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Engineering Tomorrow Will be a Game of Soccer

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Abstract. This is not a research paper, but a paper to discuss in which direction the author considers engineering tomorrow will be heading for. Engineering up to now has been final product-focused and product development has been on an indivual product basis. And intrumental rationality has been important. How faster, cheaper and better products can be developed was evaluated. The industry framework has been tree-structured. But what becomes crucially important in engineering tomorrow is fast and flexible adaptability, because environments and situations change very frequently and extensively. Therefore, not only humans, but products and further products and humans (things) must work together, as rapidly progressing IoT demonstrates. Collaboration was needed yesterday, too, but it was tree-structured and static. Collaboration tomorrow will call for adaptive network. We need dynamiclly varying collaboration as a team tomorrow. Therefore, we have to design and develop products as a dynamically adapting team from the first. Thus, organizational development and operation become crucially important tomorrow. It is only users who understand what is happening now. Therefore, engineering tomorrow must change from producer-centric to user-centric and the importance of decision making of users increases. In short, engineering tomorrow will be realizing the highest human need of self-actualization, which Maslow pointed out and will be satisfying our needs to answer to our intrinsic motivations, which Ryan and Deci pointed.

Keywords. Engineering Tomorrow, Frequent and Extensive Changes, Fast Adaptability, Product Team, Process Value

Introduction

Until today, our engineering has been product-focused. We have been making efforts to produce new products with better quality and performance. Tools has been evaluated on the basis of how fast and with less cost we can realize a prduct. And such traditional engineering has been individual product-oriented.

But the emerging IoT is changing our society into the connected one, where everything is connected, not only between humans, but also between products and between products and humans. Thus, the idea of product teams play an important role engineering tomorrow. We should focus our attention on how products work together as a team and how we can provide satisfaction to our customers as a team of products, not as an individual product.

This may be compared to a soccer game. In the old games, players were expected to work best at their own position. The team of best players was the best team at that

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time. But as Rockne pointed out that 11 Best does not make up the best team. In frequently and extensively changing situations, players who play flexibly to adapt to the changes make up the best team.

Soccer fans are satisfied when the team plays flexibly to adapt to the changing situations. They are not satisfied with high number of goals, but they enjoy how players score the goals. In other words, fans expect beautiful, flexible and dynamic game strategy often more than just winning the game. .

Current industrial framework is basically tree-based and static. But the connected society will change it into a dynamic and adaptive network. Thus. intermediate components will increase their importance, although the current framework attaches importance to final products. In other words, process-values will become critically important tomorrow.

This paper discusses how industry framework will change and how IoT should be re-examined from the standpoint of innovating supply chains for increasing process values.

1. Product Development Now Calls for a New Paradigm

Our world is changing from the Closed World to the Open World (Figure 1).

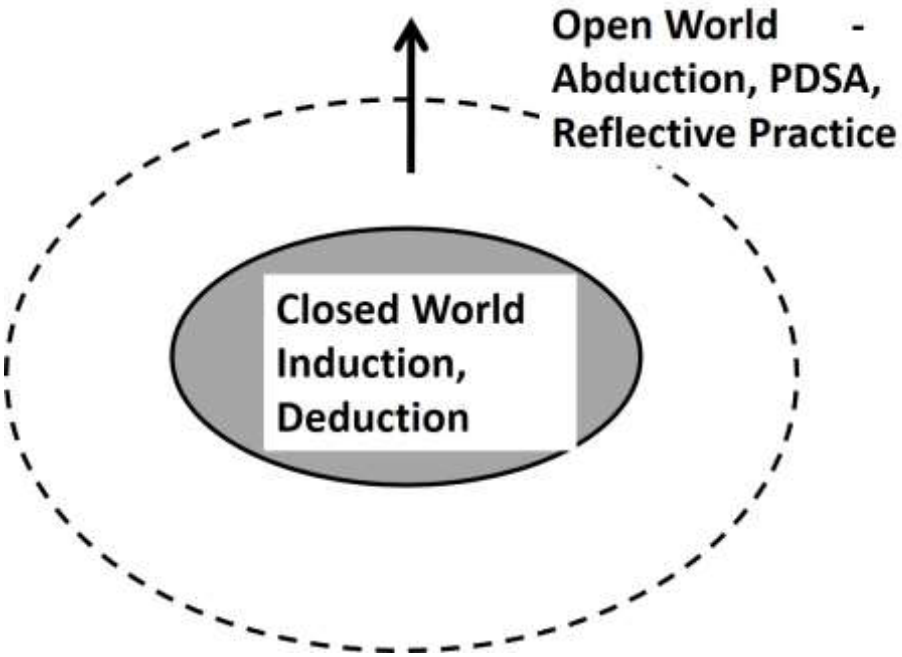

Figure 1. Closed World and Open World

There was a boundary in the Closed World and it was a small world. And in addition, although there were changes, they were smooth so that they were differentiable . Therefore, engineers could foresee the operating conditions and focus their attention on how they could improve the performance of an individual product. But our world is

