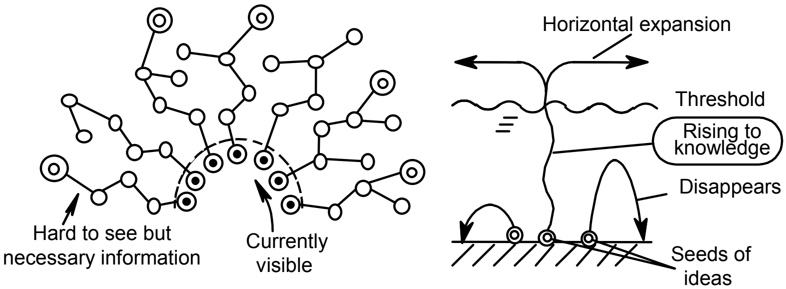
2

Describing and Transferring the Decision Process

Chapter 1 showed what a decision is. This chapter discusses the significance, for general engineering, of describing the decision process to others and what we need to do to successfully have others understand the decision process we have pursued.

2.1 The Need to Know the Decision Process

Why is it necessary to describe the decision process of inventing a technology when the technology already exists? Figure 2.1 shows the reason. Just looking at an established technology does not allow us to reach a real understanding of it, to use it and to develop it further. To enable such further steps, we need to see the process of giving birth to the technology, especially the process of making decisions. We need to know the mind process of inventing the technology (Figure 2.1(a)), and this means the inventor has to record the mind process in a form that can be communicated to other people. The description of such records has to exceed the threshold necessary for technology transfer (Figure 2.1(b)). Once the description surpasses the threshold, the technology can transfer over time, space, organization, culture, and technology field; however, if the record level remains below the threshold, the technology just disappears.



(a) Acquiring technology (b) Horizontal extension of technology

Figure 2.1 Why we make records of decision processes

Figure 2.2 shows what happens when we use records of decision processes. These situations include the following:

- When the use is undetermined at the time of making the records but the individual or the organization requires them.
- Supporting the processes of thinking, making decisions, and performing virtual exercises by technology creators.
- Supporting mutual understanding among technology creators in the group.
- Transferring and understanding technology created at or in different times, spaces, organizations, or cultures.
- Education for people to create future technology.
- Constructing systems that support the thinking processes of technology creators.
- Grasping the overall picture of design processes. The picture includes the sequence of determining matters including what the goal (functional requirement) and conditions (constraints) are, so that the designer can apply them to his own activities (design).

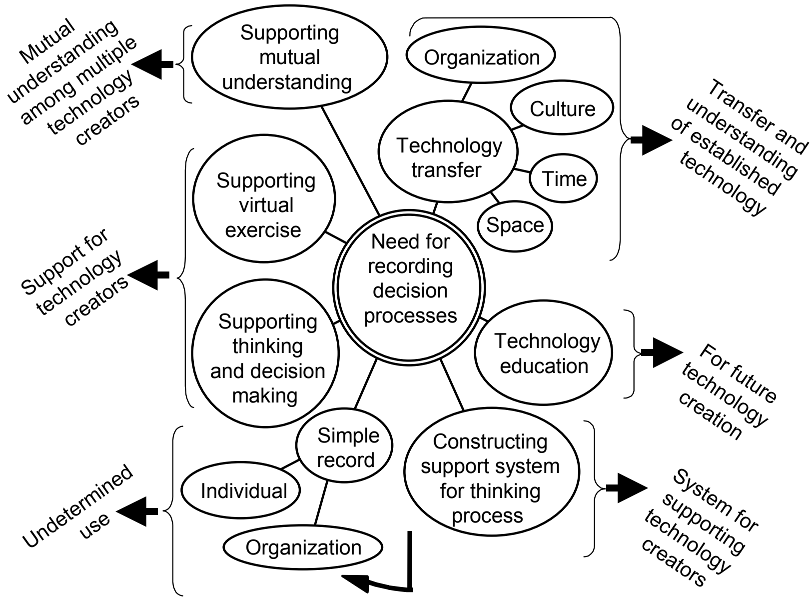


Figure 2.2 Using decision process records

Transferring the decision process is part of the wider task of "technology transfer." Figure 2.3 shows the stages that require technology transfer. They reduce to the following three situations:

(a) Across time, generations, and people:

- Different people separated by a time gap: This is what we call passing technology across generations. Many of old technologies are still needed today and unless this type of technology transfer is properly made, the whole society that relies on technology disintegrates.

- The same person at different times: We know the difficulty of remembering everything we have thought about in the past. We should occasionally review our own thoughts and actions from the past.

> Our own memos, sketches, or sentences recorded months or years ago often surprise us. I am often amazed by "That's what I was thinking!" or "What a surprise that I had accurately foreseen the situation now!" My record-keeping of actual decision processes gives me such experiences. We should always date and place titles on our records and construct our own "idea notes." I have had regrettable experiences from not marking these two even though I had the sketch and sentences. Remember to bear in mind the importance of date and title. We can also say that a memo without the date and title is the same as not having one.

- Across generations: People across different generations, even when they exist at the same time, have different experience and ways of thinking. Even though they are at the same place at the same time, they need to consciously transfer the technology to be successful.

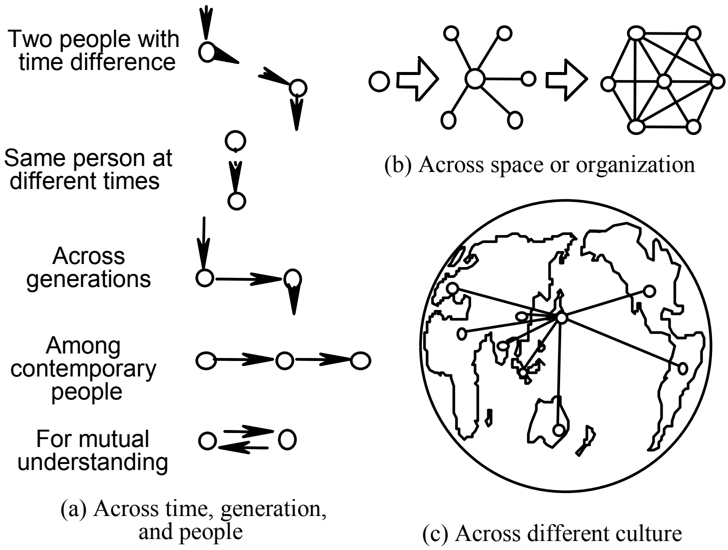


Figure 2.3 Where technology transfer is needed

- Among people at the same time: As information travels, the original contents decay over distance and they often get exaggerated and twisted. To avoid such mistakes, we need to give a solid structure to the contents.

- Mutual understanding: Concepts only transfer in a form acceptable by the receiver. We need to arrange the structure so that the receiver can share the contents.

