Value Creation and Decision-making in Sustainable Society

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Abstract

Manufacturing exists to create value. However, historically, discussion of economic issues in manufacturing primarily emphasizes cost. It is becoming more difficult to understand and control values of products and services in response to rapid globalization and networking. This paper presents a discussion of the nature of value considering a history of axiology, design problems of artifacts, social dilemmas, network externalities, and sustainability. Promising academic methodologies are presented herein with emphasis on transdisciplinary and synthetic approaches. Value creation models based on Emergent Synthesis and co-creative decision-making are presented. This paper involves some important study examples of service and production toward sustainable value creation in society.

Keywords:

Emergent synthesis, Sustainability, Value creation

1 INTRODUCTION

The value of an artifact is not determined solely by its functionality. This problem has become more important in the 21st century in light of rapid globalization of markets and explosive networking of information.

Market globalization has brought changes in industrial structures and has promoted international specialization of labor. Moreover, it intensifies severe price competition and widens economic disparity among nations. The word “commoditization” means transformation of differential goods or services into commodities [1]. In other words, a certain product with good functionality loses its particularity and becomes an ordinary product because other products have identical functionality (perhaps at a lower price). Therefore, rather than considering mere functionality, producers must infer what would increase the value of their products to the likely users. Many manufacturing industries are rapidly shifting their attention to marketing and service businesses to increase their products’ value [2]. Globalization therefore presents two conflicting goals: specialization to survive price competition and expansion of business activities to survive value competition.

Worldwide information networking hastens product and service diffusion and shortens their respective lifecycles. For instance, consumers can use a huge volume of information about products or services and learn of other consumers’ preferences through the internet. The internet media, such as internet communities, play an important role in consumers’ value judgments of products or services in place of mass media.

In simple terms, the information networking presents two contradictory aspects of values and lifestyles: diversification and homogenization. Regarding diversification, for instance, a favorite book can be chosen from among thousands of books available all over the world at an internet bookstore. Consequently, worldwide information networking enables us to embrace values and lifestyles. The so-called “long tail phenomenon” [3] is one phenomenon in networking society that underscores such diversification of consumer preferences. The phenomenon has generated niche markets that have been researched to identify new business opportunities [4].

Information networking also homogenizes values and lifestyles. A ‘‘*de facto* standard’’, for instance, exists when a certain technique (or standard) becomes dominant in the market in fact, but not by any law or regulation [5]. For example, people listen to music using the same audio player while commuting on trains in many countries. In such cases, the product value cannot be determined solely according to its functional dominance or economic advantage; its value is realized through interaction among consumers, products, and producers in a society. Consequently, the network externality is defined as an externality by which a consumer’s utility depends on the number of users who consume the same product [6–7]. Therefore, services for a product will be more enhanced as the number of users grows, although other products decline. Fortunately or unfortunately, we can maintain our lifestyles related to food, fashion, and technologies in many different countries. Global networking also plays a role in uniting different cultures and values.

Furthermore, accelerated global networking has gradually come to entail negative aspects. Because the amount of available data grows continuously, managing that information becomes more difficult [8]. Our society is becoming more complex and unstable as information networking systems develop. In fact, enormous information systems (e.g., internet networks, electric power systems, transportation systems, banking and financial systems) sometimes have caused or have become involved in large-scale accidents.

In association with globalization and networking, every industry in this century is strongly required to contribute to sustainable development, but no solution can be obtained easily when considering the complexity and instability of the social systems. Additionally, maintaining sustainability often creates a dilemma between values of a whole society and values of individuals [9]. Therefore, to resolve this problem, more attention must be devoted to value creation mechanisms. It is apparently impossible to achieve a solution from independent viewpoints such as those of technology, economy, or psychology. Instead, it is important to study the problems through integration of some aspects of values toward sustainable value creation in a society. It is necessary to rethink values from relations among humans, artifacts, and society as decision-making problems.

This paper describes how we can synthesize the value of artifacts toward a sustainable society. It specifically examines value creation mechanisms and decision-making in a society, with academic emphasis on emergent synthesis and co-creation.

Figure 1 presents an overview of this paper: it overviews the history of axiology to elucidate the nature of values from academic viewpoints. It then portrays the difficulties particularly addressing social dilemmas, decision-making problems and sustainability. It then presents an overview of some approaches to solve those problems, such as transdisciplinary approaches and synthesiological approaches. Some methodologies are examined with academic emphasis on emergent synthesis and co-creation. Value creation models are introduced, including innovation management. Finally, this paper presents and discusses important challenges confronting the realization of a sustainable society.

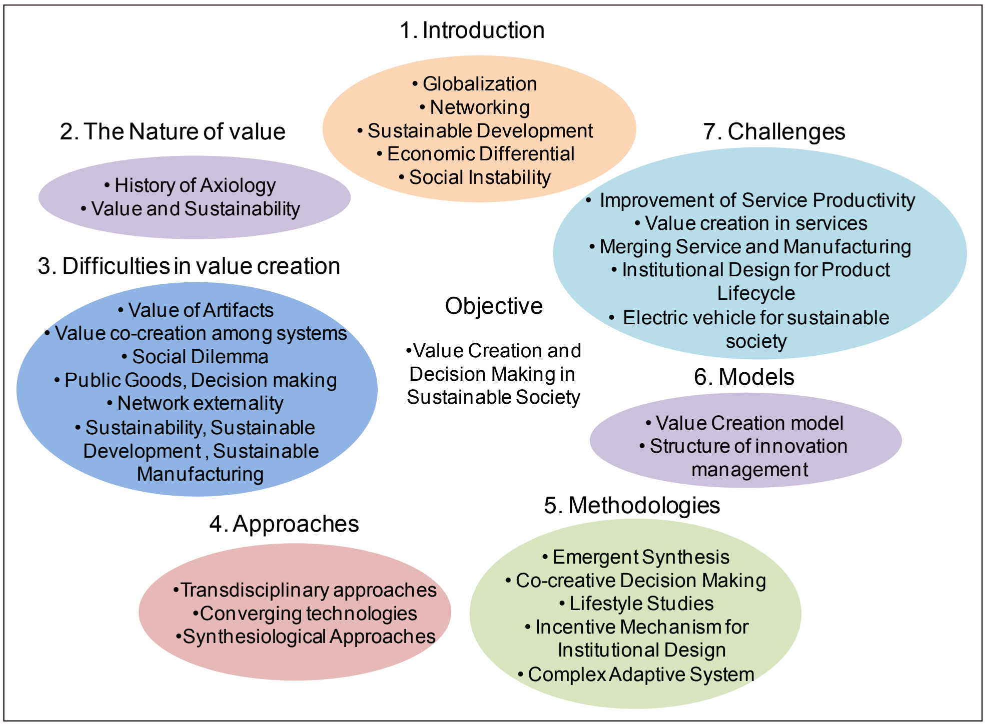

Fig. 1: Framework of this study.

2 THE NATURE OF VALUE

This section presents a discussion of the nature of value, particularly addressing historical academic challenges to related problems. As described in this paper, it specifically examines those challenges in the West. It introduces conceptions and basic attitudes related to value in philosophy, economics, psychology, engineering and ecology.

2.1 History of axiology

Historically in Europe, the first academic investigation of value was undertaken by sages of ancient Greece. Axiology, from the Greek “axios” (worthy, valuable) and “logos” (discourse, reasoning), is the discipline that deals with values in a systematic way. Nevertheless, the name axiology has been introduced only recently, not earlier than the beginning of the 1900s; ever since it has become common in academic essays. Figure 2 presents an outline of the genealogy of Axiology in the West from ancient Greek era to the present by showing important persons or institutions along with some keywords.

From the 4th to 3rd century B.C in Greece, two important origins of axiology (theories of values) prevailed: a “Theory of forms (or Theory of Ideas)” formulated by Plato [10]; and “Hedonism” which originated in the thought of Epicurus [11].

Plato’s Theory of forms asserts the highest and most fundamental reality (Form or Idea) behind individual things in the material world. In other words, values exist as absolute realities that are independent of the material world and of the limitations of human sensation. His thought is reflected in the subsequent philosophies of Realism and Idealism. Moreover, his thought affected the philosophies of Empiricism and Epistemology. Additionally, Aristotle, a student of Plato, showed slightly different thought about “Ideas” consisting of fundamental elements that are perceptible by humans as something in particular [12]. Both hold that values exist as pure or absolute realities.

In contrast, Epicurus emphasized pleasure as the most important pursuit of humans. People must strive to maximize pleasure and minimize pain. In a limited sense, value lies in the human natural pursuit of pleasure. His thought influences ethics and psychology as Egoism, and jurisprudence and modern economics as Utilitarianism. Utilitarianism holds that an action's moral worth is determined solely by its contribution to overall utility: its contribution to happiness or pleasure among all people. This idea was formulated in greater detail by Bentham and his proponent, Mill, later in the 18th century [13].

Although two different attitudes related to values existed, the main concern of the philosophers in ancient Greece might have been how people can live well. For this purpose, they necessarily considered what the right values for people are. It is therefore important to examine why people started to study value problems in different periods in history.

Given the cultural landscape of The Renaissance (14th–16th centuries), a main intellectual development was given by the new idea of nature as a fundamental value: nature is regarded as the object of study and investigation by science and not as the field of manifestation of divine forces. This Naturalism of the Renaissance considers nature as the only reality worthy of investigation, but by "iuxta propria principia" i.e., according to Nature's own principles and not by imposing on it humans' "a priori" schemes, as Telesio asserted [14]. For example, Da Vinci, who exemplifies the Italian renaissance, aggressively pursued natural reality in his paintings and inventions [15]. Many of his works can be understood as those showing the pre-separation between art and technology.

In the 17th century, the resumption of the notion of value in modern times started with the revival of the subjective notion of good proposed by Hobbes [16]. He explained "scientifically" the logical connections between phenomena of social life and their causes. Order is wholly useful and valuable to people's lives as it is conceived to provide the instrument that everyone needs against the brutality of war. Protection, safety and peace, desired by all as utmost values, are achieved through a "social contract" by which all men renounce their natural egoism, ambition and desire of power in favor of a superior political authority (absolute monarchy) which all must obey.

In the frame of the 17th century's renewed attention to value problems, it is worth mentioning Descartes [17], who founded Cartesian dualism. His main concern was how people can understand the world without the concept of a soul, by separating *mind and body*, *subject and object,* and *whole and parts*. His thought, which was classified later into Mechanism or Mechanical Materialism, is known as a basis of modern natural science. In natural sciences, physical phenomena must be understood objectively. In other words, Descartes' challenge might be understood as a challenge to define the objective value.

In the 18th century, on the other hand, philosophers started to study the subjectivity of values. Epistemology [18] (or Theory of Knowledge) is a branch of philosophy concerned with the nature of knowledge (such as truth, belief, and justification). Kant founded German Epistemology [19]. He integrated Rationalism, which had been originated by Descartes, and the Empiricism of Locke [20], Bacon [21], and Hume [22]. Although Kant's thought is difficult to explain in detail here, humans form perceptions using natural abilities of sensibility and understanding. Humans also have a scheme for understanding the world: perception does not follow objects, but objects follow perception. His thought passed to Rickert, who established Wertphilosophie, which examines human value judgment [23], to Hegel, who insisted on absolute idealism according to a dialectic [24]. His thought affected that of Husserl, who is known as a founder of Phenomenology [25], by which values can be treated as intersubjective phenomena rather than subjective judgments.