quicking changing into the Open World, where there are no boundaries. Such quick expansion brouhgt us rapidly increasing diversification and personalization.

Further, changes take place very frequently and extensively. What makes product development difficult is these changes are sharp so that they are not differentiable. In short, changes today are unpredictable. Therefore, we cannot predict the future and what becomes increasingly important is how fast and flexible we can adapt to such changing environments and situations (Figure 2).

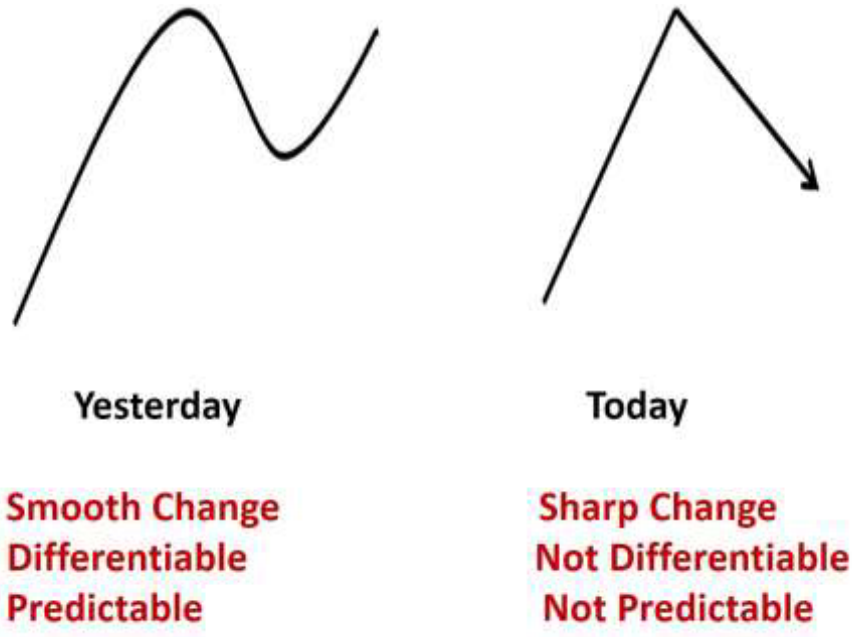

Figure 2. Changes of Yesterday and Today

2. How Can We Let Customers Understand the Qualty and Performance of Our Products?

Weber-Fechner pointed out that we cannot recognize the increase of stimulus level, unless the stimulus is increased by the amount proportional to its level as shown below.

$$\frac{\Delta R}{R} = \text{constant}$$

This law can be easily understood. When a person with a loud voice increases his voice, we cannot understand easily that he raised his voice. But when a person with a small voice raised his voice, we easily recognize that he raised his voice.

The quality and performance of our products have been being continuously improved. So we are now approaching its ceiling (Figure 3). Thus, it is becoming more and more difficult for customers to recognize the amount of upgrading or how much improvement was made.

