

PAPER • OPEN ACCESS

Axiomatic Design as an innovation framework

To cite this article: Miguel Caviue *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1037** 012015

View the [article online](#) for updates and enhancements.

You may also like

- [What kind of technological innovation will be promoted by environmental regulation?](#)
YaoJie Wu and ChunJie Chi
- [Preface](#)
- [The mapping and analysis of minapolitan innovation network-based on capture fisheries, Pekalongan City](#)
O Sumule, W I Angkasa and H W Retno



The Electrochemical Society
Advancing solid state & electrochemical science & technology

242nd ECS Meeting

Oct 9 – 13, 2022 • Atlanta, GA, US

Early hotel & registration pricing
ends September 12

Presenting more than 2,400
technical abstracts in 50 symposia

The meeting for industry & researchers in

BATTERIES
ENERGY TECHNOLOGY
SENSORS AND MORE!



Register now!



**ECS Plenary Lecture featuring
M. Stanley Whittingham,**
Binghamton University
Nobel Laureate –
2019 Nobel Prize in Chemistry



Axiomatic Design as an innovation framework

Miguel Cavique^{1,2*}, Oana Dodun³, Christopher Brown⁴

¹ Unidemi, Faculdade de Ciências e Tecnologia, 2829-516 Caparica, Portugal

² Department of Sciences and Technology, Naval Academy, Base Naval de Lisboa, Alfeite, 2810-001 Almada, Portugal

³ Department of Machine Manufacturing Technology, Faculty of Machine Manufacturing and Industrial Management, “Gheorghe Asachi” Technical University of Iași, Bdul. Mangeron, 59A, 700050 Iași, România

⁴ Department of Mechanical Engineering, Worcester Polytechnic Institute, Worcester, MA, USA

*Corresponding author's e-mail: miguel.cavique@cest.pt cavique.santos@marinha.pt

Abstract. Innovation can be defined as a set of processes for altering human activity, with economic or social relevance. Innovation has been the economic driver of several companies and countries. This article presents laws with preconditions for innovation, and it proposes a framework for innovation based on Axiomatic Design (AD) theory. There are three laws which set out necessary preconditions to initiate and maintain innovation. Research, financing, and companies that can carry out an innovation project, must be available for a project. AD can be a tool for innovation. Three main elements to AD are: Suh's axioms, to maintain functional independence and minimize information content; a structure, domains and hierarchies in which solutions develop; and a process, decomposing from abstract to detailed components and physically integrating components into a complete solution. Suh's axioms ensure that design solutions are adjustable, controllable, and robust. These are essential elements in innovation. Design matrices for functional–physical relationships select for independence, then information content is used to select the best solution. Design structures are completed by zigzagging between functional, physical, and process domains, creating the hierarchical decompositions of abstraction while applying Suh's axioms at each level.

1. Introduction

Innovation is a process of applying new solutions with economic or social profitability to satisfy the needs of society. To be innovative, solutions must be deployed, satisfying societal needs.

The most successful companies always bet on innovation. The so-called technological companies (information and related technologies) have been strongly investing in innovation. Apple Inc. grosses more than many European countries' GDP. The first ten largest technology companies in the world in 2019 include five from the USA, two from Japan, one from South Korea, one from Taiwan, and one from China. There is not a single EU company in this rank, which is a sad statement on Europe's position in a new technological world.

Creativity is coming up with new, potentially useful ideas. Developing them into complete solutions with Axiomatic Design (AD) assures technological viability and sustainability, key requirements for ethical innovation [1].



There has always been innovation, even without the aid of current methodologies and theories. A century ago, Henri Ford's phrase is paradigmatic of how to think innovation: "If I had asked my customers what they wanted, they would have said a faster horse." Ford was able to identify a need outside of the physical context of horses and innovate a new means of affordable transportation, the Ford Model-T. This new concept satisfied a need and led the company to produce 15 million of this type of vehicle. Achieving technological viability apparently took through "T" in the alphabet to label models.

Innovative solutions need a lot of work. Therefore, it is advantageous to support innovation efforts with methods or theories that guide reasoning. Innovation by a flash of genius is overrated. Innovation usually occurs after significant efforts rather than in a flash.

Regarding new solutions, there are two types of problems, those that can be solved with current knowledge and those that need new knowledge. C-K theory [2] addresses this issue of connecting innovative concepts and the knowledge required to realize them.

In many common situations, there are algorithms to achieve a solution, even though the application of these algorithms may require a lot of previous knowledge. The dimensioning of a steel structure follows standard codes; most engineering problems use codes. Similarly, in the medical field, doctors use protocols. Algorithmic problems need to be framed in a type of algorithm, asking for analysis to reach a solution. Many issues in day-to-day life use defined analyses for selecting solutions.

