooting instructions are given.

Outcomes:

For a functional description of the system: use whatever format is suitable; a system diagram, a sketch, a CAD model, etc.

For a description of troubleshooting and failures: Use the Design for Troubleshooting Observation Card. If a list of ''top'' errors are known, fill these in the column on the far left of the Observation Card. Then put any known troubleshooting steps in the Observations, Decisions and Actions categories. After this, use the Troubleshooting Enabler card to note down any enablers known so far. An example of the cards filled out for the hearing aid is shown below:

TROUBLESHOOTING ACTIVITES

	FAULTS	OBSERVATIONS	DECISIONS	ACTIONS	NOTES
1	battery dead	no sound	first trouble-shooting step	swap out new battery	ALL TAKEN FROM USER MANUAL
		see if battery working in other device	working/ not working	fixed/move to "tube errors"	
2	tube blocked	no sound	IF already checked battery	unplug tube	

TROUBLESHOOTING ENABLERS

									new battery
									spare hearing aid
									pin

User Observation

This step should enable you to:

a) See how the ''official'' troubleshooting methods found in the Technical Analysis compares to real life

b) Discover enablers and potential barriers to troubleshooting for different users

Gathering Failures

In order to test how users fix a broken product, there must be some product errors for them to fix. Some suggested ways of finding this are:

- Simulating errors (break it yourself!)
- Collect malfunctioning products which have been returned by the customer
- For products with existing service support or infrastructure, visit a service technician or repair shop

Types of Users

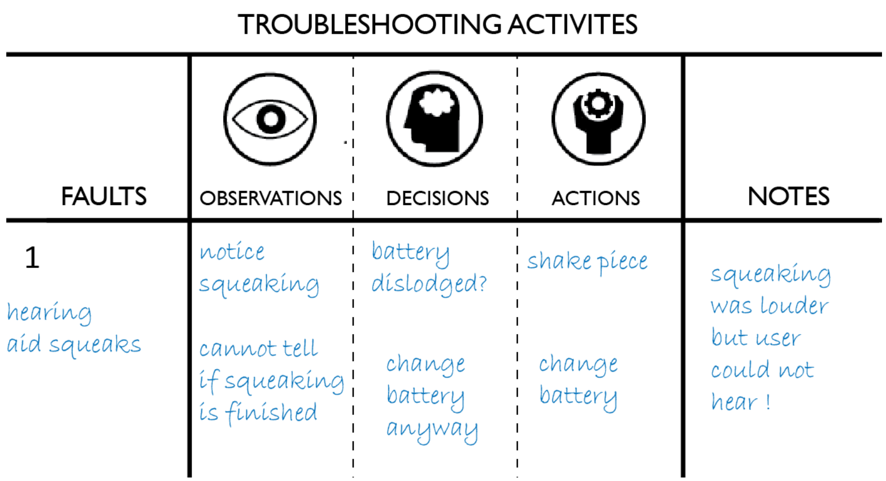
An ideal spectrum of users should include typical users of the product. The observation study should be set up such that they have as close as possible an environment and resources to ''real life''. For example, if users typically use a service (e.g. phoning a repair helpline) include this in the observation.

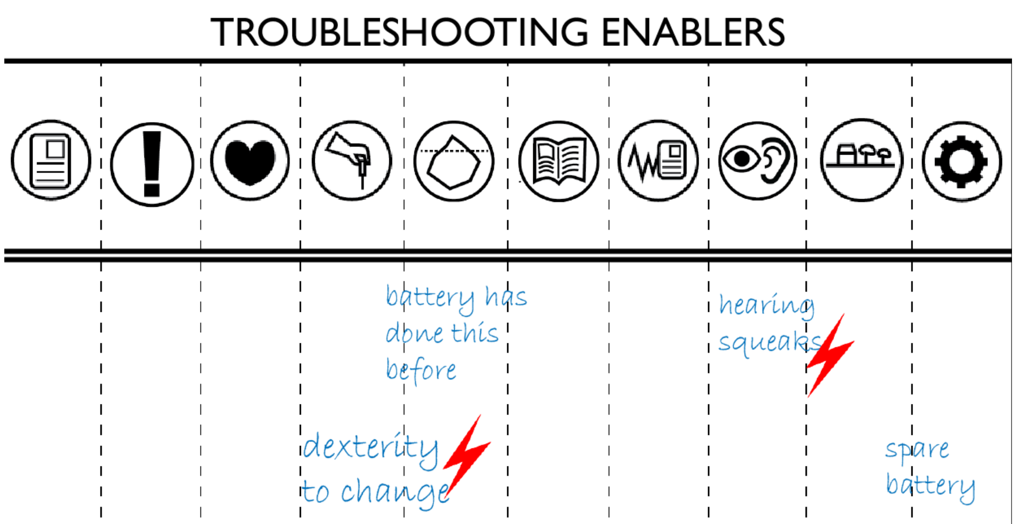
How to Observe

A useful resource for user observational studies is the field of Contextual Inquiry (Beyer & Holtzblatt). This method advises acting as an 'apprentice to the user you are observing – act as if you want to learn from them, and ask them to explain their actions as they do them. This leads to a rich understanding of the motivations behind users' actions, which is very important in troubleshooting.