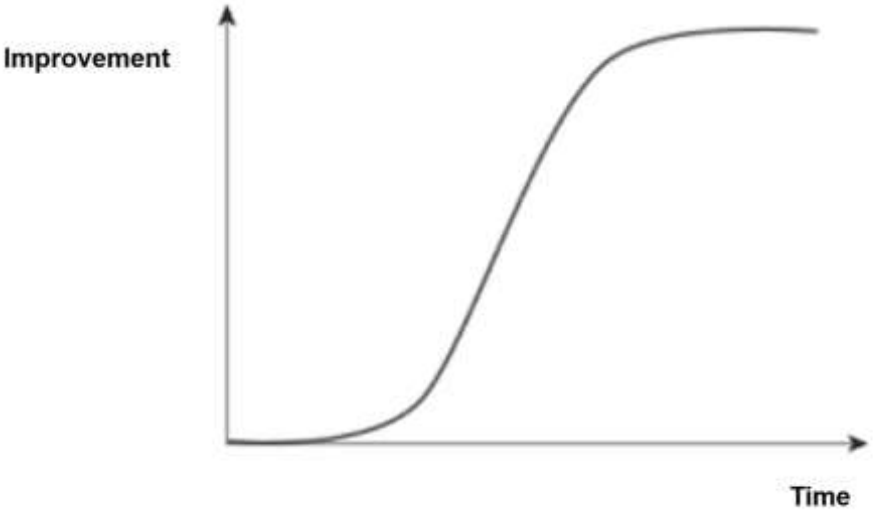

Figure 3. Quality Curve

If we could satisfy personal expectation of each customer, then customers will be happy and will be greatly satisfied. But in our traditional way of product development, we need different production system for different products. Therefore, this is impossible.

Our traditional product development is final-product-focused. Its production system is linear (Figure 4).

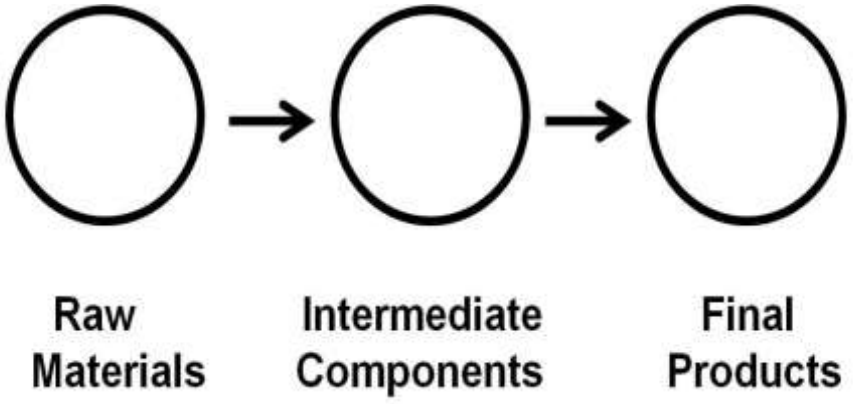

Figure 4. Linear Production

This system worked very well at the time of the Closed World, when product expectations do not differ much from cutoemer to customer and the changes were smooth and predictable. Efficiency and cost reduction were keywords then. And this linear system is based on a tree organization (Figure 5), because the goal is clear and each worker is expected to serve his own job, which is clearly defined. A tree stucture has only one output node, but it is hierarchy-structured so that it works best in terms of efficiency and cost reduction.

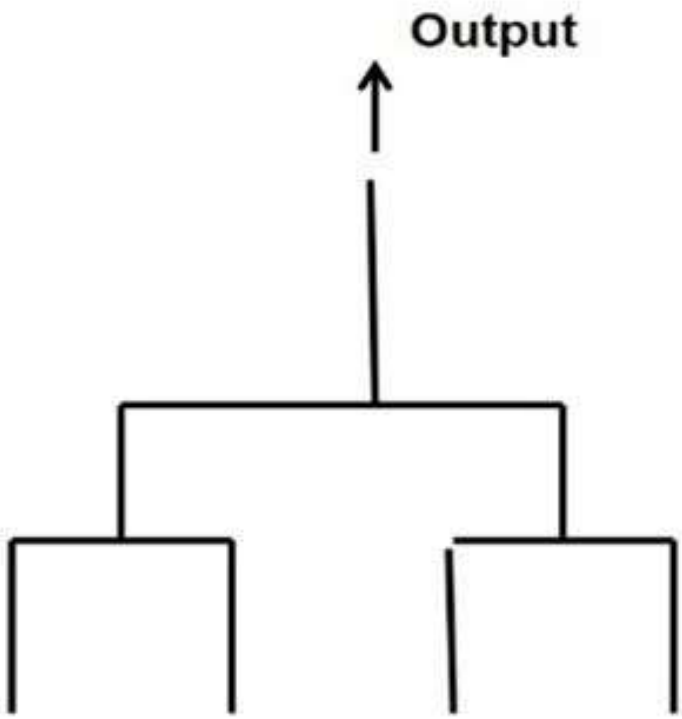

Figure 5. Tree structure.

3. Fast Adaptability is the Keyword Now

As we cannot predict the future today, what we have to do now is to observe the chaninging environments and situations and to adapt to them very flexibly and fast. If products are being developed on an individual basis as we have been doing until today, these products cannot adapt to the changes. They are developed to secure robustness. In other words, they are designed to work the same way, no matter how the situations may change. When the situations do not change much and these changes were predicable, this policy worked very well.

But today, situations change unpredictably. So instead of Robustness, we have to secure Adaptability. It may, however, be said that Adaptability may be called another Robustness, in the sense that robustness here means to adapt to the chaning situations adequately.

4. How Can We Secure Adaptabitlity – From 11 Best to Best 11

Interestingly enough, Knute Rockne, famous American football player and coach, gave us the following answer about 90 years ago, when asked why his University of Notre Dame team realized such a high all-time winning percentage (88.1%). He said, "The secret is to work less as indivuals and more as a team. As a coach, I play not my eleven best, but my best eleven." Rockne realized very well what policy we should take to adapt quickly and flexibly to frequently and extensively varying situations.

About 40 years later, "Der Kaiser" Franz Beckenbauer introduced Libero system into soccer and he introduced the same idea of 11 Best, Best 11. Until then, team formation does not change much from game to game and each player is expected to play his role. But in soccer, too, games today proceed in a very different way from game to game so how to adapt to the changing situations become crucially Important. Beckenbauer was a midfielder but what he substantially played was a commander on the pitch. He recognizes the varying situations and played a leading role in changing the team formation. The team formation up to then was a network, but it was fixed. Beckenbauer changed it to adaptive network. Each player is supposed to play the role team expects from him. Thus, his play or role changes with changing situations.

5. Industrie 4.0 and IoT

Germany proposed Industrie 4.0. Its main purpose is to re-organize Mittelstands (SMEs) and increase their global competitiveness. Yesterday was a world of Meisters, but the quickly and extensively changing environments and situations call for adaptive team working. Thus, German government would like their Mittelstand (SME) to learn how to form an addaptable, i.e., they expect SMEs to change from 11 Best to Best 11.

While Industrie 4.0 focuses their attention on industry re-organizations, Internet of Things (IoT) became very popular in the United States. While Industrie 4.0 pays more attention to how industries can be teamed up, the current IoT is focusing more on technological aspects.

However, we should remember what motivated Kevin Ashton. He was applying RFID technology to supply chain management at Procter and Gamble. He thought if these sensors are connected to the Internet, then we can reduce the burden and could manage the things in a connected way. Thus, IoT progressed with more focus on technological aspects.

Although the initial focuses of Industrie 4.0 and IoT are different, the former being on human organizations and the latter being on sensor-networks, they are now being integrated and they are bringing us the Best 11 world or the connected society. Not only humans or machines alone are connected, but humans and machines are now becoming connected

6. How Will Engineering Change?

Engineering up to now are final-product-focused and we paid efforts to make their quality and performance better and better on individual product basis. We have been making efforts to produce Meister products.

But this strategy does not work any more, because our environments and situations change so frequently and extensively. Thus, engineering is now quickly turning into team based product development. In such team based products, what is expected from each product is not to have superb capabilities of its own, i.e., a few number of links with rich thickness, but to have as many capabilities as possible, i.e., with as many links as possible, although each link might be thin (Figure 6).

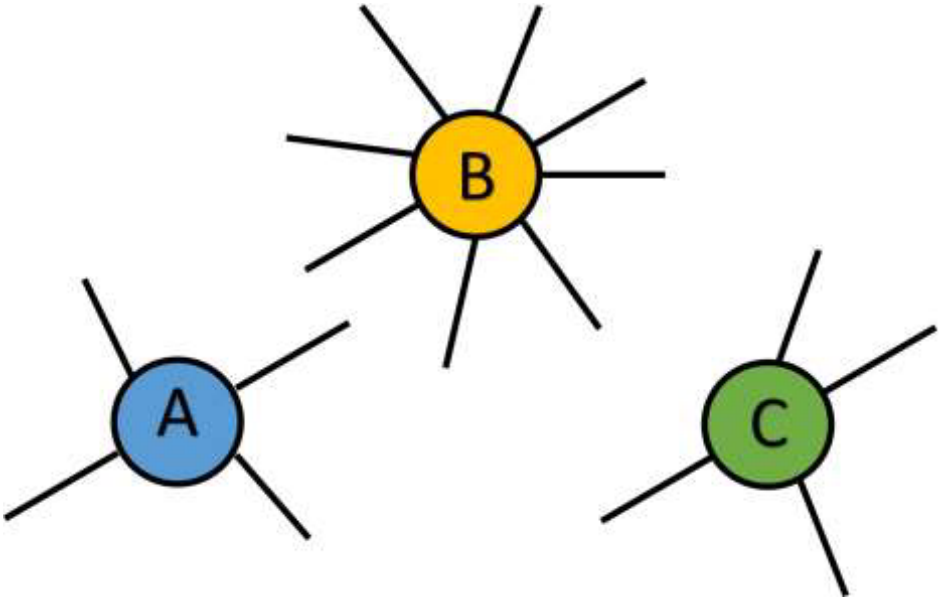

Figure 6. 11 Best to Best 11
(A node represents each player or each product.
A link represents a capability)

When the world was small and closed, we could develop products based on rational approaches. But our world is rapidly expanding and the boundaries are disappearing. The world today is an Open World.