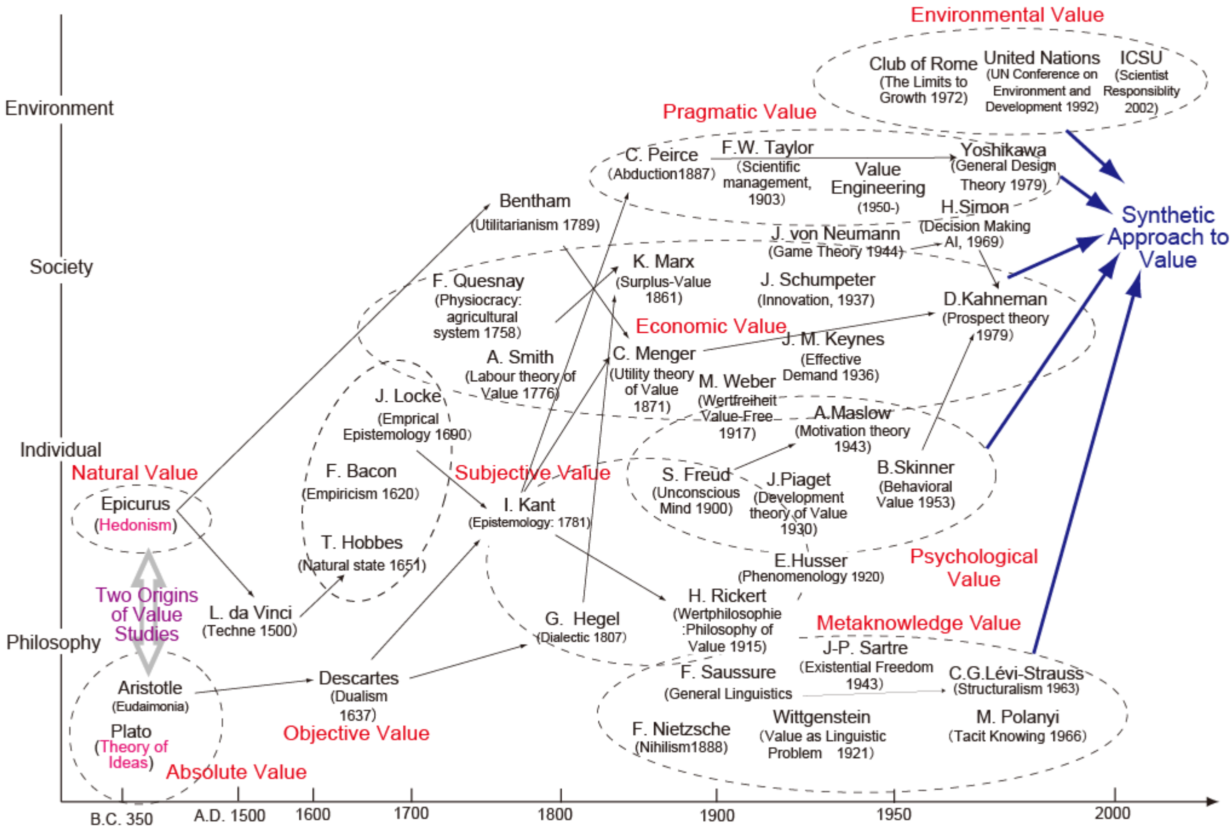

Fig. 2: Genealogy of Axiology

Subsequently, some philosophers after the late 19th century mounted radical challenges of historical assumptions to values such as objectiveness and subjectiveness. Nietzsche vehemently denied the objectivity of values with his idea of Nihilism [26]. Wittgenstein insisted that all traditional philosophical problems such as virtue, value, and freedom are nothing but linguistic problems [27]. Their challenges could be understood as Metaphilosophical or Metaknowledge-related approaches to values.

Subjective value rose to prominence as a main concern for psychology founded in the late 19th century. However, it would be a difficult problem for psychologists to define values as did philosophers in the same age. Freud, who founded the psychoanalytic school of psychology, examined human natural values from the viewpoint of unconsciousness [28]. Piaget studied value problems from the viewpoint of a child's cognitive development, particularly addressing schema that change on several stages of development [29]. In Behaviorism of the early 20th century, values were studied from the viewpoint of learning [30]. Operant conditioning is a topic of the psychology of learning, which studies the modification of voluntary behavior or "operant behavior" through conditioning using reinforcement and punishment. It could be said that those approaches did not examine cognitive values but instead examined behavioral values. One interesting fundament of the psychology of learning is the "discounting of values" which usually applies to delayed rewards. This tendency of assessment has also been revealed in economic value judgments described in behavioral economics [31].

Value problems are described also in the Humanistic Psychology literature of the mid-20th century. Maslow is well known for conceptualization of a "hierarchy of human needs", which presents values from the viewpoint of human fundamental needs [32]. His concern was how people can self-actualize, and thereby overcome negative aspects of humanity. He attacked difficult problems such as value, creativity, and morality that are avoided in other psychological research areas.

From the 1960s to the present, many psychologists have been affected strongly by cognitive sciences. Now, the cognitive approach has become the mainstream in many psychological research areas [33]. Unfortunately, in cognitive psychology, values are not explored actively because they are difficult to investigate from an information-processing viewpoint. This might be true not only in psychology but also in other cognitive sciences. Early artificial intelligence, for example, encountered a similar problem [34]. It is difficult to define abstract concepts such as values held by humans using symbolic manipulation. For that reason, value studies in many academic fields present blank periods in recent decades.

Although it might seem to be a change of subject, consideration of values from an economic viewpoint cannot be ignored. Physiocracy—as described by Quesnay in the middle 18th century—is often designated as the origin of theories of economics [35]. In physiocracy, value is defined as the volume of net products of its industries, not the stocks of gold and silver. Especially, it regarded agriculture as the only activity that generated a net product. This physiocracy subsequently affected the ideas of Adam Smith.

Smith reinforced classical economics with his concept "Wealth of Nations" [36]. In that treatise, value was classified into two types: use-value and exchange-value. Use-value is the usefulness of a product or its utility, whereas exchange-value is equal to the relative proportion with which a certain product can be exchanged for another product. Smith considered that labor is the real measure of the exchange value. Consequently, he developed the labor theory of value. Ricardo also took Smith's stand and extended the theory [37].

Marx elaborated his labor theory of value and his concept of surplus value [38]. He argued that exploitation would ultimately engender a falling rate of profit and the collapse of industrial capitalism. Based on his idea, modern Marxist economics was constructed.

As described above, classical economists such as Quesnay, Smith, and Marx assert that economic values exist as absolute values. Subsequently, economists who are classed in Neoclassical Economists have challenged the absoluteness of economic values.

In the 1870s, the marginal utility theory, formulated independently by Menger, Jevons, and Walras, presented a unified explanation of use-value and exchange value with a specific examination of the idea of utility [39]. According to the theory, marginal utility was explained according to the subjective satisfaction that a consumer derives from the consumption of one extra unit of a product. Consequently, an individual's demand for a product is determined not by its total utility but by its marginal utility. Therefore, the greater the supply of a product, the lower its marginal utility. Principles of marginal utility theory form the foundation of neoclassical economics.

However, utility under their idea was defined as cardinal utility. In other words, utility was conceptualized as measurable and the magnitude of the measurement was meaningful. In contrast, Pareto established that ordinal utility can be used to derive the same propositions as cardinal utility [40]. Consequently, it is sufficient to consider ranking of the different available alternatives, meaning that economists can be released from the torment of measuring value on an objective scale.

On the other hand, we cannot ignore an important topic when considering value in economics. It is the expected utility theorem by Neumann and Morgenstern [41]. This theory treats utility under uncertainty. It is roughly summarized that value is calculated according to a person's expected level of utility, which is represented as the probability of an event. However, utility is presumed implicitly to be cardinal utility. Although this idea becomes the fundamental basis of game theory [42], it presents an apparent contradiction to the idea of neoclassical economics that is established with ordinal utility. In addition, prospect theory by Kahneman and Tversky is presented using approaches of behavioral economics [43]. This is the theory with respect to decision-making under risk and has a close relation with value.

Apart from economic values, how has value been treated in engineering? The main challenge undertaken by engineering is how to produce goods or services with higher function at lower cost. Even if the definition of lower costs might be readily apparent from an economic viewpoint, higher function is not readily defined.

Scientific management established by Taylor [44] has been successful at cost minimization in the last century's manufacturing development. Basic problems of design and functionality of artifacts are fundamentally related to Peirce's idea in reasoning [45]. "Abduction" is the process of adopting an explanatory hypothesis in reasoning. Based on that idea, Yoshikawa invented "General Design Theory" [46], which formulated design processes and functions of artifacts. Yoshikawa's challenge can be understood as a definition of the “functional value” of artifacts.

Another challenge of production engineering is “Value Engineering” [47]. “Value Engineering” was first adopted at General Electric Co. during World War II. Its emphasis is how to improve the "value" of goods and services using an examination of function. By Value Engineering, the value is defined as the ratio of function to cost. Therefore, the value can be increased either by improving the function or by reducing its cost. Additionally, they developed a systematic methodology as a “job plan” which included “value analysis”. This idea might be useful when considering how to realize the same function at lower cost using different materials. In such a case, we must assess values of products from several viewpoints such as quality, basic function, and customer satisfaction. Nevertheless, fundamental problems about values cannot be solved by such an examination because it is not easy to define satisfaction for customers. Satisfaction comprises many factors such as comfort, happiness, good price, and pride of ownership. Satisfaction poses a more severe problem to assessment of services than products, as discussed in the later section related to service engineering.

In relation to design problems also, important discussions related to values were presented by Simon [48] who contributed to the formation of artificial intelligence from its early days. He clarified some difficulties of value problems such as bounded rationality [49], decision-making, and satisficing behavior. With bounded rationality, he points out that most people behave only partly in a rational manner; in fact, emotions and irrationality dominate the remainder of their actions. This bounded rationality is expected to be an important point to understanding human value judgments. He also described “satisficing” as an interesting mechanism of human satisfaction: it is a decision-making strategy to meet criteria for adequacy, rather than to achieve an optimal solution. These are critical problems when considering human satisfaction.

In this context, we also devote attention to the implicit aspect of values. Polanyi, using a concept of “tacit knowledge” described that people know more than they can tell [50]. Without great regard to detail herein, the word “Embodiment” represents a similar aspect of values of human knowledge. In other words, the human body plays an important role in the cognition of values.

2.2 Value and sustainability

The last and most recent topic for discussion as an academic challenge to value is the problem of sustainability. We must contribute to sustainable development to realize a recycling society with a low impact on the environment. This problem was originally raised as a social issue or an environmental issue by organizations such as the Club of Rome, which garnered considerable public attention with its report “Limits to Growth” published in 1972 [51]. More recently, the International Council for Science Union (ICSU) gave the Executive Board a clear mandate to set an international research agenda for the future that specifically examines science for sustainable production [52].

As discussed in section 3.6, sustainability has been defined within ecological, social, and economic contexts. In the ecological context, carbon-dioxide emissions, natural resources, and bio-diversity are often discussed as indicators of sustainability. In this context, sustainability is apparently a kind of absolute value or “value as it should be” as discussed by many philosophers from the time of Plato. Simultaneously, in social and economic contexts, we cannot ignore “values as they are” as originally described by Epicurus. In other words, people have a right to pursuit their pleasure or happiness, but these two conflicting values often present a dilemma between values of the collective and the individual. To resolve this dilemma, greater attention must be devoted to the mechanism of human value judgments and social value systems including market mechanisms. Moreover, this is not an analytic problem but a synthetic problem. We must construct a new design principle that particularly addresses decision-making among many stakeholders.

Now is the time to begin a new study of values toward a sustainable society. Nevertheless, as described above, no similar problems are described in the history of value studies. Instead, the problems seem to include multiple conceptions of values. For this purpose, we should integrate values such as ecological value, pragmatic value, economic value, psychological value, and Meta-knowledge value. “Sustainable value” is an important concept that targets not only ecological sustainability but also social and economic values.

This paper specifically examines the academic challenges only in the West. However, we shall devote some attention to the thoughts and cultural attitudes for values in Non-Western countries. That examination will enhance the creation of “sustainable value” from a global standpoint.

3 DIFFICULTIES IN VALUE CREATION

This section presents a description of the difficulties in value creation in the real world. It defines key issues from the viewpoint of value creation. Moreover, it presents discussion of current problems such as social dilemmas, decision-making problems, and sustainability.

3.1 Value of artifacts

As presented above, during the history of axiology, value has been studied mainly from human or social perspectives, especially in philosophy, economics, and psychology. Nevertheless, value must be discussed also from the viewpoint of design of artifacts, especially in engineering and management science.

As depicted in Figure 3, the creation of an artifact begins with acquisition of knowledge about existing things; it starts with obtaining knowledge about the existing environment (natural and social), knowledge about human beings, and existing artifacts [53]. Creation is accomplished through analyses of comprehensible knowledge, even if it is incomplete. Disciplines that cover these objects are regarded as natural sciences for existing nature, social science for existing society, humanities for existing humans, and engineering for existing artifacts.

