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PRINCIPLES FOR MANAGING TECHNOLOGICAL PRODUCT OBSOLESCENCE

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ABSTRACT
Products evolve to accommodate competitive market pressures, rapid rates of technology change, and constant improvements in performance and functionality. While adding functionality and value, the fast moving technologies also make products obsolete quickly. One of the primary reasons for product obsolescence is technological obsolescence which results when consumers are attracted to functions in newer models of products that are more technologically advanced. One way to deal with this problem is "piggybacking", a strategy that enables renewed functionality of a technologically obsolete product through the integration or add-on of a secondary devise or component. Not to be confused with upgrading strategies, piggybacking requires a device that fits adjacent to, upon, or within the existing product architecture. Piggybacking is an attractive strategy for consumer electronic products that are particularly prone to technological obsolescence as it offers a means to accommodate fast and slower changing technologies within a single product. Currently, piggyback products are realized with ad hoc methods that rely on the experience and intuition of the designer, often applied inconsistently and not well known by less experienced designers. In this work, a set of formal principles is presented for guiding the design of piggyback products. These principles are derived from the results of an empirical study of 72 different products. As part of the study, various products are analyzed with a dissection tool with representative principles derived from the data. The utility of these principles is demonstrated via the conceptual design of two novel piggyback products.

Keywords: Product Obsolescence, Sustainable Product Development, Technological Obsolescence, Design Principles, Piggyback Products

1 INTRODUCTION

1.1 Motivation and Overview
In the normal course of product development, it often becomes necessary to change the design of products and systems consistent with shifts in demand and with changes in the availability of materials and components. When the majority of constituent parts of a system are technological in nature, the short product life cycle associated with fast moving technology changes is both a problem and an opportunity for manufacturers and systems integrators. The economic ramifications of product obsolescence are apparent and staggering. Industry experts estimate that over 200,000 components from over 100 manufacturers became obsolete in 2003 alone [1]. The amount of waste generated by obsolete products can be gauged by WEEEMan (Figure 1.). The WEEE man is made from electrical and electronic waste, such as washing machines, TVs, microwaves, vacuum cleaners and mobile phones [2] and represents the amount of waste electrical and electronic equipment (WEEE) the average British person throws away in their lifetime – over 3 tons per person.
When a product evolves, it is subject to changes in its functionality, technology and form. While adding functionality and value, the fast moving technologies also make products obsolete quickly. One of the primary reasons for product obsolescence is technological obsolescence [3]. Technological obsolescence results when consumers are attracted to functions in newer models of products as the result of advances in technology, rendering older versions of the product obsolete. Furthermore, the structure and timing of these changes are very often very difficult to predict precisely because the changes are prompted by stochastic market forces (e.g., technology S curve, competitive pressure, consumer demands), consumer preferences, and other factors that are difficult to forecast. If we cannot

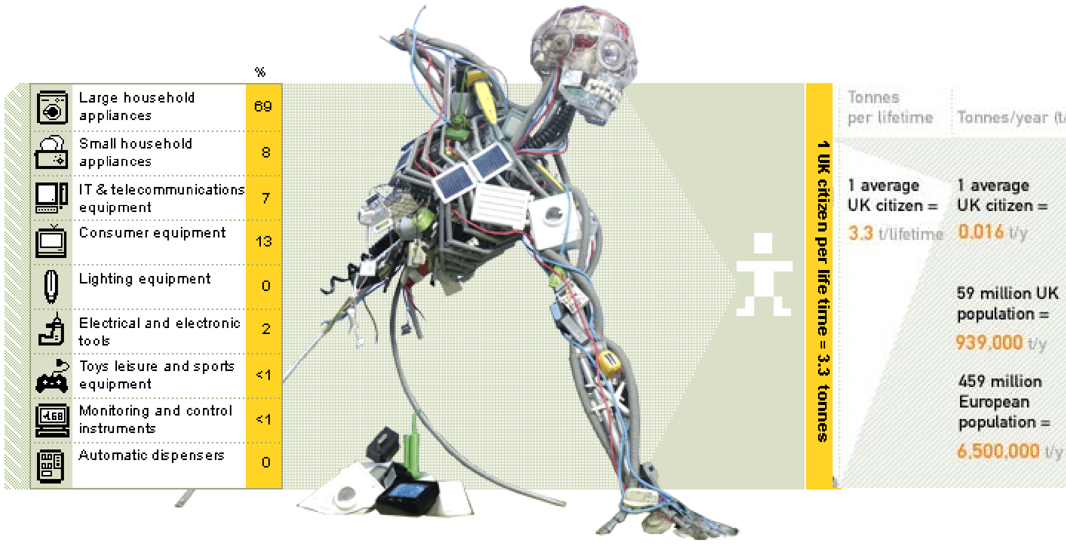


Figure 1. WEEE man: Amount of electrical and electronic waste generated by average UK citizen (adopted from http://www.weeeman.org)