Herbert Simon [1] pointed out that rationality is bounded. If the problem space is reasonably small, we can solve the problem rationally, but if it becomes very large, we have to put up with the solution that satisfies us enough. He introduced the idea of satisficing (= satisfy + suffice). In other words, we cannot look for optimized solutions, but we have to search for emotionally satisfying solutions.

7. Emotional Satisfaction

Thus, with the world expanding and with more frequent and extensive changes coming up, we have to change our engineering goal from optimization to emotioanal satisfaction.

Let us describe how our product development changes by taking an example in soccer. Although the importance of formation was emphasized in soccer yesterday, too, but that formation was fixed. Today's formation, on the other hand, must be an adpative network. It varies so much from situation to situation to adapt to the changes.

And what must be stressed is that yesterday winning the game was most important. But today, winnning the game is of course important but how strategically the team cope with the situation also attracts funs. Sometimes, the loser gets more applause because they played a game based on an excellent strategy, whch most of the funs have never dreamed of. Funs applause because they developed such a wonderful game strategy to adapt to the changing situations. Fast and flexibly adaptabiity counts sometimes more than just winning the game. In other words, what excited funs is unexpected stragetic team expansion and it provides them with emotional satisfcation. In fact, that is why gamification is increasing its importance.

8. Product Development as a Team

Up to now, products have been designed and produced on an indivual basis. Each product is designed and developed to have better quality and performance. But engineering tomorrow will call for teamworking of products. Therefore, each product does not necessary have to work excellently on its own. But they have to be able to tie up with other products if called for. Therefore, we have to develop products with such diverse capabilities to work collaboratively with others to adapt to the frequently and extensively changing situations.

Thus, going wider becomes more important than going deeper. To use the word of deep learning, we have been pursuing exploitation up to now. We have been trying how far we can go on the same track. But in engineering tomorrow, how we can find other tracks become increasingly important, i.e., exploration becomes the keyword. Each product does not have to be so excellent individually, but many different kinds of products, which have never been designed and developed as a team have to work together from now on so that teamworking capabilities of earch product become crucial. We have to look for organizational excellence.

Economists point out that the 5th sector of the economy will be decision making. We have to make decisions every time how to adapt to them, when situations change. Therefore, it is a big challenge how we can attach capabilities of such decision making to products and how we can design and develop products that will support users to make adquate decisions every time. If users can make adequate decisions and can adapt to the changing situations successfully, they will feel a sense of accomplishment and they feel very happy and statisfied.

9. Increasing Importance of Process Value

Ryan and Deci proposed Self-Determination Theory [2]. They pointed out that if decision comes from our intrinstic motivation, we feel very happy. But even when we do the same job, we do not feel so happy, if we do it on extrinsic motivation. Our tradtional engineering has been focused on how we can motive customers extrinsically. But if we change it to intrinsically motivating design, then customers feel much happier, even though the product itself may be the same.

As users tomorrow must operatae a team of products, the judgement and decision of users become very important and when users operate the team of products as they like or as they expcet, they feel their intrinsic motivation is fully satisfied and become

very happy. In fact, they would feel happier than they do in the extrinsic motivating engineering.

In short, processes will generate a great amount of value. Up to now, only the results or products have been regarded as a source of value, but that does not hold anymore. Processes satisfies our basic human needs and will satisfy us more than products. In fact, Abraham Maslow pointed out [3] that Self -Actualization is the highest need of humans. We would like to demonstrate how capable we are and when users can control processes, they feel they are actualizing themselves. Satisfying customers with product value corresponds to the lower or the bottom level of human needs in Maslow's pyramid (Figure 7).