(b) Across space or organization: Technology first starts spreading where it was born. Then its derivatives start to relate to each other in a network. When the organization that holds the technology spreads in space, the technology that originated there also spreads in a radial direction and then forms a network. The technology itself needs a solid structure as it is subject to transitions through related technology and organization.

(c) Across different cultures: Different cultures think and accept technology differently, and sometimes even evaluate it differently. We have to structure the technology from the beginning so that its records can survive such differences.

So far, we have looked at situations where we need technology transfer. For technology to transfer in the real sense, the mind process of the person who made the technology needs to transfer to the receiver. The receiver wants to understand the mind process of what, why, and how decisions were reached, and then what followed, what lessons were learned through the decision and how to make use of the decisions. The real technology transfer is made only when this information is successfully passed on to the receiver.

Many Japanese corporations are shifting their production facilities to China. Transferring production by just sending the machines to new locations does not work, and neither do the blueprints. What can make the transition easier? This book has the answer. It is to transfer the mind process of making decisions. The effectiveness and speed of absorption are high when the information originator provides what people are looking for. Japan is at a crossroads between following this book and transferring the mind processes to foreign countries or to hiding them away in black boxes. After all, the only way for Japan to survive is to place its own technology development in a black box and prevent it from leaking out to others.

We, however, shall bear in mind that the development of technology has to obey the legal system and artificially twisting the law only has temporary effects. Even if we hide the mind's process of decision-making, others will sooner or later develop their own. The advantage of hiding the processes will last only for a short time. See Korea's Pohang steel factory. They built it on their own while Japan hardly provided any help, and it is now the world's largest steel manufacturing facility.

2.2 Method of Recording and Transferring the Decision Process

How can we make event records that easily transfer the decision processes to others? "The Practice of Machine Design Research Group," which is the group that is authoring this book, have long been discussing this topic. One outcome of our discussion is the book *The Practice of Machine Design, book 3 – Learning from Failure*. In this book, we broke down a failure event description into 6 topics of event, process, cause, action, summary, and knowledge. This format allowed uniform handling of failure cases and we were then able to widely transfer the knowledge. We learned through this experience that for describing complex matters like how the human brain operates, we need a structure for organizing the information so that it flows in the natural way of the human mind process.

We then advanced our discussion into the topic of how to describe the decision process. It was then that we found that the topics in Figure 2.4 are needed for recording what, why, and how decisions were reached, what followed, what was learned through a decision and what to do to make use of it.

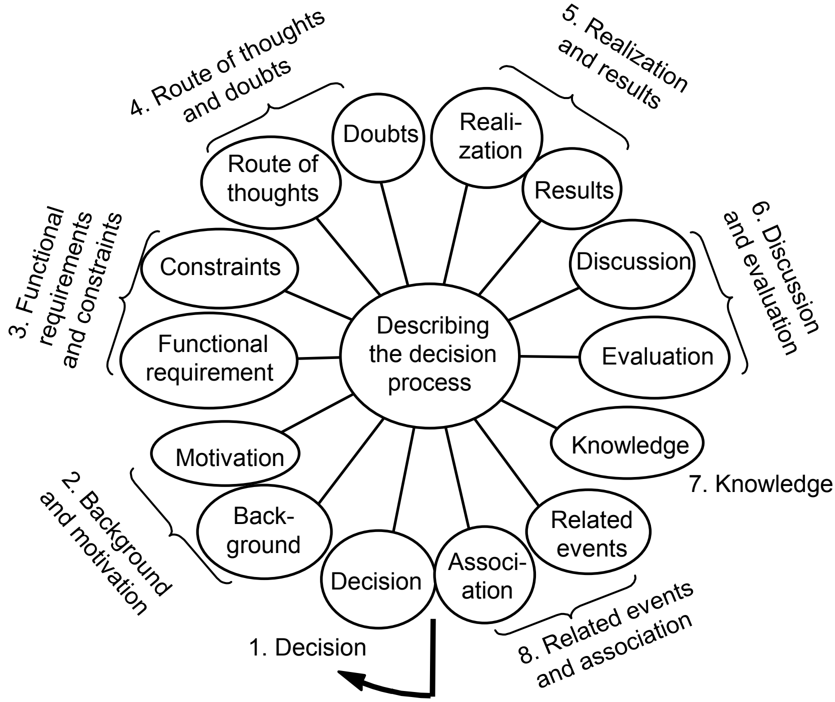


Figure 2.4 Topics necessary for transferring the decision process

The eight topics in the figure are:

(1) Decision: Record what decision was made.

(2) Background and motivation: Circumstances and supplemental information at the time of making the decision. Also record what made the decision necessary.
(3) Functional requirements and constraints: What functional requirements and specification the decision had. Which constraints were clear at the time of making the decision, and which were hidden then but were revealed later.
(4) Route of thoughts and doubts: Show the route the mind took from the problem statement (starting point) to the results (end point), what options were available for each selection, and what doubts entered the mind.
(5) Realization and results: Record the time history of events upon executing the decisions and what results followed.
(6) Discussion and evaluation: Looking back at the decision, its realization, and results, what should and should not have been done. How to make the decision useful and how some of the points are evaluated.
(7) Knowledge: What was learned as knowledge through making the decision and what followed.
(8) Related events and association: Events that resulted from the decision (direct results), and events that took place in relation to the decision (indirect results), and other thoughts that enter the mind in relation to the decision.

Among these topics, route of thoughts and doubts, discussion and evaluation, knowledge, and related events and association are usually not recorded. Technology, however, is only transferable in the real sense by recording these three topics and only then the "decision" by a single person turns into wealth shared by other people and this is what we call culture.

Once we have these descriptions, how do we use them? Figure 2.5 shows how decision process information transfers in terms of technology transfer.

- Record: Write a description and record it. At the same time separate the writing into the above topics of decision, background and motivation, functional requirement and constraints, route of thoughts and doubts, realization and results, discussion and evaluation, knowledge, related events and association, and so on.
- Store and archive: Whether we will use the information or not, we will keep a record in the form of text, figures, animation, and sound, and in addition we may want to keep the real object we are making a record of or others that caused it. Make sure to keep the records in a dynamic area that we visit often instead of storing them in a stationary manner. Unless we make these types of storage in 3D, mere documents and diagrams can never really transfer technology. Also, simple records without a scenario will never be used in later days. Just making records is the least work necessary; however, it is not sufficient. Whether it is in text or a photograph, the "scenario" we made at the time of record-making sets the value of the data.
- Search: Analyzing the contents and giving them a structure allows making use of the contents. Mere description and storage without consideration of the use are equivalent to having nothing.
- Distribute: After analyzing the contents, distribute them to proper areas of technology, product, and department so that the technology spreads into the

network. This idea comes from Mr Fukuda of Mitsubishi Heavy Industries Nagasaki Shipbuilding plant in the turbine rotor destruction article in *The Practice of Machine Design, Book 3 – Learning from Failure.*

- Publicize: Keeping the description in a dead storage is pointless. To make it common knowledge for all, we must place it in the media like books, magazines, newspaper, television, and computer networks as well as distributing the information at conferences, on journals and via patent announcements.
- Educate: Turn the described contents into knowledge and transfer them through education with real experience or virtual ones to the people of the next generation.
- Make business: Think about turning the contents of the record into a business.
- Socialize: Try to have the contents socially accepted, obtain intellectual properties, and acquire legal responsibility like product liability.