predict how a product will evolve, then we must move beyond the assumptions underlying most strategic methods available today for tackling product obsolescence: (1) that the component offering is predetermined (e.g., a predetermined, discrete set of components is available to tackle obsolescence) and (2) that only a handful of mitigation approaches (life time buys and part substitution) are available. Instead, we need fundamental principles and guidelines for designing the architecture of products that are adaptable to future changes and inherently designed to cope with obsolescence, even if the precise form of those changes is not known *a priori*.

One strategy to deal with the problem of technological obsolescence is “piggybacking”. Piggybacking is a strategy that enables renewed functionality of a technologically obsolete product. This is achieved through the integration or add-on of a secondary devise or component. Not to be confused with upgrading strategies, piggybacking requires a device that fits adjacent to, upon, or within the existing product (***parent product***) architecture. Piggybacking is an attractive strategy for consumer electronic products that are particularly prone to technological obsolescence as it offers a means to accommodate fast and slower changing technologies within a product. Figure 2 presents examples of two piggyback products. The e-film cartridge is designed to work with a conventional camera and combines the features of digital imagery (digital storage) with the best of conventional photography (***e-Film***). The mobiBLUs’ MP3 cassette player is another example which illustrates the principle of piggybacking. This product combines the best of both worlds, i.e., digital storage of MP3 with high quality sound of cassette players and helps in sustaining cassette players (***mobi-Blu DAH 220***).

Another advantage of piggybacking strategy is reduction in redesign efforts. If all the changes to deal with additional functionality and technology upgrade were to be included in the parent product, a tremendous amount of redesign effort would be required. Redesign effort can involve considerable costs, such as production costs, inventory costs, cost incurred due to reorganization of manufacturing processes, and costs due to increased cycle time. This could be avoided by designing a piggyback product rather than redesigning the overall product.

Currently, piggyback products are realized with ad hoc methods that rely on the experience and intuition of the designer. A systematic method of designing piggyback products is needed. This paper presents such a method in the form of a set of principles to formalize and guide the design of piggyback products and slow technological obsolescence. These principles are derived from the results of an empirical study of 72 different products. As part of the study, various products are analyzed with a dissection tool, and representative principles are derived from the data. The utility of these principles is illustrated through the application of these principles to the conceptual design of two novel piggyback products.

(a) (b)

Figure 2. Examples of piggyback products a) e-film and b) mobi-Blu DAH 220 MP3 cassette player

1.2 Background

Obsolescence occurs when products become ‘‘out of use’’ or ‘‘out of date”. In terms of product design, o*bsolescence* is a measure of a product’s loss in value resulting from a reduction in the utility of the product relative to consumer expectations. It should be noted that while the absolute usefulness of a product may remain constant, if consumer expectations increase, the product may realize a corresponding reduction in value. Such a loss in value is said to be the result of obsolescence. The relative loss in product value could be due to various reasons such as styling changes or quality improvements in subsequent versions of the product. Obsolescence is a state in a product’s lifecycle which occurs when a product is no longer “wanted”, even though it may be in good working condition, and fulfilling its intended function for which it was designed.

Researchers are just beginning to understand the wider scope of product obsolescence that cuts across the entire life cycle phases from cradle to grave. Research in the area of product obsolescence is steadily progressing. Many researchers have tried to define various terms and concepts related to product obsolescence [4, 5, 6]. The importance of consumer patterns with respect to product obsolescence is studied by Cooper [5]. The marketing aspect of products when faced with issues of product obsolescence is studied by Levinthal and Purohit [7]. Sandborn and Singh [8] have used forecasting models to predict the possibility of product obsolescence during its lifetime and presented some useful strategies like life time buys to mitigate the effect of product obsolescence.

While the impact and pervasiveness of technological obsolescence is a growing problem, existing work on technological obsolescence has focused on reactively managing component obsolescence, i.e., minimizing the cost of resolving the problem after it has occurred [9]. Recent studies indicate that the best time to extend a product’s life time is at the early conceptual design stage [10, 11]. It is most beneficial at this stage because it is the place where changes are least costly to make yet have the greatest impact on costs over the entire life cycle. Although initial progress has been made toward managing Diminishing Manufacturing Sources and Material Shortages (DMSMS) obsolescence [3], considerable gaps remain when one considers managing product obsolescence by embedding design principles and guidelines that prevent obsolescence from being addressed in the early conceptual design stage.