For creation of a new artifact, it is necessary to obtain a set of knowledge by collecting and selecting these acquired pieces of knowledge. It must be structured to obtain an attribute through connection of knowledge. In other words, the artifact is embodied by structure. In general, several possible combinations of connections or potential solutions can satisfy the requirements; in some cases, their number might be nearly infinite. Therefore, a common practice is to introduce an objective function and seek the optimal structure from among possible structure solutions.

From this perspective, the essence of engineering comprises analyses of the behavior of existing artifacts.

More importantly, it consists of discerning the entire structure from partial knowledge: the essence lies not in analysis but in synthetic acts. Analysis extracts partial knowledge from the whole body of an existing artifact and synthesis composes a whole body from partial knowledge. Consequently, Yoshikawa [54] asserts an inherent asymmetry between the two; this assertion presumably refers to this situation.

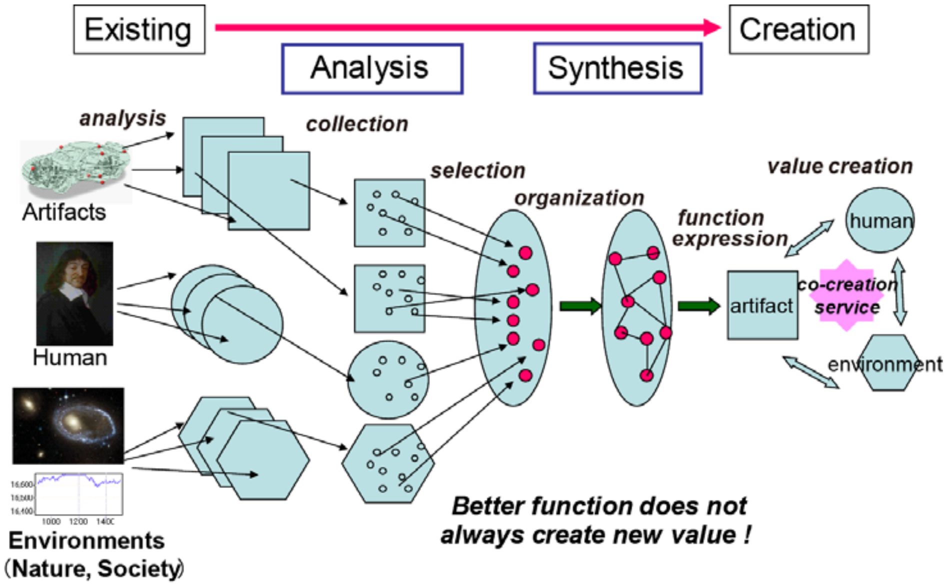

Fig. 3: From analysis of existing things to value creation [53].

The former might be called the *"science of recognition"*; the latter is the *"science of design"*. Once a structure has been determined from some knowledge, its function can be thought of as exhibiting spontaneity. It follows that the *raison d'etre* of engineering is the creation of a functional artifact.

Nevertheless, the story does not end here because a functional artifact does not always create value. It is overly optimistic for engineers to assume unconditionally that a functional artifact ensures good value. The artifact creates value by appearing as a player on the stage consisting of the environment (natural and social) and human beings. Unless it operates well in that environment, is exchanged on the market, and used by human beings, it is merely an artificial physical object that creates no value. Actually, the artifact itself does not even present a function; it functions through interaction with the environment. Simon [48] said of this relation that the problem of designing an internal environment that is consistent with the external environment is the essence of engineering as a science.

Assuming that an artifact is known to operate as a structure in a certain environment, do we begin designing the artifact's structure only after that environment is known completely? The answer is that such cases are rare. The environment undergoes unexpected changes and cases exist in which even the designer's intention is indeterminate. Emergent processes are, to varying degrees, involved in this process. The authors call such a design act and design process emergent synthesis [55].

3.2 Value co-creation among systems

The creation of value must be discussed in the relation among systems of artifacts, humans, and society. Figure 4 portrays three systems, particularly addressing values, subsystems, and problems in individual systems. It depicts functional relations or interactions among systems. In human systems, satisfaction can be considered as the most important characteristics of values: consumers judge the value of goods by the degree to which they are satisfied by consuming them. On the other hand, in the systems of society, especially in the market, the value of goods appears as a price. As discussed in the history of economic studies of values, although numerous utility theories have been formulated, subjective satisfaction is describable using a utility function in an objective form. Meanwhile, in artifact systems, from the viewpoint of production, the value of an artifact is understood by cost for function. The value as total profit for a producer can be described as an objective function or a cost function. Consequently, manufacturers have a social role of solving cost minimization problems.

However, for value creation, a manufacturer must pay more attention to value mechanisms of other systems. In other words, they must study how values of artifacts appear in the society from relations among systems: values are co-created through interaction among systems.

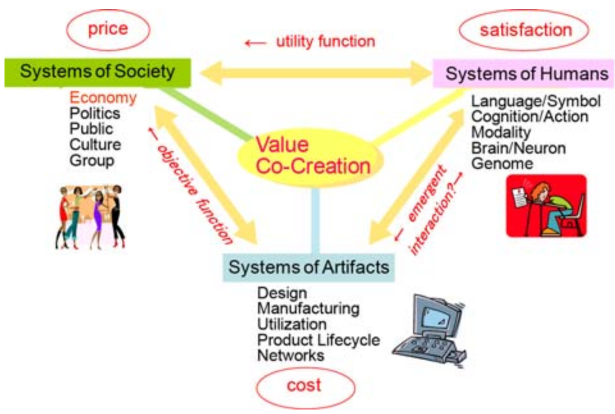

Fig. 4: Value co-creation among systems.

Furthermore, value creation of artifacts must be discussed in systems that include natural systems. According to Lubchenco [56], as the magnitude of human impacts on the ecological systems of the planet becomes apparent, there is increased realization of the intimate connections between these systems and human health, the economy, social justice, and national security.

Figure 5 depicts the relation among social systems, artificial systems, and natural systems. The goals of systems are portrayed at the apices of triangles. Desirable connections (upper) and actual problems (lower) are shown between systems. Sustainable development demands that we specifically examine problems that appear in relations among systems. However, the variances between systems often bring undesirable problems. Pursuits of the values of society deplete resources. Furthermore, artificial systems sometimes engender large-scale accidents against the original purpose of artifacts. Bloated artificial systems gradually bring environmental destruction. However, all those problems arise from various human value concepts. Therefore, to solve those issues, we must study the underlying difficulties from the viewpoint of decision-making among stakeholders. The following subsections present some current problems such as social dilemmas, public goods, and network externalities as decision-making problems.

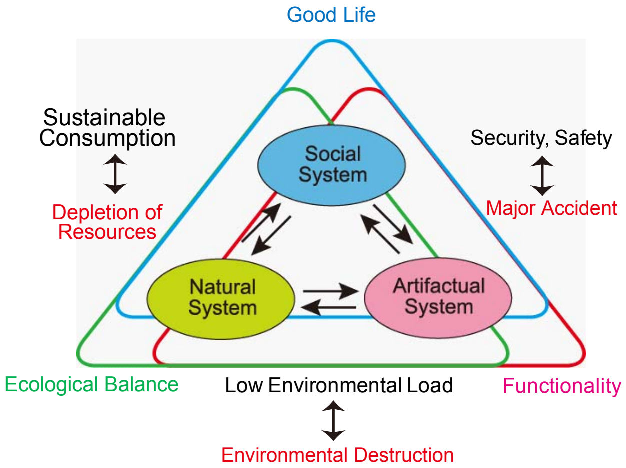

Fig. 5: Relations among social, artificial, and natural systems for sustainability.

3.3 Social dilemma

“The tragedy of the commons” presented by Hardin [57] is a famous historical parable describing a pasture that is open to all herders: all try to maintain as many cattle as possible on common lands and thereby obtain their individual benefit. The commons are thereby ruined and all herders suffer. This creates a “social dilemma”, as formulated by Dawes (1980) [58]. According to the literature, such a dilemmatic situation is defined by two simple properties: (a) an individual receives a higher payoff for a socially defecting choice (e.g., having additional children, using all energy available, polluting the neighborhood) than for a socially cooperative choice, no matter what other individuals in society do, but (b) all individuals are better off if all cooperate than if all defect. Particularly, if the interacting decision-makers are two people, the so-called Prisoner’s Dilemma arises.

Innumerable social dilemmas confront humans in the real world. For example, environmentally conscious behavior reveals characteristics of the dilemma posed by self-interest and public interest: environmentally conscious behavior is necessary to realize a sustainable society, but it is frequently unprofitable: self-interested behavior that ignores environmental issues usually brings high profit or other benefits, at least in the short term. Manufacturers confront a similar dilemma in production activities. They generally incur large costs to produce eco-friendly products: they can produce ordinary products at lower cost than eco-friendly products. The environmental burden would be increased if no one were to manufacture eco-friendly products.

3.4 Public goods and decision-making

"Public goods" in economics are goods or services with the property of non-rivalry and non-excludability. Non-rivalry is the property by which each person’s consumption of a good detracts in no way from any other individual’s consumption of the good. Non-excludability is a property by which no person can be prevented from using a good, even if they have not paid for it. Table 1 presents a classification and examples of public goods.

The public goods concept was first proposed and formulated by Samuelson [59]. Numerous similar studies have been made in several fields. Under circumstances in which people make decisions with respect to public goods, the social dilemma often arises and consequently presents free-rider problems. Perfectly rational decision-makers pursue profit maximization. Therefore, appropriate goods and services allocation is difficult.

Table1: Public goods types.

	Excludable	Non-excludable
Rivalrous	Private goods Food, clothing, car, etc. (An economic good or a tangible item that can be purchased and traded within a market.)	Semi-public goods (Common-pool resources) Fisheries, Forests, Oil fields, Groundwater basins, etc.
Non-Rivalrous	Semi-public goods (Club goods) Community service, Cable television, Computer software, etc.	Public goods National defense, Public parks, Street lighting, etc.

3.5 Network externality

Network externalities affect a consumer’s utility depending on the number of consumers who use the same product that the consumer uses [6]. Recently, markets with network externalities have been expanding through development of information technology. Mobile telephones and internet services are typical examples of network externalities.

In situations with network externalities, high technology does not necessarily create value in a society because value is created through interaction among consumers. The product value cannot be defined independently merely through technological specifications. For example, if network externalities are present, new technology might not be adopted and inferior technology might win in the process of transition despite the fact that the adoption of new technology would have greater benefits in the long run. Transition from an already installed base is occasionally difficult when network externalities are working. Farrell and Saloner called this phenomenon “excess inertia” [60]. On the other hand, an opposite phenomenon might arise in circumstances with network externalities. That phenomenon is called “excess momentum". A new technology might be adopted immediately because of effects of network externalities, even if the adoption of that new technology is premature and inefficient for a society.

Decision-making in an environment with network externalities is profoundly interdependent among consumers and producers. Therefore, network externalities are also characteristics that complicate some valuation related problems.

3.6 Sustainability, sustainable development, and sustainable manufacturing

As described above, we must make decisions in a society for value creation with consideration of difficult problems such as social dilemmas, public goods, and network externalities. Sustainability poses a difficult problem from the viewpoint of decision-making in a society.

Although the concept of "sustainability" has been defined within ecological, social, and economic contexts, it remains difficult to define it in a comprehensive manner. In an ecological context, sustainability is definable as the capacity of ecosystems to maintain necessary processes and functions and to retain biological diversity without impoverishment. On the other hand, any form of economic development is sustainable if it does not violate or destroy the limits of our human condition. There is a common understanding that these limits might be imposed by our closer and wider environment (biosphere), our social and cultural embeddednes, as well as our mental and cognitive constitutions. Note that human conditions are not meant here as human abilities or capabilities. For instance, we design, produce and apply levers to increase our muscular power; and so do we when inventing artificial intelligence techniques that amend and augment our cognitive capabilities. Our physical and mental capabilities can be surpassed, but not the conditions of our existence.

For all of these reasons, "sustainable development" has been a key issue in an economic and social context. The World Commission on Environment and Development (WCED) [61] declared that "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*"

At the national and regional level, international organizations have promoted and are promoting and managing initiatives related to sustainable development and competiveness. For instance, activities of the Division for Sustainable Development (DSD) within the United Nations Department of Economic and Social Affairs concern clusters of issues [62] such as "Energy for sustainable development, air pollution and atmosphere and climate change". The European Commission defined a set of indicators for monitoring the implementation of a strategy for sustainable development. Its primary objective is a survey of the current state of play in the implementation of the strategy [63]. The trends derived from analyses of indicators [64] are assessed against policy objectives to inform the public and decision-makers about achievements, tradeoffs, and failures in attaining the commonly accepted objectives of sustainable development.