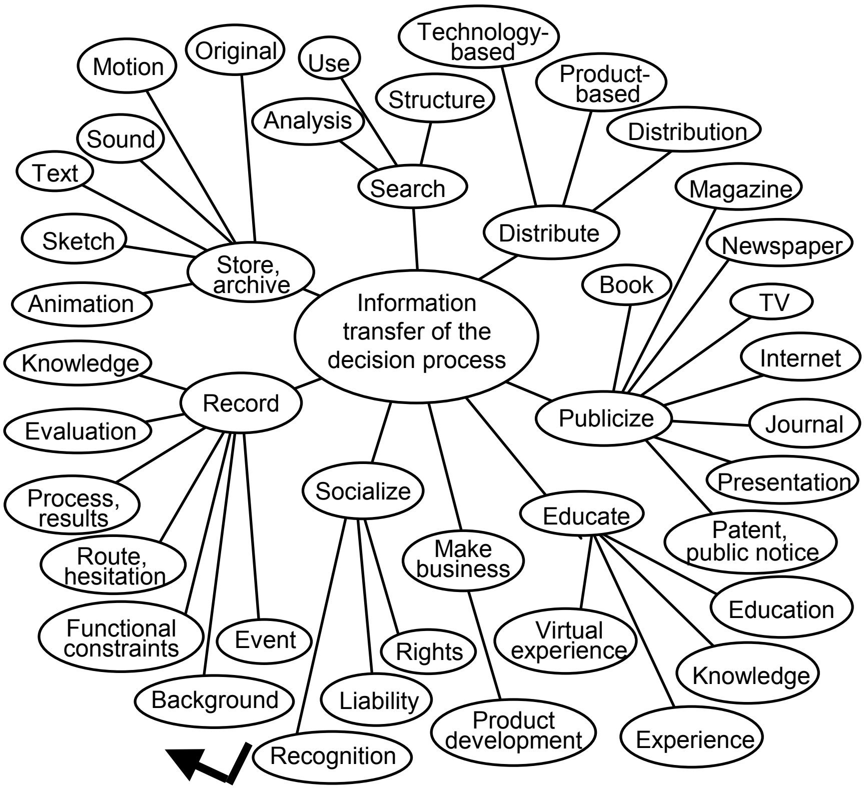


Figure 2.5 Transferring information about the decision process

2.3 Actual Methods for Transferring Decision Processes

If we really want to understand the contents of a decision that someone else has made, reading only about the final decision does not take us anywhere. Information from just the decision itself does not let people understand what facts formed the basis for the decision, what and how the decision-maker thought and what he did (Figure 2.6). That is because the decision process proceeds, as the figure shows, from the left to the right following the time line and those only at the right end cannot trace the time backwards. In other words, the readers at a later time cannot understand the actual essence of a decision made earlier due to the "irreversibility of time"; it is as if there is an invisible wall.

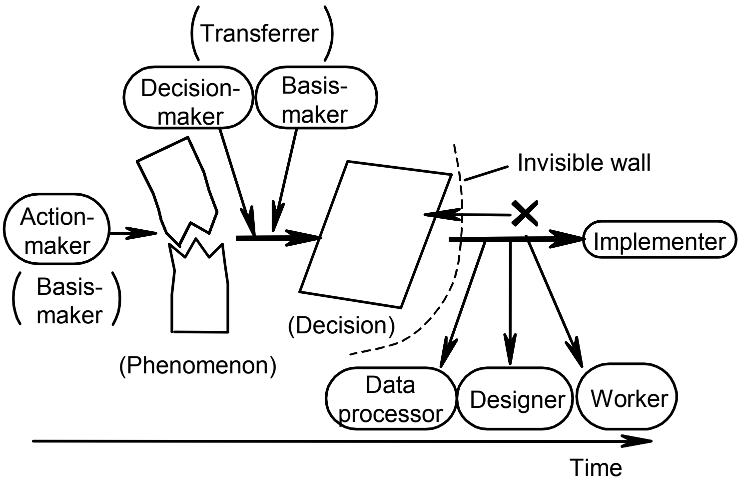


Figure 2.6. Those who implement a decision often do not understand the basis of the decision nor the decision-maker's mind

If someone was shown just the final decision and was told to make exactly what he sees, would he be able to do so? Figure 2.7 shows how a mountain hiking boot was repaired. This sketch alone cannot show much of the repair. Section 2.5 later explains this topic in detail.

Thinking that a blueprint alone is sufficient for building a part is the same as assuming that one can set the string tension by looking at just Figure 2.7.

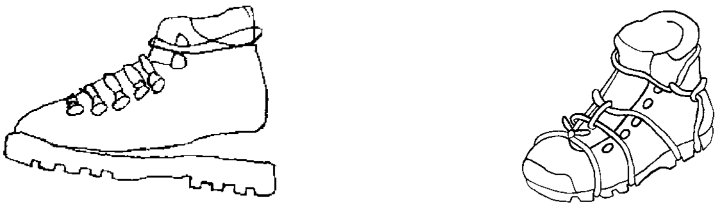
So, is it enough for real understanding to disclose the cause that led to the decision together with the final results? Figure 2.8 shows the original problem with the mountain hiking boot. The figure reveals more information than the previous one; however, in terms of transferring information to the reader it fails.

It is for the same reason that people do not make good use of accident reports. Even if the writer adds a description of the cause to the results and actions, the reader cannot plan to carry extra strings to tie up the broken hiking boot.

Why are such descriptions insufficient in transferring information? It is because they do not contain all the mind processes of the person who had the experience;

only the objective information. They are also written from a third person's perspective. Chapter 1 explained these mind processes – the wonders, trials, background, motivation, and what came up in the mind of the person with the experience. Real information transfer requires all the mind processes of the person from the first person's perspective.

Figure 2.7 Only showing the decision transfers little information



(a) How the sole came off

(b) How the boot was eventually tied up

Figure 2.8 The cause and results alone do not transfer much information

There are many trouble and accident reports, but no matter how hard the editors try, people hardly read them because they do not lead to a real understanding of the events, and thus people cannot make use of the information. A trouble report that contains only the event, cause, and action fails to transfer the mind process of those involved in the event to the reader who is trying to relive the event. It is for the same reason that a blueprint alone cannot transfer technology.

For real transfer, we need to describe the mind process that takes place within our brains. Figure 2.9 shows an example. Once a problem is set, we think and execute much to solve the problem. Record what enters to the mind, how you wondered, what you tried, and how it all came out. Then describe what value judgment you made and how you decided about the solution. This series of writings records the decision process, but it is also important to add the results of a virtual exercise to include what came to mind in relation to the decision, what effects the decision may cause and what are the countermeasures.

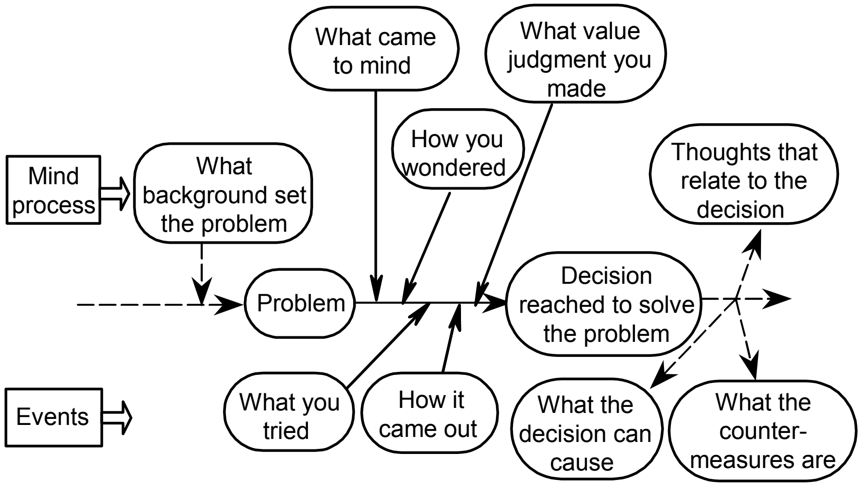


Figure 2.9 Describing the mind process from when the problem is stated

2.4 Diagrams for Expressing the Decision Process

There are two ways of expressing what goes on inside the human brain; one is by words and sentences, and the other is by diagrams. Humans tend to mix the two expressions, and deep within the mind, concepts, which are not in either form, move around. If we force ourselves to express them, we end up using words and diagrams.

People that are literature-oriented like to express thoughts with words, whereas those more science-oriented feel diagrams are more precise. There are a few that like to use equations and we may want to call them "math-oriented people".

Professor Ikujiro Nonaka claims it is important to express "thoughts by words, and words by shapes", but here we assume words and shapes coexist without either being superior to the other.

Now let's think about what type of diagrams we should use for expressing the thinking process. The author group concluded, after six years of discussion and trial and error, that the following diagrams are effective.

(a) Plane of thoughts diagram (Figure 2.10): Diagram that records words and pictures (we will collectively call them "concepts") in a random manner as they enter the mind. The words can be nouns or verbs, as well as numbers with units. We do not have to stick to words, and can draw pictures as well. Concepts in the mind are not always suited to expression by words, and pictures or combinations of the two types may well describe them. We can freely use these forms.

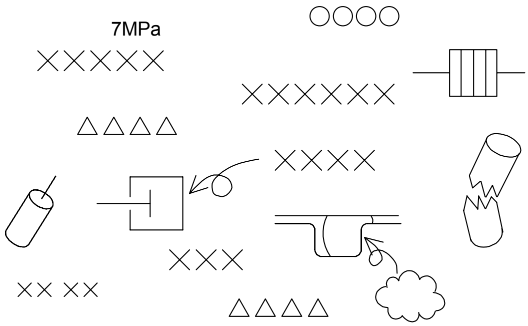


Figure 2.10 "Plane of Thoughts" where we record random thoughts which enter the mind

(b) Relation of thoughts diagram (Figure 2.11): Diagram that shows the relations among concepts that are scattered on the paper (also called a "chain of thoughts" diagram). We think about the relations among the concepts and collect those that belong to the same category, plus the relations with spatial curves, to express relations among the concepts. Putting numbers, following the sequence they enter the mind, on these curves (also called "links"), and words (also called "nodes") is sometimes useful.

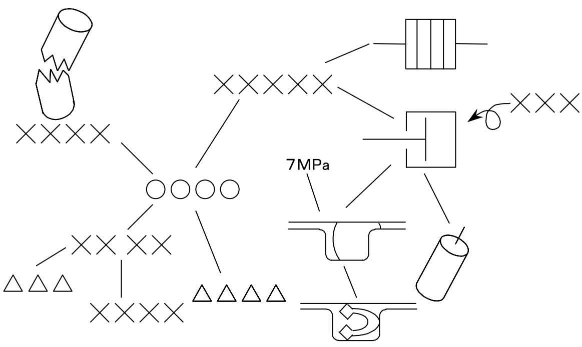


Figure 2.11 "Relation of thoughts diagram" for expressing relations and sequences of concepts that enter the mind

(c) Expansion of thoughts diagram (Figure 2.12): The basic flow of design proceeds Function → Mechanism → Structure, and this diagram shows this process. We record ideas that we selected as well as those we did not. We analyze and decompose the first given functional requirement into functions and functional elements. We think about a number of mechanism elements to meet each functional requirement, then select and decide which we think is the best. Deciding the mechanism element for each functional element is called "mapping." We then expand the functional element we selected and decided, add attributes like size or material, to form structures, and finally integrate the structures into the total structure.

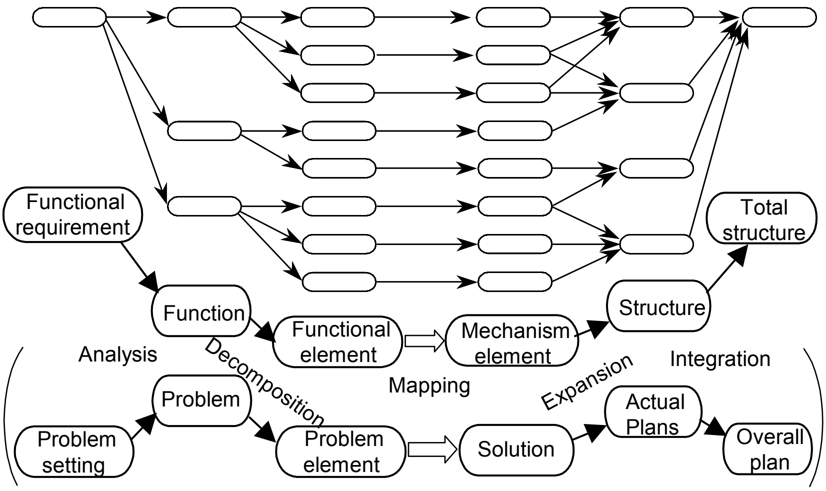


Figure 2.12 "Expansion of thoughts diagram" that expresses the design progress of Function → Mechanism → Structure

(d) The expansion of thoughts diagram is not limited to design processes, and is very useful when applied to the process of decision-making for solving problems. In this case, the thoughts expand in the sequence of Problem Setting → Problem → Problem Element → Solution → Actual Plans → Overall Plan.

(e) Selection and decision Diagram (Figure 2.13): Diagram that shows the process of selection. Recording the "selection and decision diagram" in this manner makes it easy for a reader to understand the decisions. The reader clearly visualizes which options the writer thought about and what judgment he made with which constraint. The constraints shown here (identified by double line frames with rounded corners) are usually not known in the beginning and they tend to clarify as selections and decisions take place.