Synthesis reasoning is applied in ill-defined problems that need new solutions. Universities must play decisive roles by training for synthesis processes, by focusing on synthesis reasoning [3]. Synthesis reasoning includes abduction and induction. Synthesis can use techniques such as brainstorming. These methods are experiential, relying on the experiences and intellects of participants. Assertiveness of participants can dominate solution selections when there is no tool to evaluate the quality of new proposals. Therefore, scientific methods and theories for innovation, which guide and verify the quality of proposed solutions, are welcome. It is these theories, with laws, principles, and axioms, that distinguish scientific disciplines, with broad applications and powerful problem-solving abilities from experiential ones, which have more limited applicability.

When fostering innovation in an organization, a region, or a country, it is necessary to define how innovation occurs. It is essential to know when the innovation process starts and where, to what extent it is socially inclusive or determined by a department, and what is the implicit social responsibility [4]. Homogeneous innovation asks all persons of an institution to commit; conversely, in heterogeneous innovation, only specific areas of institutions work on innovative processes. Choosing one or the other type of innovation defines ways to finance innovation. Providing resources to a department or spreading them around the institution, is a crucial decision.

Research is a fundamental pillar in innovation. Several research institutions must be financed. Some that present disruptive projects must be chosen. In Europe, the tendency has been to share large sums through different users. However, bringing disruptive projects usually requires heterogeneous financing options.

Moreover, research supporting innovation can be open or closed. Entities may share innovation with their counterparts by developing innovation in an open environment [5]. Open innovation occurs in universities, where publications, ideas, and solutions spread around the world. Researchers share ideas and receive new ideas from other researchers, building an increasingly better and more competitive system. In specific situations, entities may not want to share their conclusions. Thus, innovation occurs within the entity, avoiding competition, but reducing the benefits of exchanging ideas with other institutions. In the XV century, maps, and navigation techniques were Portuguese secrets for sailing over the oceans. Similarly, NASA innovated in the sixties, hiding patents.

In conclusion, strategies for innovation must be consistent with an entity's objectives.

Some of the most well-known innovation methods are, Value Analysis, QFD, and TRIZ can be used together in systematic models of innovation [6]. TRIZ is commonly used with AD to solve couplings and create innovative frameworks [7].

This paper uses AD theory to identify frames of innovation defined by AD entities. It presents a different way of looking at AD as an innovation tool rather than a design tool.

The following section describes different types of innovation and laws that govern innovation. Emphasis is placed on the first Innovation law, which establishes necessary conditions for innovation. Then, in the next section AD is described as a framework for innovation with Suh's axioms, structure with domains and hierarchies; and processes with decomposition and physical integration. These ensure that design solutions are adjustable, controllable, and robust, which are key elements in innovation.

2. Innovation Laws

Nam P. Suh explained Axiomatic Design theory in 1990 in Principles of Design [8] and expanded it recently with more examples of applications [9]. In 2010 Suh defined three laws of innovation [10]. The first law defines conditions required for innovation to occur:

- "For innovation to occur, there can be no lack of any element or link in the innovation continuum."

This continuum of innovation requires an infrastructure for innovation with solid bases for fundamental research and technological invention, a financial community willing to provide capital and take risks, and industries with knowledge necessary to develop, manufacture and market new products.

To innovate, problems must be identified. Therefore, many new ideas need to be raised and evaluated to achieve one winning solution. Or in other words, research processes must launch many projects for each new product that succeeds in the market. Moreover, innovation stops if any part of the innovation structure fails. There is no innovation without risking capital, without companies able to take risks to produce and commercialize an innovative product. There is no innovation without a strong and productive research apparatus. In other words, universities or research companies cannot work alone. A country with an increasing number of researchers may fail to grow its GDP if there is no capital and companies capable of leading innovation. A risk-averse structure does not innovate.

Finally, it is necessary to choose the best solutions by using a method, or theory that measures solutions' viability, which AD can do.

We will now look briefly at the second and third laws of innovation. The second law says:

- "An Innovation hub will be nucleated if the initial nucleate size exceeds the critical size needed for stability, and if the activation energy barrier for nucleation can be overcome."

And the third law:

- "For innovation hubs to nucleate, the nucleation rate of innovation in a region must be greater than the rate at which innovative ideas, people, and financial capitals can move away from the region."

Both laws explain why innovation develops in exceptional locations. Moreover, once established and productive, innovation hubs attract skilled persons and resources, making it more difficult for hubs to appear in other regions. These laws explain why there is no Silicon Valley in Texas or Europe, and why wealthy areas tend to be more prosperous in a free market.

Innovation processes respond to societal or institutional problems. Therefore, raising problems is paramount. Knowing "what the problem is" and asking questions helps to define needs. Needs and problems are two sides of the same coin. The need must be identified neutrally and fundamentally. A technique to identify the needs, while avoiding faster horses, is by asking "why" successively until reaching high levels of abstraction, thereby enlarging solution spaces.

Problem-solving involves knowing the organization. The higher the approach, the more significant the impact of innovation. Starting by clarifying an organization's mission, creating its vision, and defining its values are clues for starting innovation processes. The impact will be progressively less if action is taken on policies, departments, procedures, or technologies. Creating a culture of innovation allows organizations to act on all these levels [11]. On the other hand, identifying a disconnected problem will enable conceptualization the needs of the organization if there is an in-depth knowledge of it. How to advance problems to their solution is the aim of design theories.