The objectives of this paper are threefold: first, to present a research methodology by which principles of designing piggyback products could be discovered; second, to present the principles derived by this methodology; and third, to illustrate the application of developed principles on a product development case study.

2 OBSERVING, EXTRACTING, AND GENERALIZING PRINCIPLES

Intuitive and *ad hoc* techniques exist in industry to mitigate the effect of technological product obsolescence. In this paper we seek to apply the scientific method through empirical studies of managing technological product obsolescence. Figure 3 shows a tested approach for engineering design research [12, 13]. One of the important concepts in this approach is the use of empirical studies as a foundation for developing design methodologies. This research approach starts with an initial

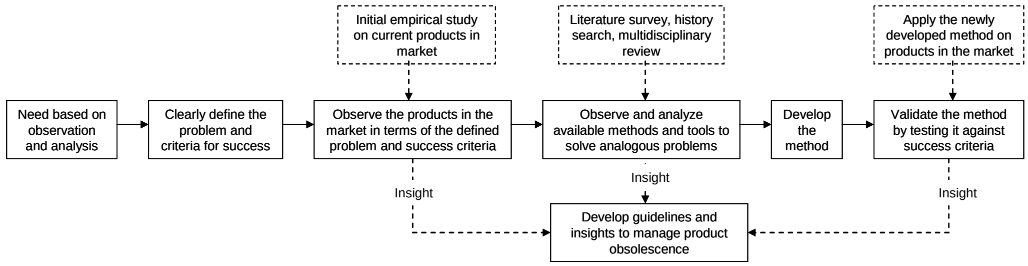


Figure 3. Engineering design research approach (adopted from (Wood and Greer, 2002))

observation or study on the products available in the market in terms of the defined problem. Design methods are developed based on the principles extracted from the studies. The developed method(s) is validated by practically applying them to new product offerings for the market. A similar approach has been used in the past to study product flexibility [14].

A hypothesis of our research is that past designs provide a basis for studying and determining fundamental principles for managing technological product obsolescence through the design of piggyback products. *However, if such fundamental principles can be found in existing products, where might one find such piggyback products? What sources of data exist to perform this study?* Such a source must reference a wide variety of piggyback products and must provide as much information as possible regarding the basis of the design that led to their development.

Our preliminary research has determined a number of suitable sources to study piggyback products. The readily available and rich sources include web searches of emerging products, product blogs maintained by product aficionados, and product catalogues maintained on the web by numerous companies. Other potential data sources that were investigated include product offerings currently in the market, a patent repository (United States Patent and Trademark Office), or, more generally, the patent repositories across the world like the European Patent Office (EPO) and the Free Patents Online, product publications of various companies, and Harvard Business Cases. All of these sources have great potential in their data richness. The vastness of data sources, especially on the web, also make it possible to extract principles using a statistical basis.

Finally, one must answer the question, *Assuming suitable data sources exist, how will we mine these sources?* This issue is addressed by collecting all the inferences made using the data from the product dissections and organizing them into a list of principles, which may then be used by designers to guide the concept generation process. In some ways, this process is similar to the approach used in TRIZ (or TIPS, Theory of Inventive Problem Solving) where Altshuller studied 200,000 patents to derive 40 principles that can be applied to similar problems [15].

2.1 Web Based Search Methods

Three different types of search methods were used to discover piggyback products which showed propensity for managing technological obsolescence. The first method is the *search engine based search method.* This method involved searching for products by relevant keywords, which express the attributes related to managing product obsolescence. This was a task not easily accomplished because one cannot simply type ‘piggyback product’ into a search engine such as Google and get a list of products since most products do not contain this expression in their description. Searches were performed over the key word combinations of products, synonyms of manage (direct, administer, supervise, handle, control, cope), and obsolete (aging, discarded, disused, superannuated, worn-out; inoperable, unusable, unworkable, useless; dead, defunct, extinct; dormant, fallow, idle, inactive, inert, inoperative, latent; ancient, antediluvian, antique, fusty, musty, old-time, aged, venerable). Searches were also performed over the antonym of obsolete (contemporary, current, mod, modern, new, newfangled, new-fashioned, present-day, recent, ultramodern, up-to-date; fresh; modernized, refurbished, remodeled, renewed; functional, operable, operational, workable; active, alive, busy, employed, functioning, operating, operative). These searches were pruned to reduce the results returned to a manageable number of products. The focus during the search was to identify only relevant products in electronics and the electro-mechanical domain.