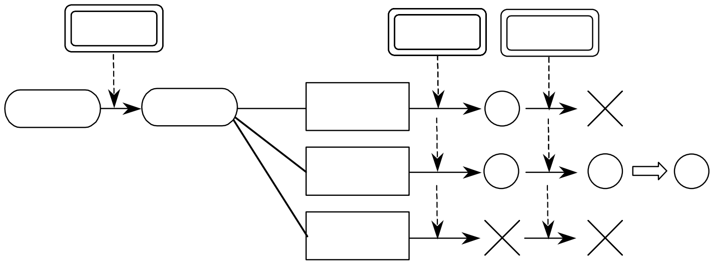


Figure 2.13 "Selection and decision diagram" for expressing the selections made while meeting the constraints

(f) Spiral of thoughts diagram (Figure 2.14): Diagram that shows how what was vague at the beginning gradually takes shape in a spiral manner. Inserting constraints and comments as the thinking proceeds makes the diagram easier to understand.

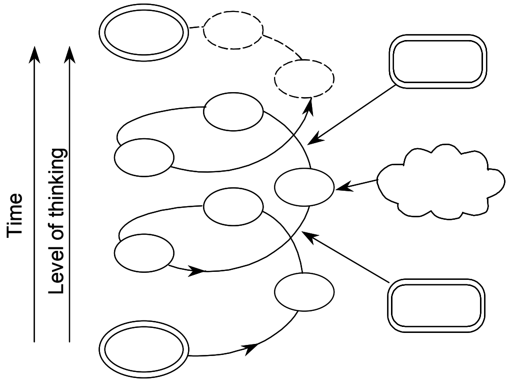


Figure 2.14 "Spiral of thought diagram" shows the mind process as it progresses with time

(g) Time history progress diagram (Figure 2.15): Diagram that shows the progress of elements, related constraints, and comments along the way. Assumptions implied on the first set problem but revealed later are written down in dotted line boxes to help clarify the process.

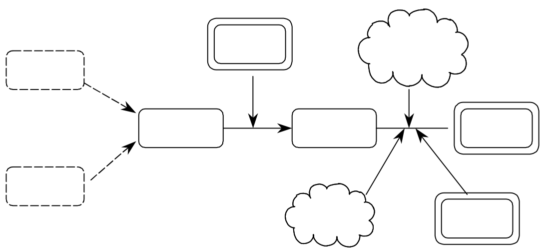


Figure 2.15 "Time history progress diagram" shows the progress

(h) Element relation spore diagram (Mandala diagram) (Figure 2.16): Diagram that shows the hierarchy among structural elements. Higher-level concepts are placed in the center, lower ones in the periphery, and the hierarchical relations among the structural elements are clarified.

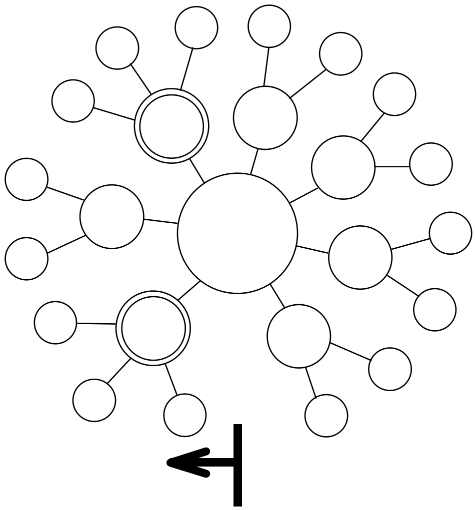


Figure 2.16 "Element relation spore diagram" shows structural elements and their hierarchy

(i) Structural element transition diagram (Figure 2.17): Diagram that shows the change of structural elements as the time progresses. The diagram proceeds from left to right with time and has comments and constraints added. Using double-lined boxes for governing elements within structures clarifies the transition.

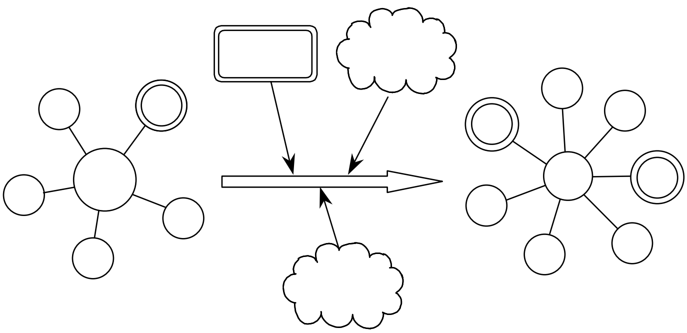


Figure 2.17 "Structural element transition diagram" shows the change of structural elements with the progress of time

(j) Structural element correspondence diagram (Figure 2.18): Diagram that shows how the structural elements correspond. Using double circles for primary elements clarifies the correspondence.

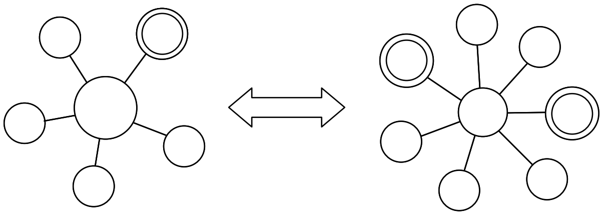


Figure 2.18 "Structural element correspondence diagram" shows the relations among elements

2.5 Example of Recording the Decision Process

Reading or viewing only the final decision itself does not allow us to understand the decision if the process of reaching it is not clear. We then cannot make use of the results from the decision. We want to know what happened in the course of reaching the decision, what the decision-maker thought, how he handled his hesitations, and how he reached the final decision. This section looks at a real experience by some of the authors of this book with a mountain hiking boot. It broke while we were climbing, and this example describes the decisions we had to make, and how to record the events so we can transfer the mind process of making decisions to the reader.

Title: "Our Temporary Fix of Tying up Mountain Hiking Boots that Broke While Hiking – How We Guessed the Mechanism of Destruction through Observation and Devised a Proper Countermeasure"

2.5.1 Describing What Happened

We first describe what happened, what we thought, what actions and decisions we took. We kept the descriptions brief by selecting only the necessary elements. When writing this part, we aimed at providing the substance of the decision and its overall structure, so that those wanting to learn about the decision can judge whether the subject is one for further study.

(1) **Event:** The rubber soles of mountain hiking boots came off while we were climbing a mountain. They broke near the glueline and not exactly on it. We guessed the mechanism of destruction by observation. We then collected strings from the party, tied up the boots to counter the forces on them, and recovered the original function of the boots. The temporary fix worked. We learned much from the actions we took.

(2) **Background:** We often went in for serious mountain climbing when we were younger, with tents and over several days or a week. We have the desire to climb mountains just as frequently as we used to, and so, instead of serious climbing once a year, we decided to go more often but in a casual manner so we in the middle age could hack it.