According to Seliger [65–66], sustainable development is directed at enhancing human living standards while improving the availability of natural resources and ecosystems for future generations. Figure 6 portrays a broad concept with interactions among three domains: the economy, society, and environment. Sustainable political, economic, and social stability can be achieved only if humankind——not merely the first world——can create jobs and living conditions that support human dignity.

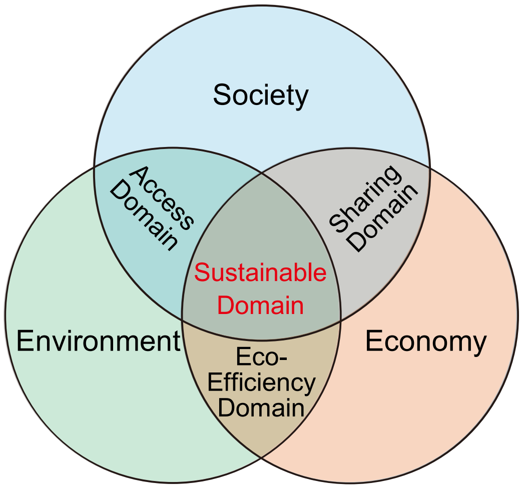

Fig. 6: Fundamentals of sustainable development [68].

Recently, sustainable development has also been discussed in the context of manufacturing. Jovane et al. deeply discussed competitive sustainable manufacturing (CSM) as supportive of sustainable development [67–69]. A reference model for proactive action (RMfPA) was proposed to develop and implement CSM, at national and global levels: see Figure 7. Necessary actions by stakeholders at different levels, extending from policymakers to Industry, University and Research Institutes, are also discussed. The CIRP, as a global academy, can play a relevant role at strategic, scientific, and technological levels for the coming global technological and industrial revolution: CSM.

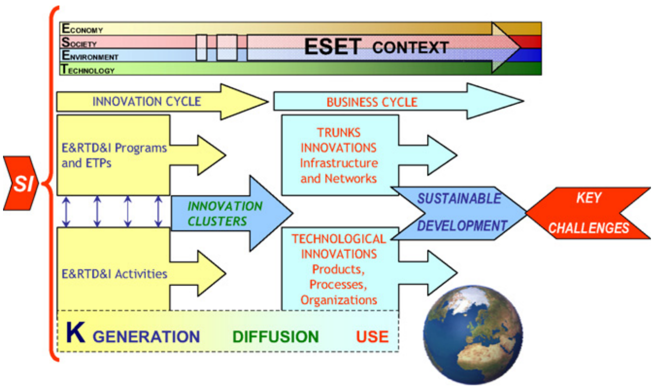

Fig. 7: Pursuing CSM: reference model for proactive action.

Yoshikawa [70] described diversified requirements for sustainability from the macro level to the field level (Figure 8). Goals of sustainability present several aspects. Problems must be solved from several perspectives.

However, as discussed in this section, diversified requirements often engender difficult problems. Environmental sustainability is expected to be a problem of public goods; discrepancies between overall purposes and individual happiness often present a dilemma structure (Figure 9). Although it might be advisable to promote sustainable actions and to exclude free riders through some law or regulation, we cannot deny individual rights to the pursuit of happiness. Simultaneously, it is expected to be inadequate to rely merely on individual conscience or social morality.

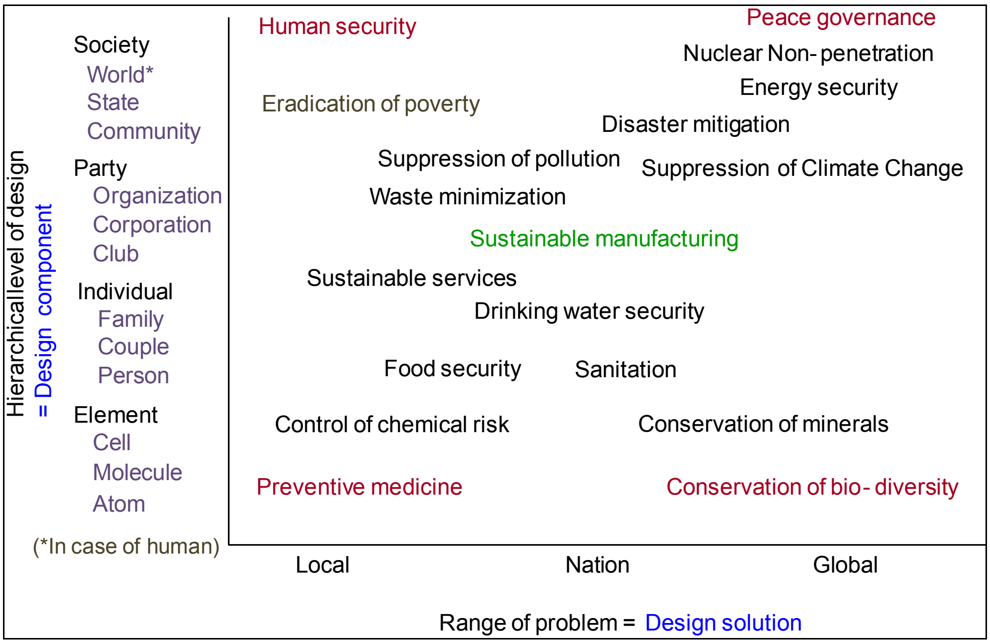

Fig. 8: Diversified requirements necessary for sustainability – Design components and solutions [70].

Therefore, it is desirable to realize a system in which both the overall purpose and individual happiness can be achieved concurrently through decision-making among various stakeholders. To this end, we must study values from various viewpoints: environmental, national, economic, ethical, and psychological viewpoints. Moreover, “sustainable value” must be a synthetic value that is achievable through dynamic interaction among decision-making agents that have various goals and values.

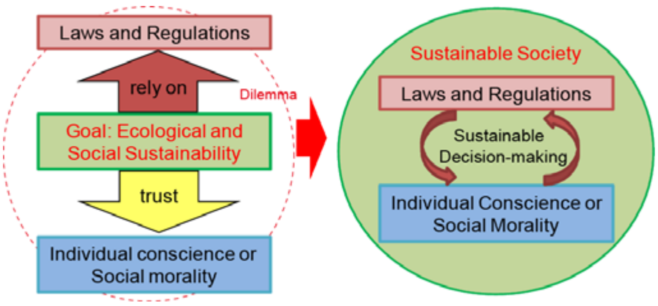

Fig. 9: Sustainable decision-making.

4 APPROACHES

Next, we discuss important approaches to solving problems and to creating sustainable value in a society. Various approaches are not domain-specific, but deterritorial and strategic ones. Both analytic and synthetic approaches to value creation are expected.

4.1 Transdisciplinary approaches

According to Koizumi [71], over the past two centuries, human culture has been split into two categories, defined as science and technology, and humanities and arts. Science and technology have been divided further into clearly specified disciplines. Consequently, it has become difficult to understand other disciplines at a professional level because of the intellectual barriers separating disciplines. Maturation of science and technology, however, has increasingly rendered it difficult to obtain new findings and breakthroughs solely within a specialized discipline. New findings and technical breakthroughs are often achieved only by bridging gaps separating different disciplines; this has been true for many years. These problems intensify as we confront the problem of sustainability.

Many scientists and scholars have recognized the importance of transdisciplinary approaches, but it is difficult to transcend the borders of disciplines in practice.

Research into Artifacts, Center for Engineering (RACE) [72], for instance, was established in 1992 as a research center at The University of Tokyo, aiming at three research fields, Design Science, Manufacturing Science, and Intelligence Science. In April 2002, RACE was newly reorganized into four new research divisions, Life Cycle Engineering, Service Engineering, Digital Value Engineering, and Co-Creation Engineering. A fifth research division named “Value Creation Initiative” was established in December 2005. Through its existence, RACE has sought to solve the problems of "modern evils in manufacturing artifacts", and has pursued activities to invent new methodologies to create unprecedented relations among humans, artifacts, and their environment without being shackled to conventional methodologies. For this purpose, Deterritorialization and Dematerialization are important concepts. Service engineering, for example, is thought to be a dematerialization-oriented challenge that enables value creation in a society.

Not only in engineering, but also in human and social sciences, transdisciplinary approaches are remarkable for value creation in society. Sport sciences and health sciences are promising disciplines that integrate medical, social, psychological, and technological approaches [73]. The targets of health sciences are the understanding of human function in addition to improving health and preventing and curing disease: synthetic studies are important for transdisciplinary approaches.

4.2 Converging technologies

In both Europe and the USA, researchers and policymakers have recognized the potential of converging technologies to improve human performance and productivity for a sustainable society.

The US Government refers to convergence as the integration of Nanotechnology, Biotechnology, Information Technology and Cognitive Science (NBIC) and envisions that the mastery of the nanoscale domain will ultimately engender mastery of all nature [74]. In the NBIC worldview, a "material unity" exists at the molecular level such that all matter—living and non-living—is indistinguishable and can be integrated seamlessly. The NBIC goal is "improved human performance" both physically and cognitively (e.g., on the battlefield, the wheat field, and on the shop floor).

The European Commission released a report on Converging Technologies, prepared by the High Level Expert Group, entitled "Foresighting the New Technology Wave" [75]. Distancing itself from the US agenda of "improving human performance," the Group emphasized a "specifically European approach to CTs." The Group proposed Converging Technologies for the European Knowledge Society (CTEKS), describing different research programs addressing specific problems such as "CTs for natural language processing" or "CTs for the treatment of obesity." The Group predicts that CT applications are "an opportunity to solve social problems, to benefit individuals, and to generate wealth," but pose "threats to culture and tradition, to human integrity and autonomy, perhaps to political and economic stability."

Recently, Jovane, Westkämper and Williams discussed promising technologies for sustainable manufacturing and propose the generic model of ManuFuture, Vision 2020 and a strategic research agenda [67].

The goal of converging technologies is producing an academic strategy for sustainable development. For this purpose, we must continue discussion of strategic integration among academic disciplines.

4.3 Synthesiological approaches

Recently, traditional analytic approaches' problems and limitations in science have been pointed out: many researchers claim a synthetic approach to problems in the real world including sustainable development issues. "Synthesiology" is a new academic journal, published in 2008 by the National Institute of Advanced Industrial Science and Technology (AIST, Japan). "Synthesiology" is a coined word joining "synthesis" and "ology" [76].

According to Yoshikawa, science traditionally starts with an object of study that it analyzes to elucidate it. The results accumulated by scientists contribute to the development of new scientific disciplines. As analytical processes advance, the object of study grows narrower as analyses become more specific and detailed in their emphases: the scientific disciplines themselves become increasingly narrow and specialized. A framework and a supporting logic must be used to integrate the massive assemblage of analytic results and facilitate their application to society if these analytic results are to contribute to society and solve problems that we face.

A traditional analytic approach is designated as "Type 1 basic research." The proposed and defined Type 2 basic research is the following [77].

"A form of research that integrates the knowledge of different disciplines or creates new knowledge when necessary, and transforms a concept into artifacts (product or service) that can be recognized by society."

According to Ueda, academic activities are classifiable into quadrants depending on analyses or syntheses according to objective and methodology: see Figure 10. Traditional engineering, resembling that in the second quadrant, conducts a study for Synthesis (or Creation) using an analytic approach. It can be said to be an assembly of existing knowledge. Therefore, it necessitates an assembly or "gathering up". So-called "pure science" falls into the third quadrant. Its target is to elucidate Nature, employing analytic methodology, i.e., analysis by analysis. In the fourth quadrant, frontier or advanced science and technologies might remain. A new and synthetic methodology is necessary to break through the limitation of existing methodologies, but the goal of those studies is the understanding of Nature. Converging technologies might also remain there. Last, but not least, design theory of artifacts and value creation in a society remain in the first quadrant. In this area, both the target and methodology must be synthesis: synthesis by synthesis. Furthermore, it is important that the achievements in the quadrant contribute to other quadrants as a theory of design.

As discussed above, synthetic or Synthesiological approaches are necessary to solve problems in the real world and to create sustainable value in a society.