Recording Data

As in the Technical Analysis, record the user studies using the Observation Card and analyze using the Troubleshooting Enablers card. This should yield far more results than the Technical Analysis, and should hopefully start to show many interesting Enablers. An example user observation record for the hearing aid is shown below. Some red lightning bolts already mark potential problems.





3. Analysis – Pain Points & Opportunities

The next step in the process is to analyze the data to find pain points – clear problems – and opportunities for how to improve the troubleshooting process of the product. Analysis can be performed in many different ways, but some effective methods are:

Missing enablers

You might have noticed during the research that a particular enabler was required, but missing. Maybe a customer made a mistake because they removed the wrong part – a sign that extra information might be needed. Or maybe a particularly delicate-looking part required a particular emotion (confidence) or skill (dexterity) to remove, which the customer did not have**. (In the hearing aid example above, a key enabler for an observation was the ability to hear a squeaking sound – something the target user could not do!)**

Are resources being used efficiently?

There could be instances where material is being wasted (e.g. an entire subsystem is changed when a small part is broken). Talent and skills might also be used inefficiently – is a highly-trained (highly-paid) technician doing simple tasks that a customer could do?

Is the process of elimination being followed?

In an ‘’ideal’’ troubleshooting process, the fault is found and solved by a process of elimination. To the expert troubleshooter, an action can give clues about the error by showing which part of the product is not at fault (e.g. “I reinstalled the software and the problem is still there, which shows it might be a hardware error instead”). A repair process has pain points if the user repeats the same troubleshooting action, or does not eliminate a subsystem – e.g. a user keeps trying to find leaks in a vacuum cleaner pipe when the real problem is in the motor.

4. Design

One of the key ideas in the Design for Troubleshooting Method is that certain products – or even certain failures within a certain product – will be more suited to user-repair than others. If a product or product failure is inherently difficult to repair by a user, then a service system may be needed.

In order to decide which parts of the process should be user-repaired and which parts should be service-repaired, the limitations of the product user-repairability and the capacity of the service system must be understood. However, to perform a complete analysis of these two would be very time consuming. The best approach is instead to start designing iteratively between product and service – pick one, see what limitations are reached and switch to the other. The following pages show hints and methods for approaching both product repairability and repair service design.

DESIGN

Product Design

Actions

You may have noticed that a common troubleshooting step involves removing or changing a part, taking up a cover, or dismantling the product in some other way.
Identify which parts these are and then apply design for repairability principles

Standardization
Use standard, universally applicable components (widely available and understood by technicians/users)
Use standard interfaces to enable quick subsystem connection.

Ergonomics
Provide sufficient space around maintenance points for ergonomically safe repair
Make regularly-replaced components easy to access and hand

Process
Use fasteners that facilitate quick removal and replacement with minimum tools
Design cues guide user to repair the machine in the 'right' way

Observations

Warning signs

If the user cannot see a key parameter which might help them understand an error or make a repair, add a signal to transmit that parameter to the user. These signals could range from software to simple mechanical solutions:

Show the Problem

If possible, make common problems visible to the user in the design of the product. For example, early Dyson cleaners had a clear body, so that the most common problem – a full dust bucket – could immediately be observed.

Decisons

Self-Diagnostics

Many complex product such as motor vehicles and medical devices contain internal software which uses diagnosis algorithms to self-diagnose faults. Before introducing such a system, make sure it has a chance of reliably characterizing all common errors and does not compromise other repairability factors (such as accessibility and modularity)

Reduce Cognitive Load

Users make better decisions when they have fewer things to think about. Making the layout of the design simple and labelling parts clearly stop users becoming confused and leave them to think only about the troubleshooting process.

DESIGN

Service

Service design uses chronological ''timeline'' tools to map the journey through a service. The following tool, the Troubleshooting Timeline, has been adapted to the specific needs of troubleshooting. It contains columns for the user (i.e. customer), the product and the service-delivery organization. There is no set rule for filling in the timeline – it can be used to model existing systems or to generate new ideas. A partial example for the hearing aid is shown below: