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SCENARIO GRAPH: DISCOVERING NEW BUSINESS OPPORTUNITIES AND FAILURE MODES

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ABSTRACT

Companies struggle to identify new business opportunities based on their core competence be it products or services. When a company focuses on improving current offerings or is too involved in them, it has difficulty discovering new applications for them. Scenario Graph is an original design method for products or services that aids design teams to envision four types of information while in the market definition phase: potential user locations, activities associated with the location, user circumstances, and the corresponding user state. By using Scenario Graph, design teams are better able to capture new values, scenarios, and behaviors of potential customers. This knowledge captured in the fuzzy front end stage can then be translated into inputs to other Design for X (dfX) tools to improve the definition of the product or service. Another benefit of the tool is that it directs the design team to discover unidentified failure modes of the current offerings by identifying unintended user scenarios. In this paper, a detailed guide, along with case studies demonstrates the usefulness of the tool when applied in the early phase of product or service development. Scenario Graph will assist design teams and managers in discovering new product or service opportunities.

Keywords: *User Scenario, New Business, Innovation, Technology-push, Failure Mode, Brainstorming, Fuzzy Front End*

1. INTRODUCTION

1.1 Motivation

Scenario Graph follows human thinking in that our thoughts are influenced by our surroundings and different surroundings suggest different needs. Consequently different inventions come about in different settings. This point is vividly reflected in the birth and success of snowmobile and personal water craft that were both based on a similar vehicle technology.

For a company, during the fuzzy front end phase (Koen, et al. 2001) of a new product or service development, the initial step is to discover or generate the needs of a market. However, breeding new and diverse ideas for new markets can be challenging since it often requires a nonlinear thinking approach. Because many design teams are accustomed to linear product development processes, they tend to converge on the product definition too early and, as a result, come up with new user applications that are similar to the current offerings. Therefore, well-structured tools are necessary to help this brainstorming process break through thinking boundaries and generate high quality ideas. Scenario Graph forces the design team to expand the usage of the core competencies or technologies of a company to help the company find new numerous directions for its products or services and visually graph them.

To attain high quality ideas, an abundance of ideas is important at every stage, starting from idea conception to product or service development (Osborn 1963). Then a system

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which directs the appropriate concepts to the next phase of the cycle needs to be in place. Both the funnel model in Figure 1.1 (Wheelright and Clark, 1992) and the cloud model in Figure 1.2 (IDEO, 2007) agree on the importance of generating numerous ideas along the development process.

The funnel model depicts the new product development process (NPD) as a sequence of a fuzzy front end phase and a stage-gate process. Many ideas emerge during the fuzzy front end phase and then are filtered at the stage-gates during the product development process.
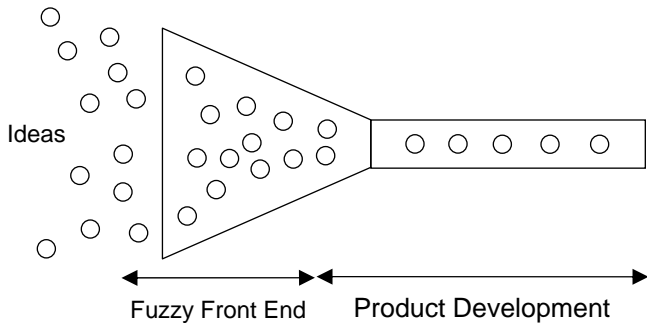
Figure1.1: Funnel Model of Fuzzy Front End and Product Development (Adapted from Wheelright and Clark, 1992)

However, similar to Pugh's (1991) concept convergence and divergence model, IDEO, a design consulting firm finds this model inadequate to capture the flexibility required in an innovative design approach. IDEO's cloud model in figure 1.2, describes the product development process as a continuous fluctuation of ideas. Expanding ideas and converging them at numerous points allows the design team to continuously consider multiple options throughout the product or service development. A design team's actively open attitude toward better ideas often results in a higher-quality concept in the end because it invites considering a wider range of ideas.
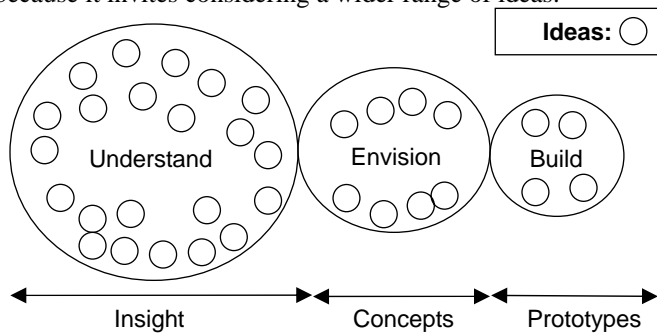
Figure 1.2: Cloud Model of a Design Approach (Adapted from Peter Coughlan, IDEO, 2007)

In any case, both the funnel model and the cloud model emphasize the importance of generating a higher number and exploring a wider range of ideas.

Linus Pauling put the process well: *"You just have lots of ideas and throw away the bad ones. You aren't going to have good ideas, unless you have lots of ideas and some principle of selection."*

Scenario Graph will assist the design team in achieving this goal. Scenario Graph is a stepping stone and a guide tool for triggering new business ideas, starting from the core competence of a company. Generated outputs from this method can be used as inputs in other dfX tools to complete the final concept design.

1.2 Previous Work

The concept of mind mapping has existed for several centuries. A mind map is a diagram of ideas branched off from a central idea and they are expressed by words or images. By placing sub-ideas and arranging them in a radial manner, the graphical and non-linear approach helps design teams to generate and keep track of ideas during brainstorming. Buzan (1991) suggests general guidelines in how to format a Mind map. Mind map shares a common characteristic with Scenario Graph in that it is a diagram technique that could help design teams express their ideas visually and communicate them more effectively,.

Concept mapping is another brainstorming technique worth noting. As part of the learning movement, constructivism, Novak (1996) had developed Concept Map to enhance learning experience by systematically framing thoughts. A Concept Map is a diagram that organizes concepts and visualizes the relationships between them. This technique is more focused in nature because the diagram develops within a predefined contextual question.

"Design for X" or dfX is a systematic sequence of design methodologies which assists design teams in defining, developing, and producing competitive products. Design for X begins with a tool called Customer Value Chain Analysis (CVCA), which enables design teams to exhaustively identify relevant stakeholders and the flow of information, money, and offerings among the stakeholders (Donaldson, 2006). In other words, CVCA visualizes the relationship between the customers and lets the design team identify the important stakeholders. However because dfX starts with a target customer, it is challenging when the team does not have a general sense of who the end users are or what the product is.

Many structured methodologies exist for the product development stage. Design for X (Hermann et al, 2004), Axiomatic Design (Suh, 1990), TRIZ (Altshuller, 1990) are some of the well-known frameworks. However they all start from a customer or a problem. This means that the customer requirements or problem needs to be specified before beginning the process. What if that information is not available because the market does not exist yet? This is where Scenario Graph can contribute to the product or service design and development frameworks. Scenario Graph augments the product development process in that it can generate a user scenario that can trigger the rest of the streamlined course.

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A systematic yet convenient guideline is necessary for the fuzzy front end stage of a product development. Much of the current research focuses on streamlining the product development phase after the market definition. However there is little research in structured methodologies for creating new ideas in this innovation process.

One move in this direction is Beiter et al.'s research (2006). They have suggested a ten-step framework for preliminary design of amorphous products based on Design for Manufacturability (me317, Stanford) methodology. Amorphous dfM suggests that once the main stakeholders and users are identified through Customer Value Chain Analysis (CVCA), use-case scenarios should be developed as a general guideline. Scenario Graph is a structured tool that can be used for creating use-cases in the amorphous dfM framework but is more effective when used before main customers are identified. In fact, it helps to discover and develop potential customers by generating possible scenarios.
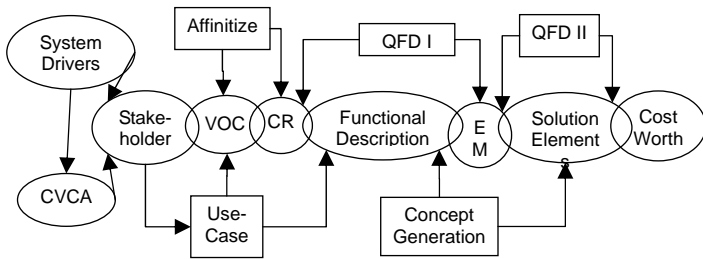

Figure 1.3: Information Flow in Preliminary Product Development: (Beiter et al 2006)

In another approach, Ashihara (2005) presents a decision-making strategy for developing a new business R&D strategy, based on an adaptation of quality function development (QFD). Inverse QFD is a tool that matches the technology to the customer requirements through QFD and can be used in a technology-push or market-pull strategies. However this approach still requires the design team to have a general idea who the customers will be before beginning, in order to understand the customer's requirements. After identifying the correct market or customer segment through Scenario Graph, this inverse QFD could be effective in strategizing the new product or service development.
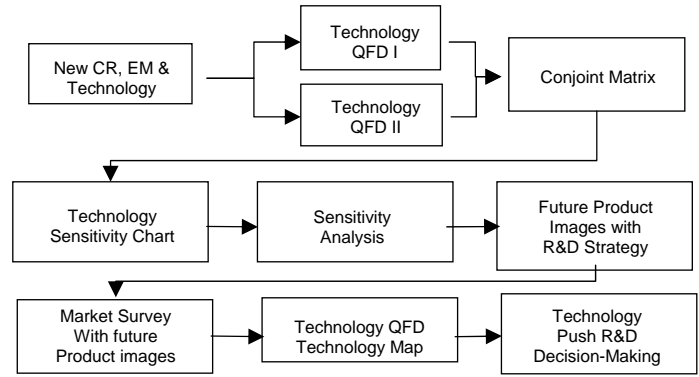
Figure 1.4: Technology-push R&D (Ashihara, 2006)

In the field of value engineering, a tool called Value Graph (Ishii 2001), or How-Why Diagrams (Cross 1994), is commonly used to ask the why (customer values), what (features), and how (functions) for a product. Value Graph is part of dfM framework and is employed after CVCA. Scenario Graph is intended to augment Value Graph by addressing the **WHERE** and **WHEN.** Together with Customer Value Chain Analysis which identifies **who** and Value Graph which specifies **why, what,** and **how,** Scenario Graph makes for a thorough description of a business offering. Answering the 5 W's and 1 H provides all the information needed to make strategic decisions about the developments of new products or services.
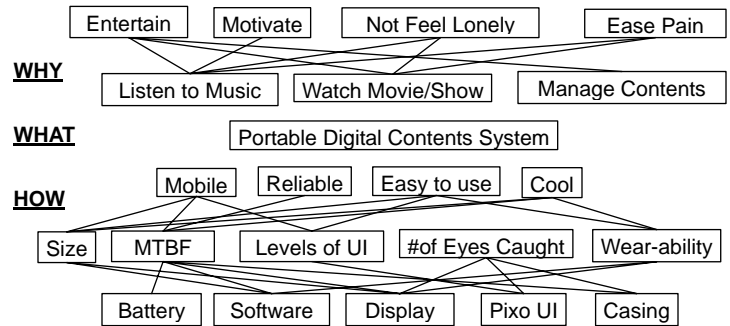
Figure 1.5: Value Graph, Example (adapted from ME317 Course Reader, Stanford University)

Strengers (2001) emphasizes the importance of selecting a few and effective scenarios to capture system behavior. Strengers refers to this skill as an art and advises to express the scenarios as simply as possible so they can readily be expressed in text of simple diagrams.

Using a mapping technique to expand ideas is not novel. However, to the authors' knowledge, there is as yet no publication concerning the development of different scenarios visually, and systematically linking developing different scenarios, and delineating activities with location and user states with circumstances.

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2. OVERVIEW

2.1 Main Benefits

The two main functions of Scenario Graph are:
1. Creating or discovering new markets with current competencies or technologies
2. Identifying unexpected Scenario Failures

The value of conducting Scenario Graph is that it will guide the design team to think about new possibilities embedded in the core competence. It is based on the idea that taking an entity or a concept and then placing it in different contexts creates new meanings for it.

Another important benefit of this methodology is that when it is employed on an existing product or service, it will enable the design team to explicitly think about unintended user scenarios that may lead to failures. Thus Scenario Graph can assist design teams to discover uses of products and services that may have not been uncovered during a routine failure modes and effects analysis (FMEA) stage.

Since scenario graph is a tool intended to stretch the boundaries of thinking and explore new territories, its ideal users are groups composed of people with different backgrounds such as marketing, engineering, manufacturing, supply chain management, etc. As the name of the method suggests, the environment of the brainstorming session will also influence the outcome of ideas.

2.2 Steps

The most important task is to identify new or unexpected scenarios and address any problems at the appropriate level. Often design teams are constrained by preconceptions of existing products or services. By asking where else the core competence can be applied, or in what other locations potential customers could use a product, service or technology, the design team can identify the activities associated with those locations. The design teams can then think about the functions associated with the activities. This brainstorming activity leads or forces the design team to generate alternative applications for the current product or services.

Below is a step-by-step guideline to conduct Scenario Graph.

Five Steps for Scenario Graph:
1. Extract the Core Competence
2. Ask Where else the Core Competence could be used
3. List Activities involved with the location and link them
4. Ask When (under what circumstances) the Core Competence would be used
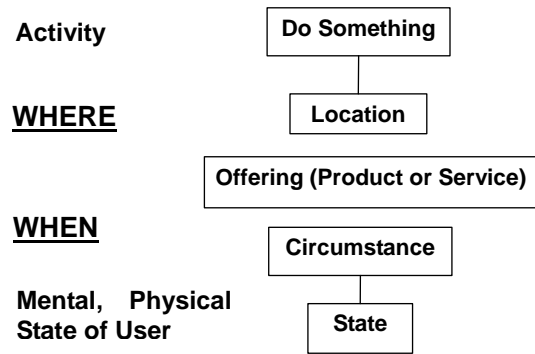5. List users' physical or mental state under the circumstances and link them

Figure 2.1: Overview of Scenario Graph

Further steps include:
7. Select a Scenario
8. Use output of Scenario Graph into downstream dfX

The following example demonstrates how Scenario Graph can be exercised in a brainstorming session for a new product or service.

3. CASE STUDY: PORTABLE DIGITAL CONTENTS SYSTEM

This case study describes Scenario Graph in more detail. For explanatory purpose, we will use a product commonly known as an MP3 player or a digital audio player. A design team has the task of launching a new application based on a conventional portable digital music player. However their thoughts are limited to the thoughts of adding and improving features of the current product and service.

3.1 Discovering New User Scenarios

Step 1: Extract the core competence or technology of the offering

Figure 3.1: Labeling the Core Competence

The design team extracts the core elements from the product. The team has labeled it as a portable digital contents system. This seed concept begins at the center and will be the root point for new ideas to sprout from.

The first step is identifying the core technology, whether it is products or services. In this example, the company's current products are the digital audio players, e.g., MP3 CD Players, or flash-memory-based players or hard-drive-based players. The enabling technologies for these products are likely to be memory storage and data encoding/ decoding. Some companies may or may not provide contents services, i.e., music, movies,

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streaming, podcasting, etc. or contents managing software. In any case, the core idea can be defined as "portable digital contents system."

The main idea is to deliberately treat the system encasing the core technology or competency as a black box, and the interactions with the system are perceived as originating from outside the system. This requires intentional effort, because new ideas can be stifled by giving the core competence a label that restricts thinking about it, such as "portable mp3 player."

Table 1: Comparison of Labeling Core Competence

Label of Core Competence	Portable Digital Contents System	Portable MP3 Player
Product Derivations	Digital Audio Player	Digital Audio Player
	Movie Player	
	TV Show Player	
	Portable Music Recorder	
	Scheduler	
	Fitness Program Manager	
	Portable Karaoke Machine	

For instance, if the design team uses the label, "Portable MP3 Player," the only product derivation may be a digital audio player. In contrast, if the labeling was less narrow, such as naming it as "Portable Digital Contents System," the range of product derivations widens. The new label could mean Digital audio player, movie player, TV show player, portable music recorder, scheduler, fitness program manager, portable karaoke machine, etc.

Maintaining ambiguity is key at this stage so that new ideas do not get filtered due to a preconception of what the current specific application suggests. Starting out with the word, "a portable digital music player" may be permissible, but it is better to go to a yet higher level term such as "a portable digital contents system." Note that "a portable digital music player" gives the impression of a one-way music contents player. However when the term is changed to "a portable digital contents system," the meaning expands from a one-way music player to a two-way feedback system or an interactive system.

Step 2: Ask WHERE people could use the system or are currently using the system

Home	Office	Car	Gym	Subway	Bike	Nature

WHERE   Portable Digital Contents System
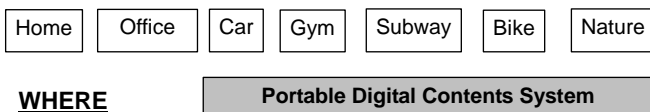
**Figure 3.2: Identifying New Locations**

After extracting the core competencies, the next step is to think about **WHERE else** this function or technology can be used. Portable digital contents system can be used at a home, car, gym, subway, in nature, office, on a bike (although that may be dangerous), or even underwater. One can also start out by imagining a person or persons carrying and using the portable digital contents system in different settings.

The design team could also search for new locations in a more hierarchal approach and categorize them by common criteria such as industry or markets. For this case study, design team took more of a non-linear approach and decided not to classify locations.

Another way to discover new possibilities is to observe people during the aforementioned activities. One approach is applying some ethnography tools. Ethnography involves observing behavior first-hand or as a third party. It also includes interviewing and studying in depth culture or perceptions of the potential customers. Analysis of the observations may uncover the rationale or the reason behind the observed activities and uncover where needs can be met. Immersing oneself in the location and "becoming" the person in the scenario can help understand what activities are taking place.

During step two of Scenario Graph, we cannot help but become aware of how the activities are connected with the locations. This brings the design team into step three.

Step 3: List Activities Involved with the Locations and Link them
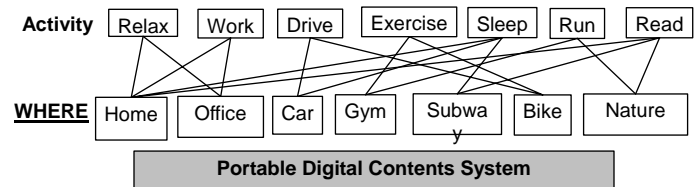
Figure 3.3: Associating Activities with Locations

Different activities occur in different settings. At the office, relaxing can be associated with home or office. Work is the main activity at the office. In a car, driving or relaxing may both be activities. Exercising usually takes place at the gym. On the subway, some people sleep, read or just sit and stand while watching others. Running, hiking are some of the activities that take place in nature.

The next step is to look for the **needs** embedded in these activities. The activities tell the design team what kind of needs the user may have during this process. For example, if the team imagines a setting of outdoor in the nature (**WHERE**), then they can think of jogging, hiking or camping (**activity**). When observing a jogging activity, design team may discover that the jogger may need extra motivation to maximize his or her exercise program. If a portable digital contents system could play music with a faster beat than the runner's current speed, it

may motivate the jogger to speed up. If the physical results (e.g., miles run, calories burned, etc.) from the jogging are displayed, then the jogger may set up a goal to improve further. Furthermore, a running management program could track the running habits and suggest a target. Running together or forming a social community of runners through a website can support and encourage the exercise activity. Competing against each other or the jogger's past records may stimulate his or her urge to run more. For most joggers, the right music could reduce the pain by occupying one's mind with music and not focusing on the pain of running.

In the case of hiking, which is another outdoor activity, hikers may need to call for emergency rescue if an accident happens along the trail. The design team can embed a repeater function in the portable digital contents system, and coordinate with emergency response agencies to provide emergency services. If the need was to add variety to the hiking trails, a GPS system with a trail shuffling software can excite avid hikers.

Table 2: Solution Elements and Needs identified through Scenario Graph: Outdoor Example

| Locations	Activities	Needs	Solutions
Outdoor	Jogging	Boost Motivation	Display Distance
			Display Calories
			Form Community
			Form Competition
			Play Music
		Reduce Pain	Play Music
	Hiking	Vary Trails	Shuffle Trail Maps
		Navigate	GPS
		Emergency Rescue	Repeaters

Another example is enjoying digital contents in a car, while driving or just sitting in the passenger seat. It could be music, an audio book or a backing track for practicing singing.

Underwater, the portable digital audio contents system along with peripherals such as earphones needs to be waterproof. A manufacturer could offer waterproof or shock-proof skins for the devices as aftermarket accessories for outdoor activities.

At the office or home, when a user of this product or service is under stress and wants to take a rest or nap listening to music without worrying about oversleeping or setting an alarm clock, the user could hit a "rest" button, which makes an alarm go off after a specified time.

Document the ideas that come up during the brainstorming session. Match the activities with the locations and use them as inputs for further developing use-cases.

## Step 4: Ask WHEN (under what circumstances) the system is used or could be used
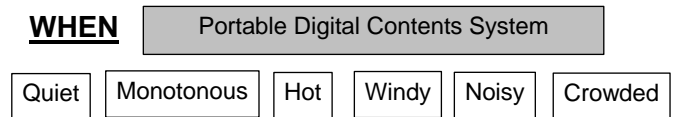
Figure 3.4: Identifying User Circumstances

WHEN refers to the physical environment surrounding the user, product or service. Note that this is not simply time, since within a same time span, different events can happen. For example, at night, let's say, 21:00 to 23:00, the environment can be dark, bright, cold, or hot. This tells us that a specified time span does not give specific information about the environment. Rather, adjectives such as quiet, monotonous, hot, windy, noisy, or crowded describe circumstances that may be possible while a person is using the portable digital contents system. Therefore the end condition, rather than the time span, is the more relevant element to consider as part of Scenario Graph.

The rationale behind examining circumstances is to discover the customers' needs, since different reactions are influenced by different circumstances.

## Step 5: List the mental or physical state of the user under the circumstances
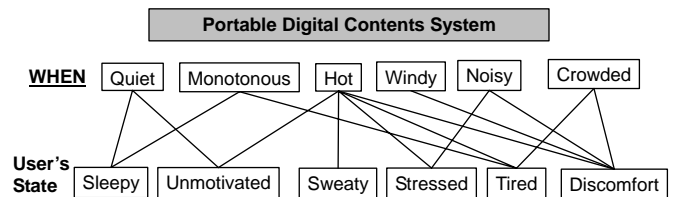
Figure 3.5: Listing Mental and Physical State of Users

When the environment is quiet and monotonous, the user may feel sleepy or unmotivated. If the weather is windy or gusty, the user may feel frustrated. If the user is running or exercising and as a result, gets hot and sweaty, handling the portable digital contents system may be difficult or may give rise to a disagreeable sensation. Trying to control a device while running could be challenging. In crowded places, such as inside a subway during commuting hours in Asian countries, there may be little room to wiggle and fumble around with the device. At the office, the user could either feel stressed from work pressure or distracted from the surrounding noise such as nearby conversations or construction work.

None of these potential scenarios are approximated in the labs or of the design centers where the products and services are designed and developed. If they were identified before the detailed design stage, the information related to them could be taken into consideration in the design phase. The benefit would

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be that failure modes from the unexpected scenarios could be prevented or mitigated by implementing design changes or documenting the specified usage in the warranty documents.

The complete Scenario Graph would look like the following diagram: (The design team can complete it together or individual members can do the exercise and then consolidate the results.)
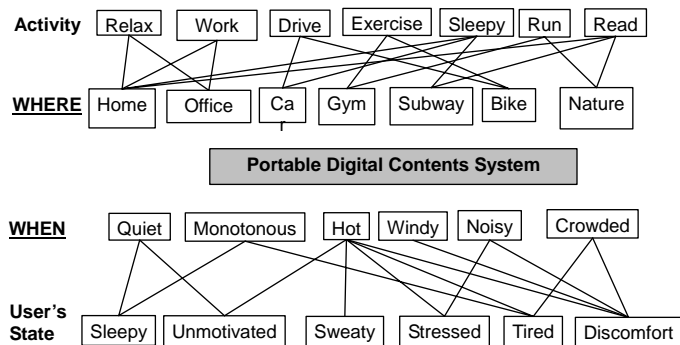
Figure 3.6: Completed Scenario Graph

Next Steps: Now that the design team has created numerous novel ideas, they should select the appropriate scenario. There are many concept selection methods. Pugh Selection[1] is one option for a simple selection of scenarios. Using business criteria such as dependence on core competence, market size, degree of need, available resource or management, the design team or the management can choose the most successful scenarios.

From here, the design team can use the Scenario Graph results downstream in the product or service design process through methodologies such as dfX. For example, the design team can start constructing customer value chain analysis and collecting voice of customers (VOC) for Value Graph after they have selected a scenario or multiple scenarios from Scenario Graph.

3.2 Discovering New Failure Modes

In the case of the portable digital contents system, Scenario Graph discovered many user scenarios that would not have been mentioned otherwise during a design stage. These scenarios may be cases **WHERE** and **WHEN** many failures occur but that were not covered in the failure modes and effects analysis before the company moved to design or product launch. Design teams may not have given enough consideration to these scenarios due to the common understanding that these products or services are not intended to be used in these conditions. However in actuality, many failures do happen in unexpected user scenarios. The company can prevent these failure modes by improving the design or even prepare for

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[1] Pugh Selection: A method for selecting concepts using a scoring matrix. It is a matrix in the form of evaluation criteria versus alternative options. The options can be decomposed, scored and finally ranked by the sum of the scores.

unforeseen claims from unhappy customers by including specific operating conditions in the warranty conditions statement.

For instance, after the third step of Scenario Graph, which is listing the activities associated with locations, the design team may encounter a scenario inside a car where the user is driving and the portable digital contents system is adjacent to a cellular phone. From experiencing signal interference between cellular phones and audio systems in the past, the design team can infer that when a call is made, the electromagnetic microwaves from the transceiver will distort the audio signal from the portable digital contents system. As a result, noise will be introduced through the speakers unless proper shielding is implemented in the design. This turned out to be the case with some of the digital audio players on the market and had caused negative voice of customers (VOC).

Another common defect that can be identified through Scenario Graph is battery failure under extreme weather conditions or temperatures. This may be recognized from step three, listing activities involved with the locations, or step four, asking under what circumstances the system is being used. Normally performance of batteries used in portable digital contents system can significantly deteriorate if they are operated outside the suggested temperature range. A portable digital contents system that can be carried anywhere from inside a car on a hot summer day to the top of a mountain in the winter could suffer from faster battery discharge if it is exposed to either high or low temperatures outside the operating range.

Design teams can document these new failure modes from unintended scenarios in the FMEA for proper actions, to address them before product launch.

Table 3: Failure Mode Effects and Analysis: Failure Modes Found Through Scenario Graph

Function or Requirement	Potential Failure Modes	Potential Causes of Failure	Occurrence	Local Effects	End Effects on Product, User, Other Systems	Severity	Detection Method/ Current Controls	Detection	RPN	Actions Recommended to Reduce RPN
Play Digital Contents in car	Interference from Cellular Phone Signal	Insufficient Shielding	5	Noise in audio signal	Unpleasant user experience	3	EMI Testing	2	30	Redesign EMI Shieflding, Specify Operating Conditions
Provide Electricity to System	Battery Failure	Outside Operating Temperatures	2	Battery Discharge	Unable to use system, Explosion	9	Battery Testing	5	90	Redesign Battery, Specify Operating Conditions

4. FUTURE WORK

The authors will do validation studies on the effectiveness of Scenario Graph by applying it on projects that are searching for new business opportunities. Additionally by implementing Scenario Graph during failure modes and effects analysis (FMEA) stage of a product or service development, we hope to

be able to validate the usefulness of Scenario Graph in discovering new failure modes. Numerous industrial case studies, along with projects from the Stanford University graduate level design course, ME317: Design for Manufacturability, should enable us to confirm its efficacy and further refine the tool.

Some of the immediate validation approaches include; comparing metrics such as 1) number of scenarios discovered before and after using Scenario Graph or 2) number of failure modes discovered by the project teams before and after using Scenario Graph. We will also gather more information by interviewing, conducting surveys such as Edith Wilson's Product Definition Checklist[2] from design teams that are using the tool in their projects and evaluating how much better they understand the project.

5. CONCLUSION

Scenario Graph is an original design method for products or services, which aids design teams in the market definition phase to envision four types of information: potential user locations, activities associated with the location, user circumstances and the corresponding user state. This tool will enable design teams to create new business opportunities based on the company's core competence. Another benefit of the tool is its promise of discovering new failure modes from unexpected user scenarios, which will assist the design team to discover unidentified failure modes of the current offerings by uncovering unintended user scenarios.

This paper introduces a step-by-step guide to Scenario Graph and demonstrates it by using a case study of a portable digital audio player. By using Scenario Graph, the design team could expand thinking boundaries and conceptualize many alternative business opportunities based on their core technologies.

Scenario Graph is a first step in guiding design teams to systematically search for new business opportunities. It is also a part of the framework, "Design for Service Innovation," which is a set of methodologies that are geared toward designing and developing service businesses building on products. The authors' aim is to further develop Scenario Graph in conjunction with other tools, to present a comprehensive collection of methodologies in designing services or products. While this paper introduces a snap-shot of a case study in the consumer electronics industry, in actual practice, we have applied portions of this methodology to other projects such as the healthcare and the infrastructure industry.

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