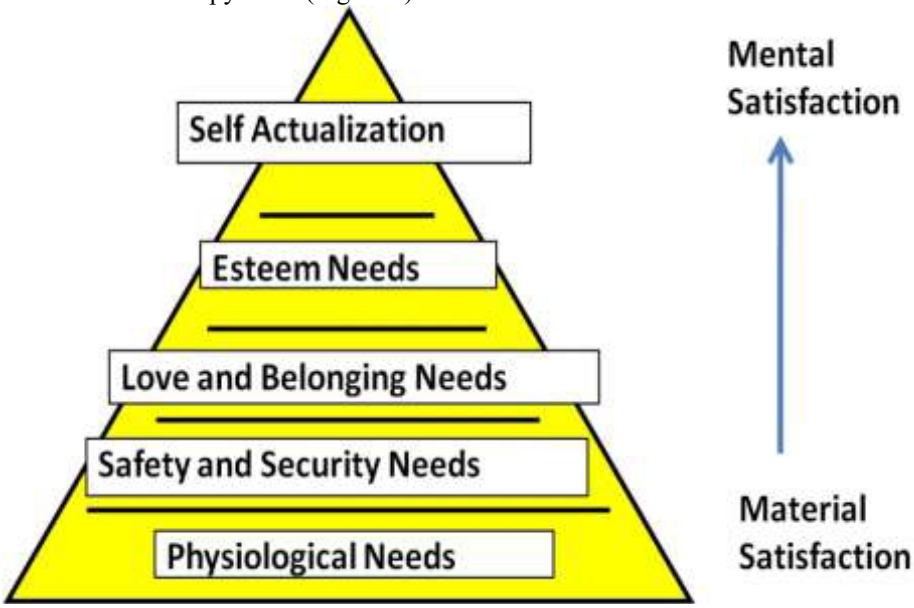

Figure 7. Maslnow's Hierarchy of Human Needs

10. Gamification

To describe such a change in engineering, it may be said that gamification plays an important role in engineering tomorrow. Games call for decision making and when we make very adequate decisions, we can win the game and we feel very happy and satified.

But we also have to remember that winning the game is important, but we are also satified, even if we fail. The faillure poses us another challenge. And challenge is the core and mainstpring of all human activities.

Deci and Ryan pointed out another important human need. It is a need to grow. Why games are fun and enjoyable is because it satifies our need to grow. We can do better next time.

11. Summary

This is not a research paper, but a paper to discuss engineering tomorrow, which the author considers will be coming up soon. Engineering up to now has been final product-focused and product development has been on an indivual product basis. And intrumental rationality has been important. The goal has been how faster, cheaper and better products can be developed. The industry framework has been tree-structured.

But what becomes crucially important in engineering tomorrow is fast and flexibly adaptability. The environments and situations change very frequently and extensively. So, it calls for team working. We cannot solve the problem on an individual basis. Engineers have to work together across many different fields to come up with the solution to adapt to such changes. And this also calls for teamworking of products. They cannot satisfy the needs or expectations of customers anymore on a individual basis. As humans work together to solve the complicated and complex problems, it becomes necessary for products, too, work together. And not only human or product teamworking alone, but their collaboration is called for.

Rapidly progressing technology of IoT (Internet of Things) is making a great step forward in this direction. As such a world is no more a closed word, but an ever expanding open world, we cannot optimize a solution as Herbert Simon pointed out because rationality is bounded. We have to satisfy ourselves with emotional satisfaction. i.e., we must look for a satisficing solution, to borrow Simon's word.

In other words, product value has been regarded as most important up to now, but in engineering tomorrow, process value becomes increasingly important.

It would be easily understood if we consider how a soccer game changed. Yesterday, winning the game was most important. But in today's soccer where a game changes so frequently and extensively, funs enjoy the game, if a new team strategy comes up to adapt to the changes in a very smart way. These processes of decision-making provide emotional satisfaction to the funs. In fact, more otten, such smart stragic operation provides them with more satifaction than just winning the game.

Yesterday, changes were smooth so they can be mathematicall differentiable and we could predict the future. Engineers can estimate the operating conditions of their products. But today, changes are sharp so we cannot predict the future.

Yesterday, customers were expected to use products as engineers told them. But today, only users know what is happening now. So, humans must become the master of the system. In short, users will be changing from slave to master tomorrow. And what becomes important is not intrumental rationality, but value rationality, i.e., the product team works as you like or as you expect. Value tomorrow will be generated by how smart a team can be operated to adapt to the frequent and extensive changes.

Engineering systems tomorrow will be **Self-Motivated, and Self-Determined Systems.** Thusrefore, A word for engineering systems tomorrow will be **Self-Satisfying Systems.**

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