The second type of search was the *product catalogue search method.* This web based search method involved searching product catalogues of various companies and retailers. The search was limited to find product categories, mainly consumer electronics and household appliances, in which the rate of evolution was high and technological obsolescence is highly visible. The search in this category also used a single company or entity mainly involved in producing consumer electronics or household products to find suitable candidates for the study. The third type of search method was the *web based product blogs method*. In this method various popular blogs on the web were searched. This involved reading blog sites of many product aficionados, where they have posted their opinion about various products and performed some technical analysis of the products. The results obtained in this way were also limited as before by eliminating certain types of product and reducing the scope of the searches to the consumer electronics, household appliances, and electro-mechanical domain. The results of different types of searches were "subjectively" pruned to find suitable products for this study.

2.2 Search Results

The search methods resulted in numerous products which showed potential to offer good insights about managing technological obsolescence. The initial tally of discovered products was 200 distinct products. A careful filtering resulted in a list of 72 products for detailed study. These products showed highest propensity of yielding principles for managing technological obsolescence. The product list is presented in Figure 4. The websites from which they were located and other details pertaining to the products is available at the SMART Lab website at Virginia Tech [16].

2.3 Product Data Sheet Tool

After collecting a list of piggyback product for analysis, a systematic way of extracting data from this list is essential. The data extraction process developed should lead to easy comparison of various features of products on common basis. A template for data sheet tool was created for organizing the data that will be helpful in understanding the facets of a piggyback product's design which make the parent product immune to obsolescence. The data sheet tool is a well thought-out collection of questions which are designed to lead a designer towards specific information which is relevant to designing piggyback products. The data sheet tool contains various questions pertaining to various facets of piggyback products. Using questions instead of directive statements is a well known method [Socratic Method, 17]. Socratic method helps to stimulate thinking in focused areas. This data sheet tool was then used for formulating a list of principles.

Since the design of a piggyback product is dependent upon the design of the parent product, the questionnaire also contains questions related to the parent product. These questions can help in identifying various facets of the parent product that lend themselves to the design of piggyback products. It also provides insights into which design features of a parent product are less complicated and easier to design piggyback product for. The questions in data sheet tools are organized into various general categories. These general categories provide the designer with a context from which information is being extracted. The complete data sheet tool for an example piggyback product is presented in Appendix A.

2.4 Design Principles

A total of 26 principles (20 new principles) of designing piggyback products resulted from the data sheet tool. The other six principles [principle 5, 17, 19, 20, 21, and 26] are similar to those in Qureshi et al., [14]. In order to attain a similar semantic level a categorization of these principles is essential. The discovered principles are divided into six different categories. Each of these categories is followed by the principles themselves. The individual principle statements can be applied directly to drive concept generation. The complete list of principles is presented in Figure 5. Principles that pertain to design consideration of both parent and piggyback product are marked (G), principles pertaining only to design of parent product are marked (Pa), and principles pertaining to design of only piggyback product are marked (Pi). Details of these principles can be found on the SMART Lab website at Virginia Tech [16], along with brief explanations and examples of devices which show aspects of each principle. Some excerpts from the website of the principles are presented in Figure 6.

KitchenAid Grain Mill Attachment	Shimano XT ST-M760 Dual Control Levers	Blackburn Basic Trackstand Trainer	Blackburn Mountain Mirror
Nashbar Bashguard	Manhattan USB VOIP Analog Phone Adapter	PS/2 to USB Keyboard/Mouse Converter	Kinamax Executive Notebook Cooler Pad
Go Industries Air Flow Tailgate - Painted V-Gate	Bladez XTR Seat Kit	Sportrack Frontier Hitch Adaptor	Tippmann E-Trigger Electronic Upgrade Kit
Pace Edwards Pop & Lock	Just Cooler Monitor Cooling Kit	Avid Mechanical Disc Brakes	AcomData 250GB External USB 2.0 Hard Drive
Cell Phone Battery Booster	Servo Type 150 Power Feed	Coolant Pump for Machine Tooling Applications	Dynex™ 3.5" External USB Floppy Disk Drive
Lehmans Electric Motor for Butter Churn	Tippmann Double Trigger	Super Antenna Booster	RS-300 Remote Car Starter w/ Keyless Entry
Malco Turbo Shear Attachment	Milwaukee Extension Bar	Dewalt Rotary Laser Wall Mount	Milwaukee Chuck Arbor Assembly Adapter
Dremel Flex Shaft attachment	Milwaukee Right Angle Drill Attachment	Rock Shox Judy Suspension Fork	Plantronics Cordless Phone Headset
Cannon Waterproof Camera Case	Crimestopper Advantage Car Alarm with 2-Way Pager Remote	Cables To Go Port Authority 6-Ft. USB Serial DB25 Adapter	Motorola Bluetooth® Home Stereo Adapter DC800
Snap-on Amplifier	KitchenAid Citrus Juicer Mixer Attachment	PCI Wireless Adapter Card for Desktop Computers	PC sound-card
Sony SB-V55A AUTO-SENSING A / V Switcher	Fanstel Compact Caller ID	Mobi-Blu Dah 220 Cassette Player	Smarthome PowerLinc USB
PS3 Remote Control	Sony Playstation 2X Network Adaptor	Nintendo64 Controller	Revo Power Wheel
Nintendo64 Expansion Pack	Sony USB Fingerprint Micro Vault	Electrolux Trilobite 2.0	Lumipad - Fridge Message System
Virtual Keyboard	Fisheye Lens Camera	Motosk8 Motorized Inline Skate	LightWedge Reading Light
Tacx Virtual Reality Trainer Track	Pacific Wind Thrust Pack	Mojopack	Electrocharger by Texas A&M University
Belkin Portable Keyboard	KitchenAid Food Grinder Stand Mixer Attachment	Food Processor Attachment Blades and Discs	Immersion Blender Chopper Attachment
Just Cooler Monitor Cooling Kit	Vacuum Muffler	Mini-Vac Attachment	Westin Bed Xtender
Maidenform Bra Extenders	Bluetooth Adapter for Computer	Tippmann Collapsible Stock Kit	e-film

Figure 4. List of products analyzed for deriving design principles

3 APPLICATION OF PRINCIPLES: CONCEPTUAL PRODUCT DESIGN

The conceptual design of two new piggyback products, BlueCell and MP3Video-Cassette player, using the design principles (Figure 5) is illustrated in this section. These piggyback products help in managing product obsolescence of a cell phone without Bluetooth technology and VCRs respectively. To the best of our knowledge, products similar to BlueCell and MP3Video-Cassette player do not exist in the market and hence are totally novel products. The two examples also elucidate how to apply these design principles to drive concept generation for piggyback products.

3.1 BlueCell

Cell phone technology changes fast. One of the newer features in cell phone technology is Bluetooth capability. Bluetooth capability is a type of short range wireless communication adapter for cell phones and computers. A USB Bluetooth adapter is available for computers that are not previously equipped with Bluetooth technology. However, Bluetooth adapters are not currently available for cell phones that lack built-in Bluetooth capabilities. The main reason for lack of Bluetooth adapters in cell phones is lack of a USB port on cell phones. The BlueCell concept is a Bluetooth adapter for cell phones that attaches via the headphone jack (Figure 7).

It has a battery inside to provide power that the USB would normally provide. The battery can be changed out when it fails to work any longer using a screwdriver. Bluetooth devices such as headsets can be configured to work with this adapter. This prevents the need to buy a new cell phone if you want Bluetooth capability. Different parts/ideas of the conceptual design of BlueCell are derived using eight different principles (Principles 2,3,9,11,12,13,17, and 25). The applications of these principles are illustrated in Figure 7. The design of BlueCell consists of an interface that is located on the exterior surface (Principle 2). It is important to recognize that it would not have been possible to build such a product if there was no interface available on the exterior surface of parent product. Hence, Principle 2 is related to the design of both parent and piggyback product and thus is categorized as belonging to the G category, since there is no standard interface such as a USB being available on most cell phones. The BlueCell has a built-in adapter that communicates with cell phones through head phone jack in the cell phone (Principle 3).

Interface Related Design Principles

1. Making the interface as universal/standardized as possible. (G)
2. Positioning the interface on the exterior surface. (G)
3. Designing appropriate adapters (if no standard interface available) for suitable interface between parent and piggyback products. (G)
4. Ensuring the inputs/outputs of the interfaces are labeled properly. (G)
5. Simplifying the geometrical features of the interface. (G)

Power Related Design Principles

6. Implementing the functional module associated with the final output power within a simple attachment. (G)
7. Simplifying modules associated with manual input power so that automation interfaces may be easily integrated. (G)
8. Routing power to supplementary external mechanical/electrical interfaces (G)
9. Making power source easily accessible/changeable (G)
10. Utilizing the power source of parent product to operate piggyback products (Pi)
11. Providing independent power source for piggyback product (in case no power source on parent product can be used) (Pi)

Material/Structural Design Principles

12. Using compatible material between piggyback and parent product (G)
13. Making piggyback and parent product system out of as few different materials as possible (G)
14. Ensuring there is no magnetic/material interference (G)
15. Increasing the structural integrity of piggyback and parent product system by increasing the number of support points (G)
16. Using material in piggyback product that extends the life of parent product (Pi)

Modularity Principles

17. Implementing different functions of the product in separate modules (G)
18. Allowing large modules of the device to be easily disconnected for repair/maintenance (G)
19. Attaching modules of the product using compliant fasteners that promote easy disassembly/assembly by the user. (G)
20. Putting parts using same energy domains to perform a function into separate modules (G)
21. Locating modular interfaces in the exterior of the product (G)
22. Creating a common “bus” component with simplified geometry to which modules may be attached via a standard attachment interface. (Pa)

Usability Principles

23. Implementing functions that require direct user interaction in separate module on the external surface of the product. (G)
24. Using the usability principles of the parent product to operate piggyback product. (G)

Spatial Principles

25. Allowing small parts to be incorporated inside larger components (G)
26. Locating frequently evolving modules on the exterior of the product (G)

Figure 5. Principles for designing piggyback product

Interface Related Design Principles

1. Making the interface as universal/standardized as possible. (G)

Explanation: This principle is illustrated in Dynex external floppy disk drive, if the USB connector between the drive and the computer was not standard size, then the device would not be able to adapt to each brand of computer.

Power Related Design Principles

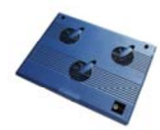
6. Implementing the functional module associated with the final output power within a simple attachment. (G)

Both the standard electric screwdriver and rotary tool execute the final output power of the device through an easily fastened attachment. This feature allows additional tools with entirely different functions to be used in conjunction with the original tool by utilizing the power source.

Material/Structural Design Principles

12. Using compatible material between piggyback and parent product (G)

The laptop cooler shown here is a great example of using materials which work well with parent product. Laptop cooler is built of material that would not melt even if the laptop gets too hot.



Modularity Principles

22. Creating a common “bus” component with simplified geometry to which modules may be attached via a standard attachment interface. (Pa)

Water bottle holder and headlight for standard bicycle. Each of these piggyback products is attached to a common “bus” component of the parent product (the bicycle frame). The simple, cylindrical shape of the bicycle frame allows each piggyback product use this as a standard interfacing method.

Spatial Principles

25. Allowing small parts to be incorporated inside larger components (G)

The mp3 cassette player by Mobiblu does a good job of having the power source fit neatly into the cassette package, while allowing it to easily pop out for easy charging.

Figure 6. Sample principles and their explanation

The lithium battery powers the BlueCell and is easily accessible/changeable (Principle 9). Since power cannot be withdrawn from cell phones to power BlueCell, the BlueCell uses an independent power source (lithium battery, Principle 11). The material used for building BlueCell is tested for material compatibility and is built of similar material as that of a cell phone to minimize the usage of different materials (Principles 12, and 13). The design of the BlueCell is highly modular in nature and primarily consists of five modules i.e., Battery, Signal Reciever, Adapter, Casing and Interface modules. Each of these modules implements different functions (Principle 17). The battery operating BlueCell can easily be placed inside the enclosure module (Casing) (Principle 25).Other features of BlueCell include compact design with dimensions of: 2.5" x 0.5" x 0.5". The design is based on the Bluetooth 1.1 specification, making it compatible with other Bluetooth enabled devices. The BlueCell has a high level of security for communication provided by the standard 128-bit encryption and a range of 36 feet.

3.2 MP3Video-Cassette Player

This device helps to connect technology from two different eras. It provides an interface between the new generation of video mp3 players and the older generation of VCRs and VHS tapes. This device would have the same dimensions as a standard VHS tape, namely 7 $^{3}/_{8}$” x 4 $^{1}/_{16}$” x 1” and would have an external, detachable plug of nominal length whose other end is an input to any standard mp3 headphone input. It prevents obsolescence of VHS and VCRs. It allows for the playing videos as well as music in MP3 format in various storage media through the use of VHS and VCRs. Different parts/ideas of the conceptual design of MP3Video-Cassette Player (MP3-VCP, Figure 7) are derived using 11 different principles (Principles 2,3,4,9,11,12,13,17,19,22 and 25).