(3) **Course:** One day in the fall of 2001, seven graduates from the same lab (all authors of this book), took the mountain route from Tengendai in Yamagata prefecture to Mount West Azuma. As we walked the track, one of the party broke his boots (Figure 2.19). Their soles started to peel from the heel (A in Figure 2.19), and the crack gradually advanced forward.

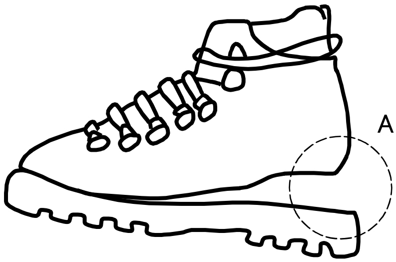


Figure 2.19 The sole of the boot started to peel off

(4) **Countermeasure:** At first we thought we simply had to tie the upper to the sole. We did not have any spare bootlaces and first tried vinyl bags we were carrying but they quickly proved useless. We then started to pull strings out from our backpacks and jackets to tie up the boots. After much trial and error, we successfully tied up the boots to recover their original function (Figure 2.20, Figure 2.21). Without having to change our plans, we enjoyed our mountain climbing.

Figure 2.20 How we tied up a mountain hiking boot

Figure 2.21 Tying up Mr F's broken boots

(5) **Mind process:** We repeatedly pondered over what happened. Our thoughts went into the micro-mechanism of breaking, planning a countermeasure, and executing the plan. In the regular course of design, the mind process proceeds Function → Mechanism → Structure; however, in this case, it went Observation → Guess the Mechanism → Countermeasure. We then tried and went back to the spiral of thoughts and onto devising a countermeasure (Figure 2.22). Figure 2.23 shows the mechanism of how the boots broke.

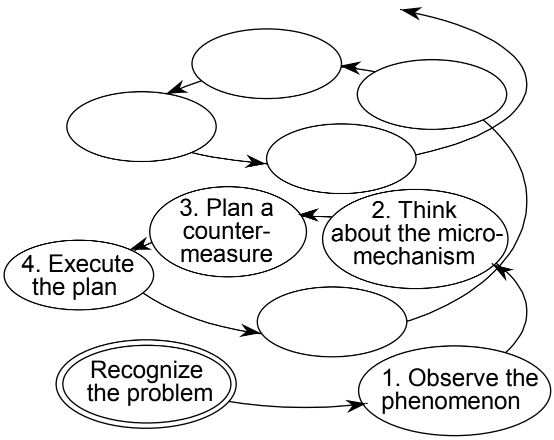


Figure 2.22 Spiral of thoughts from recognizing the problem to executing the solution

(a) Shearing at the connection (b) Peeling at the tip

Figure 2.23 Mechanism of how the boot sole came off

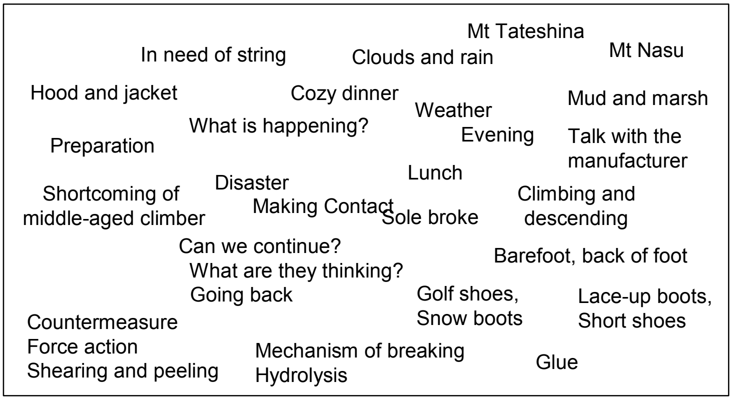


Figure 2.24 Thoughts that came to my mind as I saw the shoe sole peel (plane of thoughts diagram)

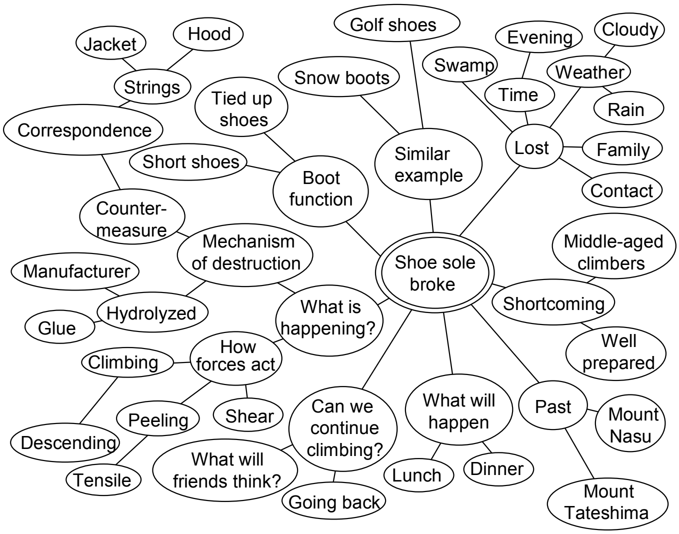


Figure 2.25 Relations among thoughts that came to my mind (relation of thoughts diagram)

As we saw the boot sole peel, many thoughts came to me. Things related to peeling, about continuing the climbing, countermeasures, and unrelated matters – all sorts of things just popped up in my mind. Figure 2.24 shows the plane of thoughts I constructed afterwards by remembering what came to my mind. Figure 2.25 is the relation of thoughts diagram that organizes the contents of Figure 2.24 and arranges the elements for easier understanding by the reader.

The peeling was not caused by a weakened gluing that attached the sole to the body. It was caused by repeated stress on the weakened material. I used to think boots had two functions: to cover the outside of our feet and the bottom of our feet. Figure2.26 shows the corresponding expansion of thoughts diagram. Further thinking and observation made me recognize the third function of "transferring the upper movement to the bottom". Figure 2.27 shows the relations among the functions of boots and their structure.

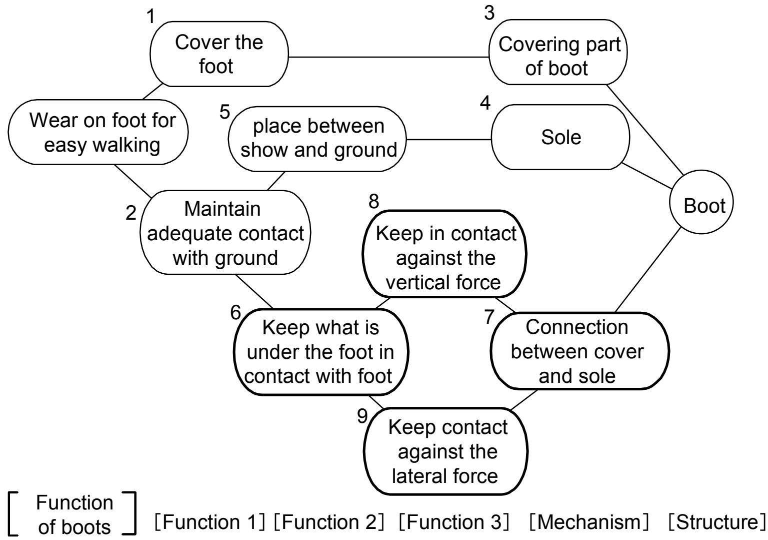


Figure 2.26 Expansion of thoughts diagram found by observing the boot sole peeling and expanding the boot functions and mechanisms

(6) **Knowledge:**

- Understanding the functional requirement and constraints through observation allows proper countermeasures even when in the mountain.
- Knowing the mechanism of deformation and destruction, and countering them led to the same conclusions with old-time technology (straw shoes and their tying up), which in turn have led to modern technology.

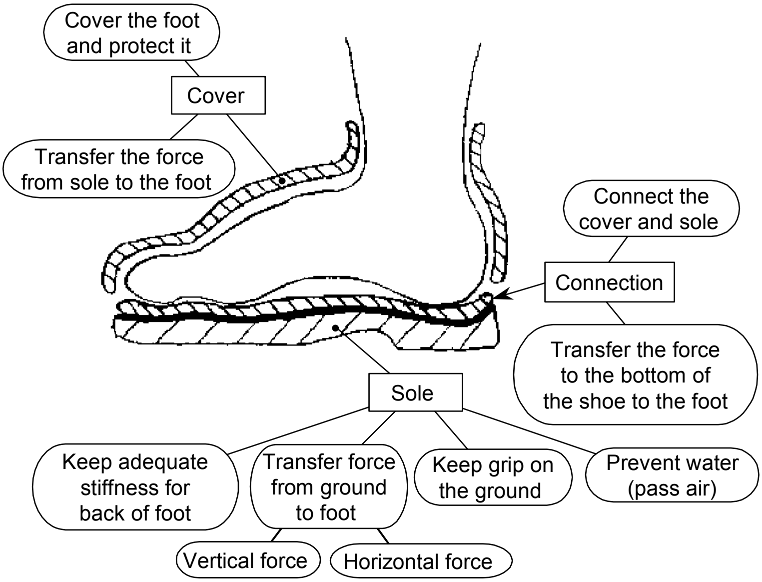


Figure 2.27 Structure of a shoe and function required to each part

(7) **Lessons:** Thorough preparation is necessary for climbing mountains. Maps, compass, flashlight, string, knife, matches, warm garments, and raingear are the minimum.

(8) **Sequel:** The story of these boots was the main topic for the party after we came down the mountain. The object that we finally produced (Figure 2.20) was very like the old straw shoe widely used in Japan. The functions required of what we wear on our feet are the same for the old straw shoes as for the mountain hiking boots. That is why the way strings were tied were in almost the same way once we were done.

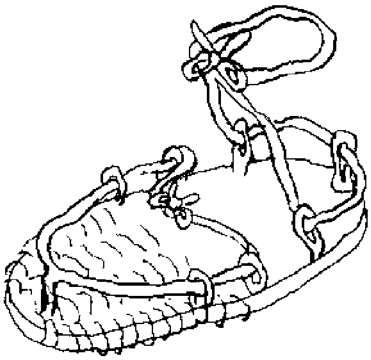


Figure 2.28 Structure of a straw shoe and the mechanism for wearing It

One of the authors (Hatamura) was evacuated from Tokyo to Tottori prefecture during World War II for safety. There he experienced the making of straw shoes. The sketch (Figure 2.28) is based on his memories.

Back in the lodge, the party warmed up their bodies and hearts with some help from alcohol and extended their talk to right-angle and parallel tying of bootlaces, people not tying bootlaces properly, people not knowing how to hold chopsticks, children not being disciplined, and so on. We just started with the mountain boot and enjoyed the evening talking about technology and culture.

2.5.2 Processes and Contents from This Event

For the reader who judges that this decision is something to learn from, we shall write down in detail the contents and processes of making the decision, the other matters related to the decision, so as to transfer the decision in a three-dimensional manner to the reader.

(1) When and where the event took place
Date: October 6, 2001
Place: We climbed Mount West Azuma, which is located north of Mount Bandai, which is north of Lake Inawashiro. Our climbing had a typical middle-aged schedule with a walk up a height of about 250 meters.
Weather: Cloudy

(2) Detailed course of events: As soon as we started climbing, the boot soles of our friend (Mr F) started to come off, and when we reached the top the heels had almost completely peeled off. It started with the right boot, but the left one came off at the same time and both eventually completely disintegrated. It is not easy to make two things break at the same time. All of us wondered what kind of manufacturing control the makers had. Mr F offered to turn back to avoid troubling the rest of us, but we thought that if we stuck together we could do better than letting him return alone, and we could think our way through. We told Mr F so, and got him thinking the same way, *i.e.* that he could walk the whole course.

The photograph shows how we temporarily tied up the boots with the peeled-off soles (Figure 2.21). The peeling started from the heel and gradually advanced forward. When we first thought about tying them up with something, we tried a vinyl bag, which did not work. We then decided that we should use some strings, but we could not find any. None of us had the standard mountain hiking equipment of spare laces, so we had to them from our jackets and backpacks.

(3) Mechanism of peeling: Here is a record of the peeling mechanism we reasoned by observing the problem (*cf.* Figure 2.23). We quickly realized that it was the shearing force in the remaining contact area between the sole and the boot body that caused the peeling, however that force was just a part of the mechanism. Further observation revealed that the force at the tip of the crack pulled the two apart. In all, the horizontal shear and the force to pull the two pieces apart caused by the shoe bending were responsible for the peeling.

(4) Process of trial and error with the tying: This paragraph describes the process of tying up the upper and sole of the boot until we successfully integrated them into one piece (*cf.* Figure 2.20). Until we understood the entire mechanism, the tying was just groundless. We first tied the heel of the sole to the upper with string (a) by one loop, but it was not easy to walk with. So, we fixed the center with string (b). We then thought we could make it work better and hooked the heel to the original bootlace (d) by looping string (c) around it. This made it much more comfortable. Firmly tying up the ankle string (d) with (c) and then pulling string (c) with string (e), the boot upper and sole were held firmly together and stopped coming apart. This step was crucial. Mr F walked without worrying about his boots at all for the last hour and a half. This last string was the most important one.

(5) Expanding the thoughts to general footwear: I then realized that the tying was the same with the straw shoes I used to make.

Let me discuss some about straw shoes (*cf.* Figure 2.28). I hear there are different types of straw shoes. I used to make them myself and the bottom piece is made of straws wound around four straight straws in the long direction. One of the straw shoe strings starts from between the big toe and the second toe, then splits into two parts which pass through rings on both sides of the bottom piece and are tied together above the foot. This string arrangement is the same with beach sandals, and I have shown the arrangement in a Y-shape in the figure. The strings come horizontally from the branch between the toes and turn upwards at around the middle of the foot, then are tied on top of the foot to pull the bottom piece against the foot to keep it with the foot. The heel part is pulled up towards the ankle. A straw shoe attaches itself to a foot at three locations: between the toes, on top, and at the ankle.

(6) Generalizing knowledge and structure: Looking at the stringing alone, we realized that how we tied up Mr F's boot (Figure 2.20) resembles a straw shoe (Figure 2.28). This means that the stringing system has to be this way to accomplish the function of keeping our foot and what is underneath it (a sole or a straw shoe) together when we walk. We realized that the straw shoe has a logical structure.

(7) Relation of concepts and example: When we trace the process of the peeling of the mountain hiking boot sole and how we countered the problem, we can draw the spiral diagram of thinking about the micro-mechanism of how the boot sole disintegrated, planning the countermeasure, executing the plan, observing again, iterating the plan and executing it (Figure 2.22).

(8) Expression with an expansion of thoughts diagram: We can express the process starting with identifying the function of the boot and eventually reaching the tying system in an expansion of thoughts diagram (Figure 2.26). Among the functions of the boot, those of "protecting the foot" and "protecting the bottom of the foot" prevailed even when the sole came off; however, we then recognized the important function of "keep the foot and sole in contact to transfer force," which did not.

The actual thinking progressed by going back and forth rather than in a steady left to right movement of Function → Mechanism → Structure.

(9) Generalizing the function and mechanism relation: Our further thinking revealed that what came out as the result was almost the same as what had been in existence for a long time. In other words, pursuing the same functions led to the same basic structure. We can say that there is an inevitable relation beyond time between a function and the mechanism to realize it. There is an intriguing universal generalization in the world of technology.

> The tying reminded me of ancient Roman warriors in movies wearing sandals tied like the straw shoes. Some of the current running shoes have their markings modeled after those Roman sandals.

(10) Finding similar events: When we arrived at our lodge that evening, we took a closer look and found the stacked layers of rubber between the boot sole and the boot body had turned into crumbs of a layered cake.

I had expreienced similar failures before. Once my old golf shoes on one of the sole suddenly came off. What broke was the material near the glueline, but not the glueline itself. I first thought it was the glueline and complained to the manufacturer, who replied "Such peeling is common in shoes that are not worn often and kept in storage." They said the moisture inside hydrolyzes the material producing H or OH, and that reaction causes the internal destruction.

Another example is snow boots. I was on a Shinetsu line train (the Nagano bullet train construction shut down the local tracks near Usui summit and only part of Shinetsu line is still in service today) when my snow boots suddenly started to disintegrate, and by the time we reached Nagano station I was barefoot. I had to buy rubber rain boots at a shoe store near Nagano station. I wished the boots had broken into something like beach sandals with soles. Unfortunately, the bottom of a snow boot is in one piece with the rest. So my snow boots had something left on the top of the foot but the bottoms of my feet were in direct contact with the road. I walked through the town of Nagano in those boots to the shoe store. The people at the shoe store laughed but told me it was a common thing to happen.

Asking around, I found that there were quite a few people that had experienced similar troubles. The common factor among them was "occasional use" only a few times a year. Shoes worn daily do not have such troubles. Shoes that break abruptly are those kept in boxes for years or ones that are called for once or twice a year for middle-aged mountain hiking or middle-aged skiing. They break not at the glued surface but rather disintegrate like cake crumbs. Observing the failed material, we saw a ragged surface, probably due to hydrolyzed plastic. The manufacturer wrote to tell me that shoes break in a such manner. I was somewhat upset by such a comment, but having now heard more of such happenings, I think that it is something we have to put up with.

> There have been accidents caused by ski boots breaking during skiing. I have also heard about a recall triggered by the ski boots breaking in the middle of competition. Such incidents were probably due to the same mechanism as described here.
>
> If this happened on a mountain 3,000m high, there would not be much we could do about it. It is horrifying to think of getting lost in the mountains because the soles of your boots broke off.

(11) Understanding the chemistry of the destruction: It is a commonplace among chemists that materials made from polymerization break easily when hydrolyzed. If we think that way, this trouble with the shoe sole is better described as "destruction", rather than "peeling".

(12) Model to build in the mind: When we look microscopically at the shoe sole near the glued surface, the material has many small holes, *i.e.*, a number of microscopic pumps are connected to one another. In other words, we will imagine a porous pump model. If we use the shoes daily, the water is pumped out, but if we store the shoes for an extended period of time, the pumps are kept still, causing hydrolyzing in the material (Figure 2.29).

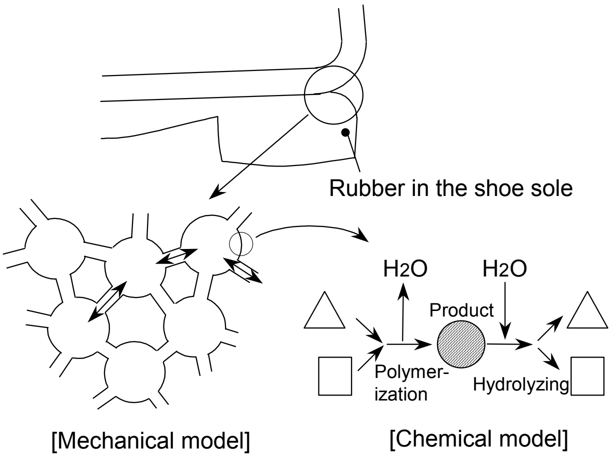


Figure 2.29 Model to build in the mind about the shoe sole peeling

Manuals Stop Your Thinking Process

Manuals are all over the place. When a scandal is revealed, a typical countermeasure is "We will strengthen our management" or "We will revise our manual." Can such actions really prevent scandals? I always wonder about it. Now I have started to think that these problems are caused by the laziness of large corporations that force manuals on their employees who eventually end up working without thinking.

The production area cannot run proper lines without the manual (documented job standards). Manuals are absolutely necessary. So, why did I end up thinking that manuals are the source of problems? I realized that manuals themselves do not cause problems but rather the mind or the thoughts of the humans that use the manual. That's it! It is the dead manual! The thought that "I am following the manual so there is nothing wrong that I am doing" is the wrong course of thinking.

I read, the other day, the book *Economy of Yoshinoya* coauthored by the president of Yoshinoya, Mr Shuji Abe, and Professor Motoshige Itoh of the University of Tokyo. President Abe, in the book, says "Manuals are there to follow, but also to change." I believe this is the true meaning of a manual.

There are plenty of examples of dead manuals. Whenever I enter a store and hear the flawless but also emotionless greeting, I believe the recession in Japan will still continue and unbelievable failures will keep mounting up. We must not blame it on manuals. We are the ones to be blamed who stopped thinking about each step just because following the documents is so easy. Let's start correcting our actions.