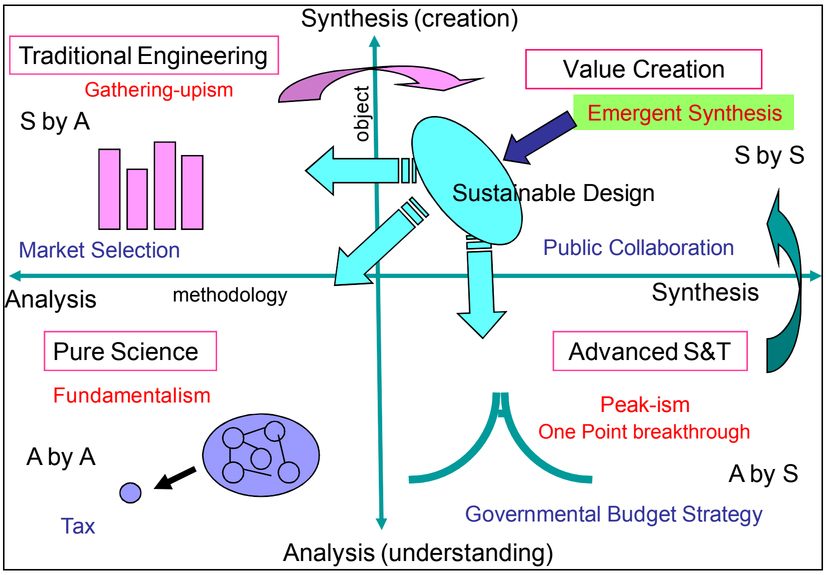

Fig. 10: Research Positioning by Synthesis and Analysis

5 METHODOLOGIES

Some important methodologies for value creation and decision-making in the real world are discussed in this chapter. Emergent synthesis and co-creative decision-making are introduced as bases of academic methodologies. This chapter presents discussion of important topics such as lifestyle studies, incentive mechanisms, and complex adaptive systems for institutional design as remarkable methodologies to elucidate and resolve problems in society with increasing instability.

5.1 Emergent synthesis

The problem of synthesis, which must be solved for designing artifacts that satisfy required functions, is called the inverse problem: determination of the system's structure to perform its function and thereby achieve a purpose under environmental constraints. Figure 11 portrays the problem of synthesis, which is the design process from function (purpose) to structure (action).

Figure 12 presents a diagram of *emergence* [55]. The term emergence is used to signify "a global order of structure expressing a new function that is formed through bi-directional dynamic processes, where local interactions between elements reveal global behavior, which imposes new constraints on the behavior of the elements". Most important is the formation of a stable global order, which is neither fixed, periodic, nor chaotic, but which is complex. A stable global order imparts a new function. It can be a solution if the function meets a specific purpose.

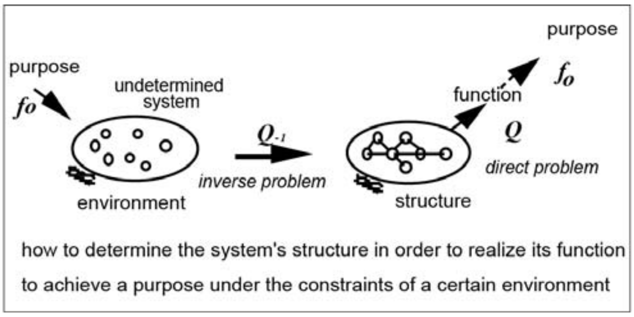

Fig. 11: Problem of synthesis.

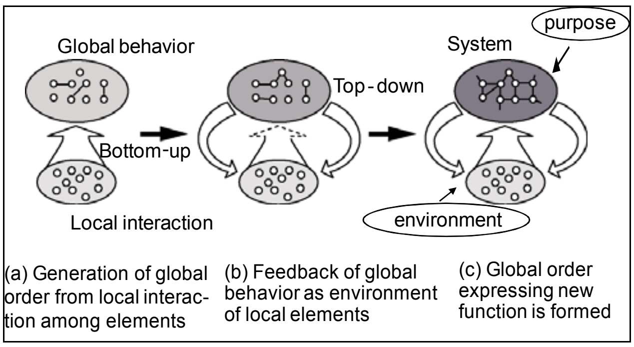

Fig. 12: Concept of emergence.

Instead of traditional approaches, which are analytic and deterministic approaches based on top-down problem decomposition, emergence-based approaches are being developed with both bottom-up and top-down features. They include evolutionary computation, self-organization, behavior-based methods, reinforcement learning, multi-agent systems, and game theory. They are promising for offering efficient, robust, and adaptive solutions to the problem of synthesis. Recently, Monostori et al., for instance, surveyed software agents and multi-agent systems comprehensively and discussed their potential manufacturing applications [78].

Authors of those earlier reports asserted that emergent approaches are more useful for solving these problems than usual approaches—either analytic or deterministic.

In previous studies [55, 79, 80] because of incomplete information related to the environment or purpose, difficulties in synthesis have been classified as follows.

- Class I – Problem with complete description: if information of the environment and purpose is given completely, then the problem is entirely described, but it is often hard to find an optimal solution.
- Class II – Problem with incomplete environment description: the purpose is complete, but information related to the environment is incomplete. Because the problem is not described completely, coping with the unknown environment's dynamic properties is hard.
- Class III – Problem with incompleteness: the environment description and the purpose are incomplete. Problem solving must therefore start with an ambiguous purpose. Human interaction becomes important.

For Class I, because specification of the purpose and the constraints attributable to the environment are fixed, the problem is known completely from the beginning. However, in most cases, too many feasible solutions exist, which engenders combinatorial explosion and creates so-called NP-hard problems. Consequently, it is necessary to develop efficient, robust search methods to identify optimal solutions. For this type of problem, evolutionary computation methods have been applied: genetic algorithms, genetic programming, evolutionary strategies, and evolutionary programming. This class of model can be characterized as fixed in both its syntax and semantics.

In Class II, despite the fixed specification, missing information about the environment engenders unforeseen constraints of problem solving. These constraints must be identified through repeated interactions with the environment. Approaches based on learning and adaptation, such as reinforcement learning or adaptive behavior based methods, are feasible to resolve this class of problems. Fixed semantics and adaptive syntax characterize models of this class.

In Class III problems, in addition to the lack of environmental information, we must cope with the ambiguity of human intention. Problem solving in this class must include iterative determination of system structure. Moreover, human designers must be considered to include changing specifications. Therefore, realization of human participation in the design of the target system (object)—including the designer itself (subject)—necessitates additional emergent properties in this class: co-creation, co-evolution, and self-reference.

5.2 Co-creative decision-making

Co-creative decision-making is collective decision-making that creates an effective solution as a whole system through mutual interaction among varieties of agents, as presented in Figure 13. In a co-creative system, in contrast to a simple emergent system, the elements are agents that make various decisions. An agent is a subject that makes its own decisions. Therefore, it has an internal structure and itself forms a system that causes behaviors to emerge. In other words, in a co-creative system, the agents cause a behavioral solution to emerge through the organization of their own internal structures; moreover, they mutually interact. A so-called multiplicity of emergence co-creates a behavioral solution of a whole system through the self-organization of their own internal structures.

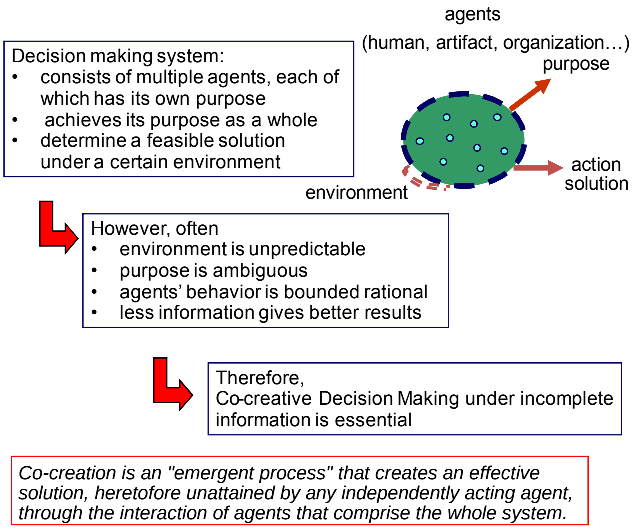

Fig. 13: Model of Co-creative Decision-making.

Furthermore, a salient feature of a co-creative system is that the system designer can become a system component. The system's purpose can be given by the designer from outside if the designer can exist outside the system. However, the system's purpose will also emerge through interaction among agents if the designer exists inside the system, which implies that the designer, who was externalized as a purpose-giver, enters the system in a conventional decision-making model. The entire system's purpose is self-created internally, with accompanying emergence of a behavioral solution for the overall system. The authors call this a Designer's Problem. Separation of recognition and design are unlikely to take place here.

The co-creative decision-making problem in manufacturing is related to the problem of interaction between manufacturers and consumers. Ueda et al. proposes an interactive production system that specifically examines human interaction in a production domain based on Biological Manufacturing Systems [81]. Márkus and Váncza propose a generic product positioning tool in which viable product families emerge from various technically feasible product alternatives through interaction between customer preferences and the reallocation of manufacturing resources [82].

5.3 Lifestyle studies

Recently, studies of consumers' lifestyles have received attention in service and product design studies [83–88]. Concomitantly with rapid networking and globalization, it is becoming difficult to understand consumers' values and lifestyles [89–90]. As an apparent contradiction, information technology advancements support the gathering of data from records of prepaid cards, credit cards, mobile cards, mobile wallet, etc., related to consumers' daily behaviors: purchasing, transfers, and communications from logs of various devices. Nevertheless, it remains difficult to grasp various lifestyles and to design new services based on diverse lifestyles. New methodologies for modeling human lifestyles and values based on large amounts of data are required.

However, studies of lifestyles in the traditional fields of psychology, sociology, and marketing will not necessarily satisfy engineering necessities of addressing design or creation of new services specifically. Many survey studies of human lifestyles conducted by government-affiliated organizations or private research institutions often report only a percentage of respondents to each question. Often, the questions are too general to construct multiple models of human lifestyles from a design viewpoint. However, some marketing surveys pose limited questions that are connected directly to business purposes. Moreover, they typically classify results according to age and sex.

To cope with these problems, Ueda et al. describe results of a lifestyle survey to build agent models of humans that are useful for a service design, and conducted multi-agent simulations to examine diffusion of services in a market [91–92]. The survey comprised multiple questionnaires that assessed daily behavior, leisure, personality, and attitudes toward information technologies. Through analyses of those results, they intend to identify effective segmentations of lifestyles and to specify effective parameters to build human agent models. The survey results reveal interesting relations among personalities, daily behaviors, and usage of information technologies (e.g., internet, mobile telephony). Results of factor analyses suggest that people are apparently of two types according to their capability of planning daily behavior and dependence on information technologies.

Components of lifestyles are not mutually independent. A lifestyle seems to have holistic characteristics or a global order. Moreover, individual lifestyles are not independent of those of others, according to effects of network externalities. Therefore, lifestyle must be treated not only as an individual problem but also as a social phenomenon. Moreover, good opportunities will arise to create new values of services or products by synthesizing some different components of lifestyles.

Therefore, the study of lifestyles is expected to be an important common challenge for psychology, sociology, economics, management, and engineering in the networking and globalizing society. Especially, it will be a good benchmark of how we can build human models for creation of valuable services and products based on the large amounts of data gleaned from consumers' behavior. For this purpose, transdisciplinary approaches such as integration of findings of cognitive psychology, data processing technologies, and optimization techniques must be encouraged [93].

5.4 Incentive mechanism for institutional design

In general, whenever decision-making is done, decision-makers confront rules or institutions that determine their mutual relations. Particularly in economic systems, decision-makers behave under rules or institutions that shape the structure of economic incentives: they make decisions to increase profits. However, a serious question is how institutions are designed to allocate goods efficiently and to realize social welfare maximization. For example, buyers and sellers sometimes haggle too hard and therefore fail to trade; desirable joint projects are sometimes not undertaken because the projects' beneficiaries fail to agree about how to share costs.

Mechanism design theory [94] provides tools for analyzing and answering these questions and many other similar ones. Mechanism design theory defines institutions as non-cooperative games, and compares different institutions in terms of the equilibrium game outcomes. It enables economists and other social scientists to analyze the performance of institutions relative to the theoretical optimum. Mechanism design has produced numerous important insights in widely various applied contexts, influencing economic policy and market institutions [95].

The key concepts in mechanism design theory are incentive compatibility and the revelation principle. The notion of incentive compatibility is expressed as follows: the mechanism is incentive-compatible if it is a dominant strategy for each participant to report private information truthfully [96]. In other words, the truth-telling strategy is more rational than any other strategy. The revelation principle presents an insight that simplifies analyses of mechanism-design problems. The principle states that a researcher, when seeking the best possible mechanism to solve a given problem, can restrict attention to a small subclass of mechanisms; such direct mechanisms satisfy the condition of incentive compatibility.

Mechanism design approaches can become a powerful tool for constructing social institutions to realize sustainability.

5.5 Complex adaptive system

The theory of *Complex Adaptive Systems* (CAS) put forward by Holland [97–98] is a new paradigm with the goal of studying the structures and dynamics of systems and the question of how the adaptability of systems creates complexity. A CAS can be considered as a multi-agent system with seven basic elements in which "a major part of the environment of any given adaptive agent consists of other adaptive agents, so that a portion of any agent's efforts at adaptation is spent adapting to other adaptive agents". The first four concepts of Holland's seven basic elements, i.e., aggregation, nonlinearity, flow, and diversity, which represent certain characters of agents, are extremely important for adaptation and evolution processes, whereas the other three concepts, i.e., tagging, internal models, and building blocks, are mechanisms of agents for communicating with the environment.

Furthermore, CAS is applied to manufacturing systems, coupled with the concept of emergent synthesis [99–100].

6 MODELS

This section introduces a value creation model based on the concept of emergent synthesis [92, 101]. Moreover, it discusses innovation management based on value creation models.

6.1 Value creation model

In light of the discussion of value creation in society, the grounds for the assumption that artifacts, human beings, and society can be treated as mutually isolated systems is no longer valid. In the real world, they are closely interrelated. Therefore, it must be understood that value is created through their mutual interaction. This problem might be readily apparent not only in products but also in services. In this context, many researchers are devoting attention to the value of services and discussing them from several points of view, sometimes particularly addressing the difference between products and services [102–106]. However, it is important to treat products and services in a comprehensive manner from the viewpoint of value creation of artifacts, as discussed above.

Figure 14 presents three value models classified from the viewpoint of emergent synthesis: Providing Value Model, Adaptive Value Model, and Co-creative Value Model. The figure shows that producers, customers, and products and services are treatable as agents. Figures 15–17 show detailed value models based on emergent synthesis.

■ Class I value creation model (provided value)

The value for the product or service provider (producer) and receiver (customer) can be specified independently and the environment can be determined in advance. The model can be described as a closed system. The problem to be addressed is the search for the optimal solution.

■ Class II value creation model (adaptive value)

The value for the product or service provider and receiver can be specified, but the environment changes, making it difficult to make a prediction. The model is a system that is open to the environment. The problem which must be addressed is the adaptive strategy.

■ Class III value creation model (co-creative value)

The value for the product or service provider and the value for the receiver cannot be determined independently. The two interact. Therefore, they cannot be separated. The provider enters the system. The problem which must be addressed is value co-creation.

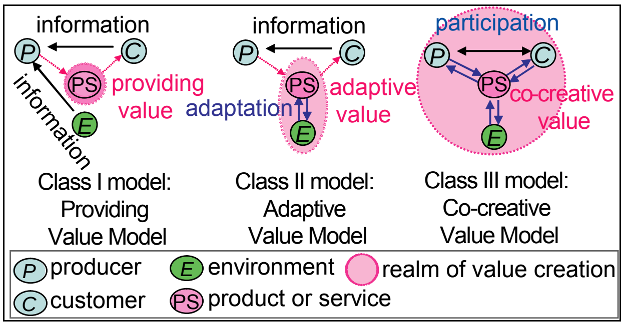

Fig. 14: Classification of value creation.

In the Class I model, product and service producers as well as customers are defined independently of their values. The objectives and environment are clearly specified. The model can be described completely using a closed system. However, in most cases, too many feasible solutions exist, which engenders combinatorial explosion and creates so-called NP-hard problems.

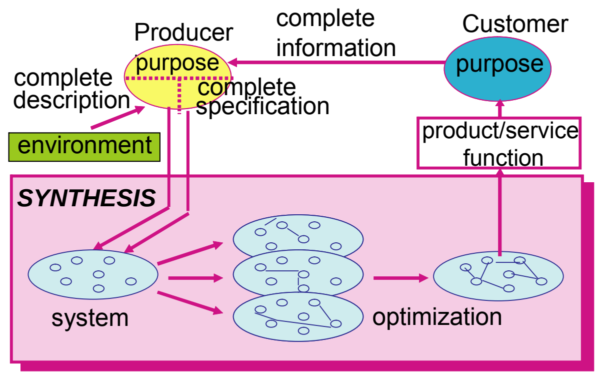

Fig. 15: Class I model – value provision model.

Therefore, it is necessary to develop efficient and robust search methods to identify optimal solutions. In the real world, this model can apply to mass-produced products or routine services. In mass-production, a designer determines the specification of a product based on available information about the environment (e.g., consumers' average demand or production costs) in advance. Consequently, the designer treats the information as complete information. In a routine service such as a fast-food service, the service must always be provided in the same way.

In the Class II model, the customer objective is defined completely. However, environments are changing and unpredictable. Therefore, the model is an open system. In our models, environmental changes of two types can occur: changes attributed to customers (e.g., diversity of preferences or societal influence) and changes attributed to producers (e.g., changes of technologies and resources). In this class problem, approaches based on learning and adaptation, such as reinforcement learning or adaptive behavior based methods, are feasible to resolve this class of problems. This model is applicable to customer-oriented products or services such as semi-order-made goods and recommendation systems of books based on collaborative filtering. Adaptive strategies are necessary to respond to diverse customer preferences.

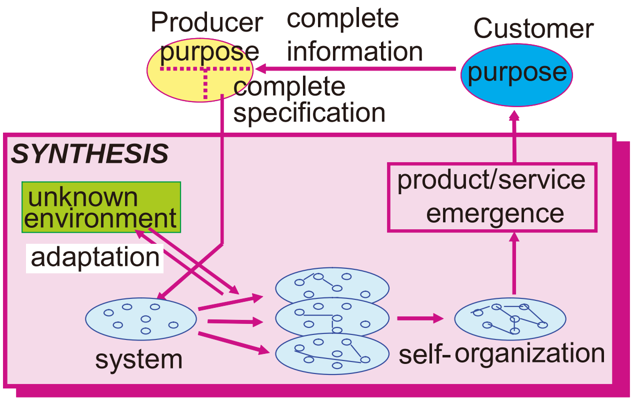

Fig. 16: Class II model – adaptive value model.

In the Class III model, along with the lack of environmental information in advance, the customer objectives are ambiguous.

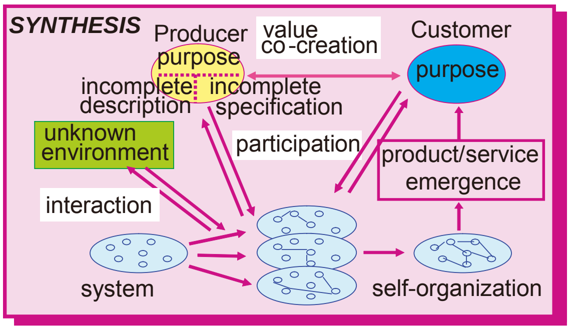

Fig. 17: Class III model – co-creative value model.

The producers and customers are mutually inseparable in terms of value creation. Consequently, the producers are involved with customers to co-create the value. In the real world, open source software such as Linux, knowledge databases, and doctor-patient medical services might correspond to such a value model. In such cases, it is usually difficult to control the value that emerges through the interaction between producers and customers. In addition, a *de facto* standard can be treated as a co-creative value. In such cases, network externalities can play important roles. From the viewpoint of synthesis, the authors believe that one solution to create and control class III values is to treat products or services as agents that have their own purpose and self-organized internal structures.

6.2 Structure of innovation management

Innovation has been studied in various contexts of technology, commerce, social systems, economic development, and policy construction. Schumpeter defined economic innovation in the Theory of Economic Development [107]. He classified innovations into levels according to what is innovated, such as new goods, new methods, new markets, new sources, and new organizations. Figure 18 depicts these innovation structures.

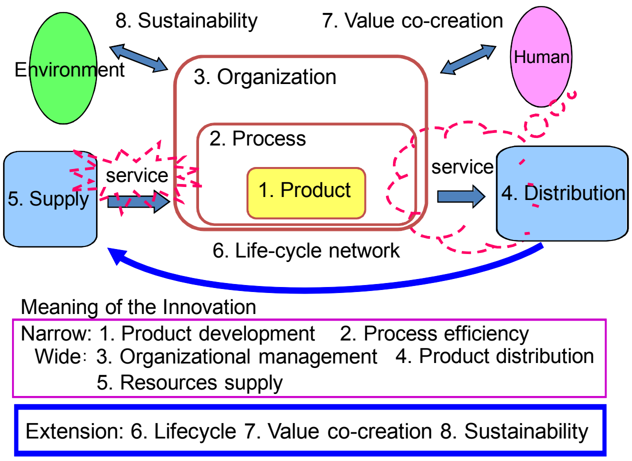

Fig. 18: Innovation structure.

Innovations can be sorted according to their included systems. Distributions of products and supply of products and processes of an organization intrinsically include the problems of services. Therefore, product innovation management outside of the organization is expected to include service innovation management. Moreover, management of their lifecycles is an innovation problem. Value co-creation with humans or society is thought to be an innovation management in a society. Finally, the sustainability problem can be treated as innovation management.

The following discussion addresses innovation management based on value creation models.

Figure 19 shows the value creation classes associated with services, products, processes, and organization management. The present state of the real world might be said to be the theory-less Class II. For instance, an industrial country like Japan has so far maintained an advantage in the manufacturing industry at the process level. This advantage is ensured because problem solving can be performed smoothly using Kaizen [108], JIT [109] and the like because of the implicit knowledge and collective cooperation principle in the workplace without scientific theorization of problems. Compared to the manufacturing industry, the inefficiency of the service industry might be readily apparent simply from the viewpoint of Total Factor Productivity (TFP) [110].

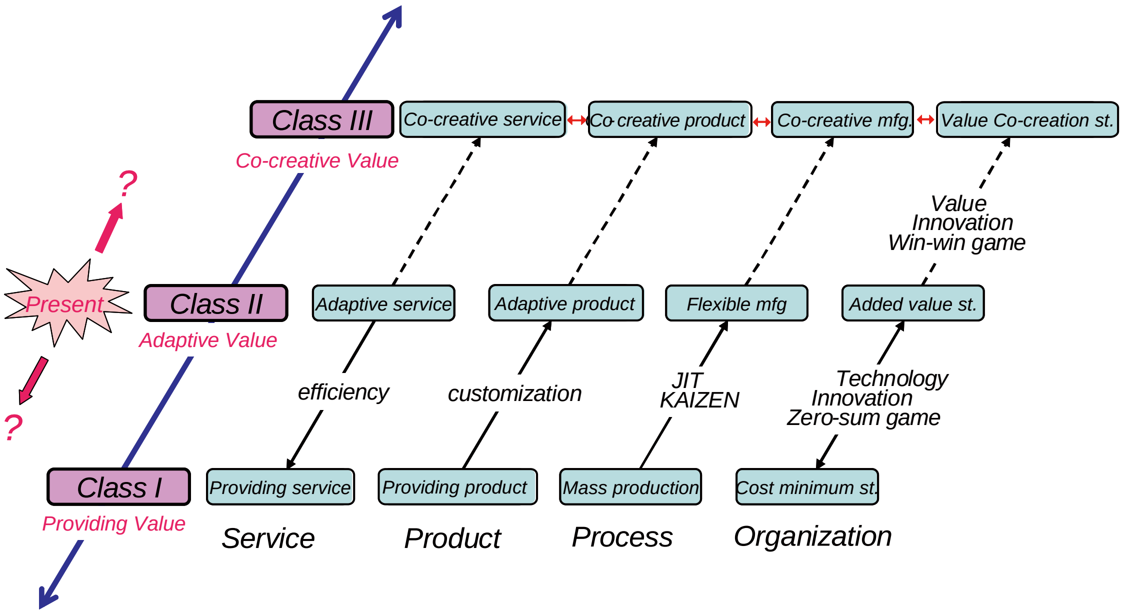

Fig. 19: Value creation classes associated with service, product, process, and organization management.

To raise service-sector productivity, it is important to make a Class II problem into a Class I problem in the same manner as manufacturing. The phrase 'manufacturing-oriented service' might represent such a challenge. Moreover, productivity at the organization management level cannot be said to be good not only in the service industry but also in the manufacturing industry. The phrase 'service-oriented manufacturing' represents a challenge to integrate the value of a product and the value of a service. According to the classification presented above, it is an attempt to make a Class I problem into a Class II problem. It also becomes more important to consider the Class III problem. The phenomenon of 'brand value' [111] or '*de facto* standard' addresses Class III problems, by which customers and providers are involved dynamically to a great degree. Co-creation is a promising concept to enhance value and create new value in a society.

7 CHALLENGES

This chapter introduces and discusses some important attempts at value creation in the real world. It specifically examines studies of services that attract major attention to increase the productivity of service sectors. Moreover, it addresses studies of manufacturing intended to expand the value of products in an increasingly complex environment. Integration of products and services is expected to be important for value creation in a sustainable society.

7.1 Improvement of service productivity

In many developed countries, manufacturing industries' share of the workforce has been decreasing since the 1980s concomitantly with the development of service industries. Explanation for this phenomenon includes increased outsourcing of operations such as information services, rental, and leasing businesses, along with software development [112]. Manufacturing industries must now confront how to expand their activities into service businesses to increase the value of their products. In contrast, service industries are expected to increase their productivity because many existing services are thought to be provided less efficiently than manufactured products. For instance, the Japanese Ministry of Economy, Trade and Industry has investigated best practices of actual services and established a commission for academic–industrial co-operation with a view to increasing service-industry productivity [113]. The main concern of the commission is how science and technologies can support actual service provision and can contribute to creation of new services.

Takenaka and Ueda [90] examined studies of services that involved 150,000 articles, particularly addressing historical trends and key technologies using an academic database. Figure 20 presents the quantities of articles including some technical keywords that co-occurred with "service" during 1995–2007 recorded in Oct. 2008. "Optimization" and "complexity" show characteristics of academic interest during several years. Moreover, "agent" and "adaptation" suggest that the researchers explore not only static optimized solutions but also dynamic and adaptive solutions for changing environments through interactions of service components as agents [114]. In addition, human characteristic-related words such as "cognitive" and "personality" are garnering attention recently in service studies. Additionally, human sensing technologies such as Global Positioning System (GPS), Radio Frequency IDentification (RFID), wearable sensors, and human navigation are attracting researchers' interest (e.g. [115–117]). Interest in service innovation and concerns about sustainability might reveal uncertainty about service specifications or service environments in the real world. Some studies have specifically examined the tradeoff between sustainability costs and technology benefits to manage production and enterprise growth aiming at both ecological safety and economic return [118]. Laszlo [119], for example, described some companies for which corporate environmental responsibility can enhance both shareholder and stakeholder value.

As described above, for improvement of service productivity, we must address not only efficiency or optimization of service provision but also expansion of the value of services. To this end, we must pay more attention to the concept of valuation and the value mechanism in a society. Furthermore, sustainability is expected to be a good target for studies of services because individual happiness and the overall purpose (environmental and social sustainability) were solved simultaneously through dynamic interaction among various stakeholders.

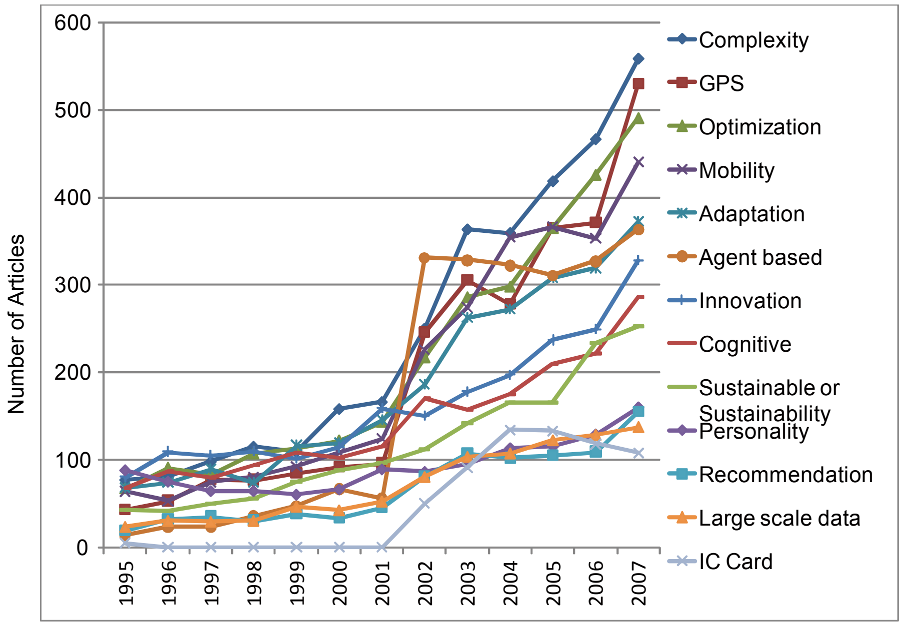

Fig. 20: Articles including some technical keywords co-occurring with “service”.

7.2 Value creation in services

In recent studies of services, many researchers have a strong interest in valuations made by customers and the methodologies of value creation in services. Using the Web of Science database [120], we sought articles and searched their contents using keywords. Table 2 portrays the top 10 research areas of articles including the keywords “service” and “value”. The articles published during 2000–2008 were 15,126. The number of articles increased rapidly after 2002. It is apparent that those articles address many research areas.

Additional investigations of those articles, especially in engineering and computer sciences, reveal concerns about services: customers’ demands, satisfaction, evaluation, customization, and recommendation.

Table 2: Research areas of articles that co-occurred with “service” and “value” (Period: 2000–2008). The numbers include duplication according to research areas.

Research Areas	Articles
Engineering	10,924
Computer Science	7085
Communication	5574
Instruments and Instrumentation	3364
Business and Economics	1403
Health Care Sciences and Services	823
Psychology	591
Behavioral Sciences	581
Transportation	564
Chemistry	562

Arai and Shimomura specifically examine values of services for customers and propose a service CAD system [105, 121, 122]. A service model consists of three sub-models: a scope model, a view model, and a flow model. A computer-aided design tool—Service Explorer—has been developed to represent a network of parameters and determine the influence weights sequentially. Moreover, Arai and Shimomura propose a method for evaluating previous service solutions using service Quality Function Deployment (QFD). They aim at a service design that considers various aspects of values including customers’ satisfaction.

Recommendation and mass customization are also important topics in recent service studies in response to rapidly increasing customer purchasing and demand data. For those purposes, intelligent methods such as Bayesian networks or Collaborative Filtering that can calculate customers’ preferences play important roles. Moreover, those problems are applicable to both service and manufacturing businesses.

Flexibility of supply and demand is necessary for successful implementation of a mass customization strategy that delivers sustained competitive advantage [123–125]. Wang and Tseng [126], for instance, propose a probabilistic model that can incorporate and adapt customers’ preferences continuously into the concurrent engineering methodology. The new methodology enables a product development team to carry out a product specification process by guiding customers to seek what they want intuitively and naturally. It can eliminate redundant query items and improve the efficiency of the product specification task.

In addition to the problem of discerning individual customers’ preferences, the value of a service in a society emerges through dynamic interaction among producers and consumers. Ueda et al. examined service diffusion in a society considering consumers’ lifestyles and network externalities [53, 91, 92]. As introduced in subsection 6.1, three value creation models: Providing Value (Class 1), Adaptive Value (Class 2), and Co-creative Value (Class 3) are proposed considering interaction among producers, customers, and the environment. They conducted multi-agent system simulations of service markets to examine the validity of the proposed models, with discussion of the diffusion of new products and services in a society. Figure 21 presents results obtained using each model: the number of each case corresponds to that of each value creation model. The producer can gain the greatest profit under a predictable service environment in the Class I model. Adaptation to changes of each customer’s value perception results in increasing customers' profits in the Class II model. For the Class III model, the total profit of the producer and customers is the highest of all cases because of the increased value perception by customers as a result of network externalities. Although the cases of the introduced simulations are simple and limited, their results can explain, qualitatively, real-world business activities such as mass production strategies, adaptation strategies, and a *de facto* standard strategy.

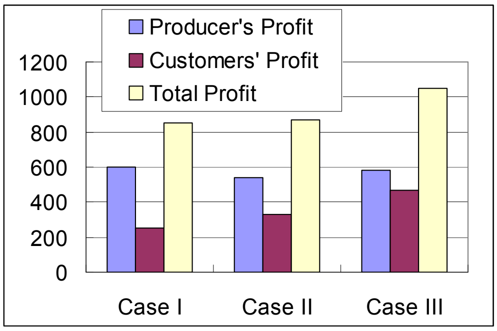

Fig. 21: Averaged Producer's Profit, Consumers' Profit and their Total Profit in Value Creation Models [93].

As explained above, the value of services must be examined not only as individual problems but also as social problems. Co-creation is a promising concept to enhance value and to create new value in a society. Actually, "co-creation" is used expressly in some recent service studies [e.g. 127, 128]. Although most of those articles mainly address examples of existing services, the concept of co-creation has attracted attention for the design of new services.

7.3 Merging service and manufacturing

For value creation in a networked and globalized market, integration of manufacturing and service activities is necessary to increase the total value of products. For this purpose, many challenges exist from the firm level to international level. Additionally, considering the realization of sustainable development, the life-cycle management (LCM) of products [e.g., Takata et al., 129,130, Hauschild et al., 131] is expected to be a good example of merging products and services.

According to Aurich et al. [132], one promising way to maximize product performance is to consider the entire product life cycle: product engineering, production, product usage, and recycling disposal. Service activities such as technical, maintenance, and disposal services must be included to realize life-cycle management of products.

Meier proposes a life-cycle-based service design for innovative business models [133]. He analyzes machine-oriented service development with the goal of standardization, rationalization, and automation of life-cycle-oriented service processes. A service configuration was developed for the efficient supply of customer-based services. The configurator also incorporates suppliers of the machine manufacturer. Meier points out that, in the future, services and material goods must be planned, developed, produced, and marketed as a hybrid product. This process will engender new life-cycle-oriented machine concepts and business models that generate maximum customer use with a minimum of resources.

Váncza et al. propose new cooperative planning methods for sharing information and coordinating decisions between a manufacturer and its suppliers considering incentive mechanisms and channel coordination [134, 135]. Planning production in a supply network that consists of autonomous enterprises is a distributed and recurring effort to match future demand with supply by relying on asymmetric and unreliable information. Although the network as a whole is driven by the overall objectives to meet market demand at the possible minimal production and logistic cost, the efficiency of operations and the economical use of material, energy and human resources hinges on the local decisions of the individual partners. Clearly, they can never be completely aware of each other's goals and intended courses of actions.

Information asymmetry and local autonomy lead together repeatedly to inefficiencies such as acute shortage situations or excess inventories. Váncza et al. regard this phenomenon, which was known for a long time as *double marginalization*, as a symptom of the prisoners' dilemma in supply networks [136]. They present a novel coordination mechanism in which sharing information truthfully and planning local production optimally serve both system-wide and individual objectives. Their work is also nested in practice: application examples are taken from the mass production of customized products.

For realization of flexible supply chain management, information technology enhances the communication of different business partners that are geographically dispersed. Mourtzis et al. proposes a method of dynamically querying supply chain partners to provide real time or near real time information related to the availability of parts required for the production of highly customizable products [137]. They also provide examples of a ship repair yard [138–140] by integrating in an open and flexible system a number of critical business functions with production planning, scheduling and control. In their proposed system, data can be exchanged among cooperating companies using heterogeneous software applications.

Teti and D'Addona [141] described a Multi-Agent Tool Management System (MATMS) for automatic tool procurement in a supply network based on the emergent synthesis concept. The main purpose of that study is the optimization of tool management while performing in a complex made-to-order manufacturing environment that is rendered uncertain by the behavior of external tool manufacturers in charge of worn-out tool dressing and responsible for unreliable tool deliveries. A dependable and robust dressing cycle time forecasting method, founded on knowledge evolution, was developed for solution of the Class III synthesis problem through an emergent methodology based on adaptive and dynamic purpose assignment. They describe classification of the problem according to incompleteness of manufacturing environments based on the concept of emergent synthesis (see Fig. 22).

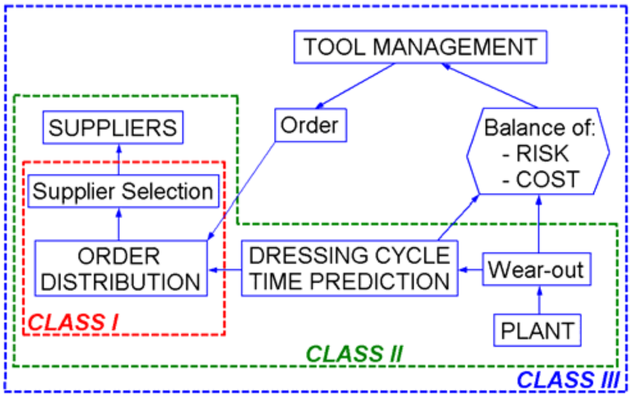

Fig. 22: Multi-Agent Tool Management System in a supply network: Classification of problems based on the concept of emergent synthesis

Management of the supply chain network is a good benchmark for value creation among manufacturers, suppliers and consumers. For this purpose, integration of values of different types and effective institutional designs are needed.

The collaborative research project Transregio 29 "Industrial Product-Service Systems – Dynamic Interdependency of Products and Services in Production Area (IPS²)" is aimed at establishing an innovative and user-oriented understanding of products and services [142,143]. This understanding views product and service shares in an integrated and mutually determined way as Industrial Product–Service Systems and engenders an increased solution space (see Figure 23).

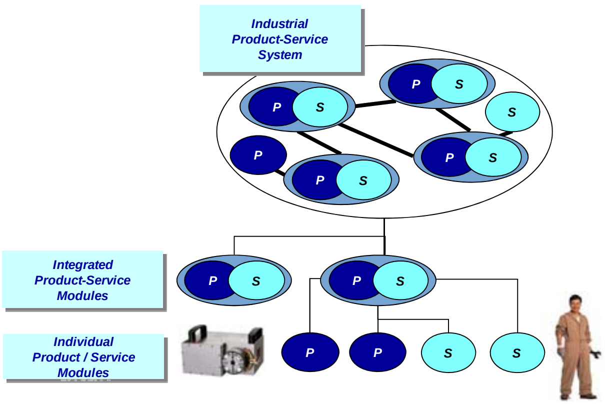

Fig. 23: Industrial Product–Service System (IPS²).

According to Meier, new possibilities for innovations arise from an integrated view of product and service shares. The increased solution space also engenders a better marketing of highly complex machines because the customer is offered an increased utility value. This is of great importance because the only chance of highly industrialized countries' mechanical engineering competing on a global level is in the field of high-technology products. Given the current circumstances, winning the competition based on price reduction is not possible. Less complex machines manufactured in developing countries are more economic if the customer is not able to exploit all technological advantages offered. Therefore, technological market leadership does not directly result in corresponding market success. Only the integration with an appropriate service avoids the danger of technology traps.

The Trans-regional initiative span the complete life cycle of Industrial Product-Service Systems [144]. Approaches, methods and tools to plan, develop, deliver and use Industrial Product–Service Systems are developed in this collaborative research project. Effects of the initiated change of paradigms are being investigated in projects in the fields of "Planning/Development", "Delivery/Usage", "Life Cycle", and "Demonstrator".

Although IPS^2 targets many aspects of actual businesses, an important topic is cost management of products and services. Considering the lifecycle of products, estimating costs accrued at various stages is not a simple problem. Moreover, as discussed in Chapter 3, costs of products are inseparable from their values for consumers from the viewpoint of design of artifacts.

Bernard et al. proposed a new cost modeling method for actual manufacturing firms [145,146] and propose a tool-based method of product cost estimation during conceptual design [147]. The main objective of this tool is to assist the designer in the process of manufacturing cost calculation of a product that is defined by little and inaccurate information in the preliminary design. For such a situation, it is important to integrate available data, various concepts and expert knowledge according to manufacturing processes and cost criteria. Estimation of costs in design processes therefore necessitates a decision support system. Furthermore, they expand their idea to value chain modeling based on a value-oriented approach [148]. The definition of the processes that create value is strategic to estimate the impact of a given production on the Value/Cost/Risk triptych. A flow simulation tool provides results in terms of performance indicators to analyze manufacturing processes.

Cost estimation becomes more difficult when it includes services such as maintenance services provided over a long term. Datta and Roy [149] recently presented a matrix-based cost impact analysis methodology at the bidding stage of service support contracts. They study different service support contracts and report the cost modeling techniques used in availability type contracts in the context of the defense and aerospace industry. Practices in the aerospace sector demand that suppliers agree with the airplane manufacturer in a particular fixed price contract for a system or component. To obtain a fair agreement based on a clear visibility of the economical impact of requirements change is a challenge. Rios et al. [150] address the cost impact analysis for change in requirements in airframes.

Lifecycle management of costs and values necessitates mutual agreement among manufacturers, suppliers, and consumers. To support integration between manufacturing and service in the real world, both synthetic and transdisciplinary approaches will be more important. The CIRP, as an international academy, is expected to contribute to it by developing an academic strategy. For this purpose, values in service and manufacturing must be integrated for creation of new and sustainable values in society.

7.4 Decision-making and institutional design for product lifecycle management

Product lifecycle problems are limited not only by technological issues, but also by economic and social issues. Decision-making in social systems is deeply interdependent. The dilemma can be exposed among stakeholders. For analyzing such a situation, Ueda et al. [151] constructed an agent-based model of decision-making systems consisting of human subjects such as producers, consumers, dismantlers, and used-unit dealers. Figure 24 presents an overview of the model, which subsumes that each agent makes decisions based on its own economic incentives. The focal point of this study is this: which economic agents should collect used units? The study hypothesizes three potential collectors of used products: consumers themselves, an independent waste dealer, and the producer.

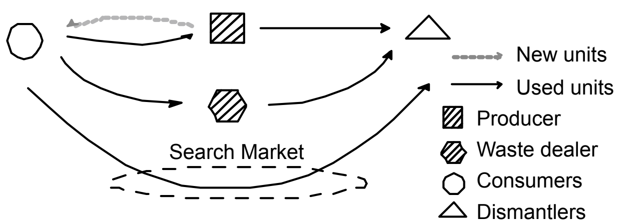

Fig. 24: Model of decision-making related to waste collection in recycling markets.

The model is analyzed using an integrated approach with theoretical analysis, multi-agent simulation, and experiments with human subjects. Results show the following discussion of institutional design through comparison of experimental results with current institutions using real-world data for several product types.

- Both theoretical and experimental results show that the producer's profit is greater than in the case in which another collector collects wastes instead of the producer. Regarding the home appliances recycling law in Japan, results of our analyses show that the producer's collection is forced by legislation, but that the legislation might provide producers a new profit opportunity.
- Where social surplus is at the maximum theoretically, experimental results show worse performance than in the case of producer's collection because the producer and the waste dealer collude implicitly. Therefore, the total surplus decreases overall. It is therefore implied that a policy or regulation that prevents collusion between producers and waste dealers might engender a social framework that might improve the total surplus in society.

This approach, which specifically addresses decision-making and institutional design, is useful for application to real-world problems related to sustainability.

7.5 Electric vehicle for sustainable society

In this subsection, as an example, we present how a series of challenges related to sustainable road transportation can be cast as Class I, II, and III problems. It is widely accepted that new technological and organizational approaches are necessary to secure sustainable future mobility (for a particular European strategy, see [152]). Road transportation, while heavily relies on fossil sources, plays in Greenhouse Gas (GHG) emission a significant role, and in CO^2 emission a critical one. Hence, any sustainable solution lies in the displacement of fossil energy sources and an improved vehicle fuel economy and reduced emission. Especially for urban mobility and transport, electrification is meant to be the right answer to this challenge.

Class I model:

Improved fuel economy and emissions require comprehensive reduction of energy losses with vehicle level optimization during the early stages of design. Consumption can be decreased by numerous factors such as engine efficiency, vehicle mass reduction, aerodynamics, tire and internal friction optimization, shifting power trains from mechanical to electrical, high-energy-density cells, etc. These engineering problems are definable and can be tackled as clear-cut Class I problems. Finding satisfactory solutions is extremely difficult but not hopeless: for instance, in the past, because of the combination of active and passive safety systems and the application of advanced information technology, cars became lighter, and simultaneously, safer. Now, major carmakers almost unanimously claim that reducing energy consumption of cars by 50% is feasible with existing state-of-the-art technologies, and that the full electric vehicle (EV) in particular can be made a technically viable option for transportation.

Class II model:

Battery powered vehicles are more sensitive to efficiency losses (energy available from battery is less, but mass is more) than vehicles with traditional drive. Consequently, they can cover shorter ranges and restrict mobility in general. A vehicle that is powered completely by electricity needs a system of external source of energy, namely an electric grid with appropriate connection points.

Plug-in hybrid electric vehicles (PHEVs) possessing both internal combustion engine and significant battery capacity however, can not only receive electricity from the grid but can also send electricity onto the grid, thereby acting as distributed, mobile energy sources. As a recent report has described, vehicle-to-grid power might provide a significant revenue stream that would improve the economics of grid-connected electric-drive vehicles and further encourage their adoption. Further on, it is expected to improve the stability of the electrical grid [153]. The grid can also be extended with buildings powered by renewable energy sources. Proper service requires standardized, mutual communication between vehicles and the grid and smart charging methods. In fact, for the energy provider, the heart of the matter is cost efficient energy storage and load balancing, whereas the primary goals of vehicle owners are to get to their targets in time with the lowest cost. Both parties must manage their operations under continuously changing conditions, following their own clear, well-defined objectives. Consequently, they typically face various Class II problems.

Class III model:

The above scenario points toward a novel integrated energy and mobility paradigm whose many elements (batteries, EV and PHEVs, electrical grid, charging stations, network and communications technologies, building infrastructure, etc.) are more or less ready. As it seems, in this wider context electric vehicles can be made both technically and economically feasible, particularly in rapidly urbanizing environments. However, in these areas a number of critical issues arise such as congestion, road safety and urban pollution. Looking ahead a couple of decades, it is expected that over 70% of the population will be urban and will emit half of the current CO_2. In this scenario, no technological or organizational reduction of emission can be achieved without reducing actual usage. A new high-energy, low-carbon society with the present US rates of 0.8 cars and trucks per person will not be sustainable [154]. Hence, services such as public transport for routine travel (work, school, healthcare) must be re-designed, and novel services, especially IT services, must be invented to provide people a kind of "automotive" freedom. The emergence of such services in urban communities, with the appropriate regulations and business models, is a Class III problem.

8 CONCLUDING REMARKS

This paper presents a discussion of value creation toward a sustainable society. Historically, values have been studied from philosophical, ethical, economical, psychological, and technological viewpoints. Values can be classified by absoluteness, objectivity, and subjectivity. However, the current problems of values confronting us are apparently new problems; they are not analytic problems but synthetic problems. The problem of sustainability is expected to be a decision making problem in a society; discrepancies between overall purposes and individual happiness often present a dilemma structure. Therefore, it is desirable to realize a system in which both the overall purpose and individual demand can be achieved concurrently through dynamic interaction among decision-making agents that have various goals and values. For this purpose, we must devote more attention to social mechanisms of values, such as network externality, social dilemma, public goods, and lifestyles. Transdisciplinary and synthetic approaches are necessary as academic approaches. This paper presents a proposal of value creation models based on Emergent Synthesis and co-creative decision-making as models that elucidate the difficulties of problems.

In the real world, manufacturing industries must now confront how to expand their activities into service businesses to increase the value of their products. In contrast, service industries are expected to increase their productivity. The integration of both industries is needed from the viewpoint of value creation toward a sustainable society. Co-creation is a promising concept to integrate values of industries and those of consumers. Mechanism design approaches are also important for constructing social institutions to realize sustainability.

Future research will elucidate the mechanism of value co-creation in a society. It will be increasingly important to treat product and service innovation problems as a Class III benchmark. One solution to create and control class III values might be to treat products or services as agents that have their own purpose and self-organized internal structures in a society. Sustainable value should be co-created through the dynamic interaction among social, natural and artificial systems.

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