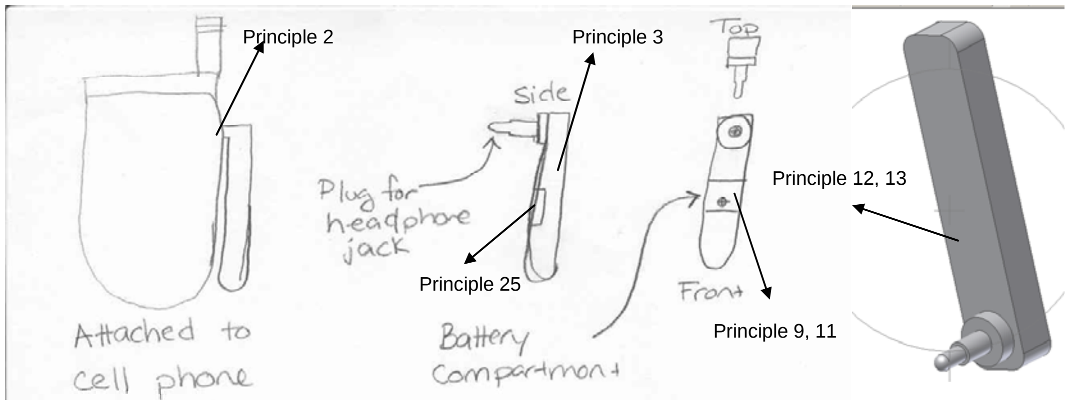


Figure 7. Conceptual design of BlueCell

The interface between the MP3-VCP and VCR that plays MP3 video and music is located on the exterior of the product (Principle 2). An built-in adapter which converts MP3 videos and music to VHS format is provided in MP3-VCP (Principle 3). The input/output of the interfaces are labeled (Principle 4). A built-in rechargeable battery powers the BlueCell and is easily accessible/changeable (Principle 9). Since power cannot be withdrawn from VHS to power MP3-VCP, the MP3-VCP uses independent power source (rechargeable battery, Principle 11). The material used for building MP3-VCP (especially the casing and interface modules) is very similar to VHS tapes (Principle 12). The design of MP3-VCP, Figure 8, is highly modular in nature and primarily consists of four modules i.e., Battery, Adapter, Casing and Interface modules. Each of these modules implements different functions (Principle 17). The MP3-VCP casing could be opened easily via a compliant mechanism (Principle 19). The MP3-VCP casing acts as a "bus" component on which other modules are attached (Principle 22). Once the MP3-VCP is inserted, the remote or control panel of the VCR can be used to play MP3 videos and music from the MP3-VCP (Principle 24). The detachable cord and other modules could be kept inside the large MP3-VCP casing (Principle 25). The cord could be neatly wrapped around the two casing spools. Other uses for the space involve adapting the VHS tape to be able to read a variety of memory cards.

4. CONCLUSIONS AND FUTURE WORK

The problem of product obsolescence is pervasive and growing at an alarming rate. The direct effect of product obsolescence is the tremendous amount of waste it generates. Technological obsolescence is one of the primary reasons for product obsolescence. An effective strategy in dealing with technological obsolescence is that of "piggybacking". Piggybacking is particularly effective in preventing product obsolescence of consumer electronics and household appliances. This paper presents a set of formal principles for guiding the design of piggyback products. Although initial progress has been made towards the goals of defining and applying principles for designing piggyback product to manage technological obsolescence, many areas still remain unaddressed. The study of

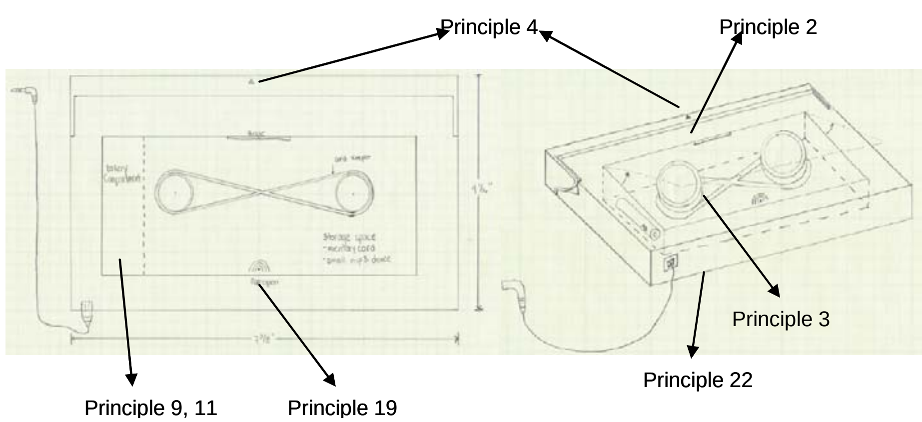


Figure 8. Conceptual design of MP3-VCP

products on the web should be continued. Although 26 principles have been discovered, there may be others yet to be uncovered. Continued investigation may reveal additional design principles. Other sources of data should also be examined. A thorough analysis of physical products and patent repositories would be interesting and useful. The approach followed is this paper is experiential and depends on the expertise and subjectivity of the designer. A systematic tool (graphical in nature) based on analytical approach to easily organize and apply the discovered principles in the design of new piggyback products will be beneficial.

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APPENDIX A: Product Dissection Data Sheet Tool

Product Name: Mobiblu DAH-220 MP3 Player
1. Related to piggyback product
Company behind piggyback product:
Mobiblu
Website for piggyback product:
http://www.mobiblu.com/eng/e_sub_d220.asp
Q: Does the product operate in conjunction with another existing product (is it a "piggyback product")?
A: Yes
Q: Is the piggyback product modular?
A: Yes
Q: Is the piggyback product helpful in adding functionality to the main product?
A: Yes
Q: What features of the piggyback product add functionality?
A: Flash memory, voice recorder, USB port attachment, external multi-media card slot, rechargeable battery, AC/DC port, upgradeable firmware
Q: Will these added functionalities increase the lifetime of the parent product?
A: Yes
Q: Are there other products that can implement these added functionalities independent of the parent product?
A: Yes
Q: What material is the piggyback product composed of?
A: Mostly Metal
2. Related to parent product
Company behind parent product:
Any company to make a cassette player
Website for parent product:
N/A
Q: What is the main function/purpose of the parent product?
A: To play cassette tapes
Q: What is the domain?
A: Audio, electrical/mechanical
Q: What is the price range of the parent product?
A: $10 - $40
Q: How long before the first version of the parent product was designed?
A: 42 years (first cassette player in 1964)[2]
Q: What is the approximate rate of technological change in the market segment associated with the parent product?
A: 2 – 5 years/change
Q: What are the competing products?
A: CD players, MP3 players, satellite radio
Q: Are there competitive products in the parent product's market that contribute to the obsolescence of the parent product?
A: Yes
Q: If so, what features and functionality in the competing products contribute to the obsolescence of the parent product?
A: Allows more songs per insert (i.e. CD, memory stick), choose which song easier, better design, better sound quality, inserts are more compact
Q: What are the differences in the technology and functions of the parent product and its competing products?
A: They take different kinds of inserts and plays the music off the inserts differently
Q: What is the average life span of the parent product?
A: 10 years
Q: What material is the parent product composed of?
A: Metal and plastic
Q: What are the limitations of the parent product that may contribute to its obsolescence?
A: It cannot play updated inserts such as CDs
3. Related to interaction between parent and piggyback product.
Q: Does the piggyback product permanently replace a functional chunk implemented by the parent product (i.e. component upgrade)?

A: No
Q: Does the piggyback product add new functionalities that operate in conjunction with the original functional chunks implemented by the parent product?
A: Yes
Q: Does use of the piggyback product temporarily alter the primary function of the parent product?
A: No
Q: Is the technology involved in the parent product similar?
A: Yes
Q: If not what is the main difference in the technology?
A: N/A
Q: What functionalities does the piggyback product add to the existing parent product?
A: Can play more songs and switch between songs easier
4. Related to Obsolescence
Q: Is the piggyback product helpful in prevention of obsolescence of the main product?
A: Yes
Q: What features of the piggyback product prevent obsolescence?
A: Can play more songs and switch between songs easier which is what you would get with a CD player
Q: What is the target market of the parent product?
A: Ages 8 – 30, anyone that enjoys music
Q: What are evolution characteristics of subcomponents of the product?
A: Storage capabilities is a fast evolving subcomponent, all other subcomponents are slow
Q: What characteristics of parent product make it evolve at that speed?
A: No part of the parent product affects the evolution speed of the storage capacity. The interface evolves slowly due to the parent interface.
Q: Is it a sustainment dominated system?
A: No
Q: Among 3E's (Economics, Environment, and Ethics), which is the most important cause of obsolescence?
A: Economics
Q: What additional products can perform similar functions?
A: CD player, MP3 player, Satellite radio
Q: What is the level of automation, ease of use, and level of human product interaction?
A: Level of automation is high, ease of use is moderate and human product interaction is moderate
Q: What is the limitation of use of parent product?
A: Only used when want to listen to audio
5. Related to Interface
Q: What is the domain of the interface/ Does the product incorporate some type of mechanical or electrical interface in order to function with the parent product?
A: Mechanical interface, vibrations transfer the sound from piggyback product to parent product
Q: Describe the interface.
A: There are two interfaces, one for the cassette player which creates vibrations for the player
Q: Is the interface defined previously by the parent product's design, or is the interface specifically designed by the piggyback product to work in conjunction with the parent product?
A: Defined previously
Q: How standardized is the interface?
A: Cassette players have a very standardized interface
Q: What are the number of products that can be attached at once on the parent product?
A: One
6. Related to Architecture of the Parent Product
Q: What type of product architecture does the parent product exhibit?
A: Modular
Q: Does the architecture of the parent product influence the method of interfacing between the parent and piggyback product?
A: Yes