3. Axiomatic Design Theory

Axiomatic design theory states that the best design solutions can be selected using Suh's two axioms [8].

- First, Independence: "Maintain the independence of functional requirements";
- Second, Information: "Minimize the information content of the design."

This study focuses mainly on the first Axiom, independence. AD develops design solutions in four domains: customer, functional, physical, and process. In the customer domain, elements are customer needs (CNs). Functional requirements (FRs) belong to the functional domain. The functional domain contains answers to "What needs to be achieved?". The physical domain answers, "How can it be achieved?", with the design parameters (DPs). Finally, the process domain contains process variables (PVs), answering the question "How can it be built?".

CNs define needs, bounded by constraints, that design solutions must comply with. Figure 1 depicts the four domains and the mapping between the domains. Functional mapping occurring between CNs and FRs, can be called the conceptual project. Physical mapping is about the relationships between the FRs and the DPs, which can be called the physical design. Finally, each DP needs to be manufactured, or obtained in the market. The relationship between DPs and PVs can be called process mapping.

A complete design solution representation should contain all four of these aspects, although most only contain physical designs, drawings of physically integrated DPs. This kind of limited representation inhibits design modifications because design intent, contained in the FRs and CNs, is not included.

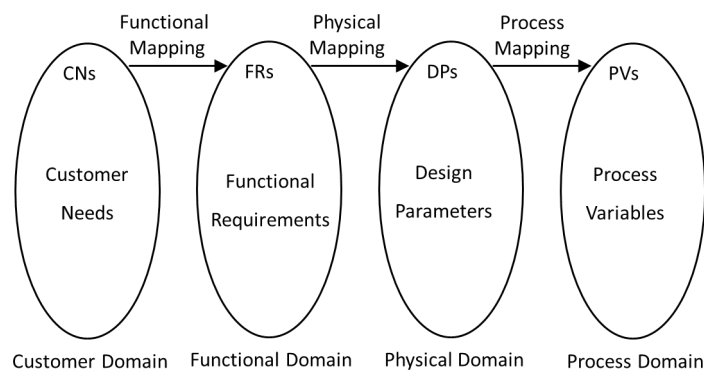


Figure 1. Design Domains and Mapping

After defining the CNs, the highest level FRs are defined. This deserves attention. Good FRs are essential to innovation. Design solutions can be no better than their FRs. Each FR has a corresponding DP, which constrains child FRs. If a DP in one branch proposes pneumatics for transferring loads, then all lower level FRs should address pneumatics, as opposed to electromechanics or hydraulics. However, at the lower levels, if it is found that a pneumatics solution violates Suh's axioms or a constraint, then an alternative DP should be selected.

This decomposition process is called zigzagging. It continues until reaching a set of DPs that are obvious and can be purchased or manufactured. At each level of a decomposition, children should be collectively exhaustive with respect to their parents and mutually exclusive with respect to each other (CEME), which complies with Suh's axioms. In this way, each level in each domain can be represented as vector with independent, i.e. orthogonal, components.

Figure 2 shows zigzagging, decomposing between functional and physical domains. The solid arrow from the physical domain to the functional domain reveals that a choice of a design parameter has implications on FRs at the next level of decomposition. Zigzagging is one of the fundamental aspects of Suh's AD theory. Complete design solutions are developed simultaneously across domains, at each level of their abstraction hierarchies, rather than one then another. A good solution has just the minimum number of FRs to guarantee satisfaction of the CNs. In turn, each FR should ideally be fulfilled by a

single DP, unique to that FR. This is required to comply with Suh's first axiom, independence. DPs are adjusted to control FRs and keep them in tolerance. If a single DP influences more than one FR, independence is diminished. One FR cannot be adjusted by changing that DP without changing other FRs influenced by that DP.

Design equations express relationships between FRs and DPs, $[FR] = [A] \cdot [DP]$, where $[A]$ is a design matrix (DM), and $[FR]$ and $[DP]$ are vectors. DMs in Equation 1 shows three different types of designs, where unspecified elements of $[A]$ are zero. From left to right, a) is diagonal and uncoupled, b) triangular and quasi or decoupled, and c) full and fully coupled.

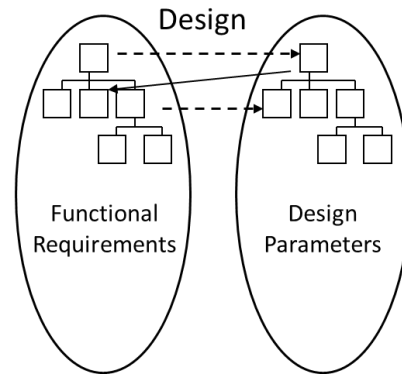


Figure 2. Zigzagging between the functional and the physical domains

Uncoupled designs (1a) allow FRs to be brought into tolerance by adjusting their corresponding DPs in any order without iterating. In these designs FRs are sensitive to variations in only one DP, because each DP influences only its unique, corresponding FR.

$$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} a_{11} & & \\ & a_{22} & \\ & & a_{33} \end{bmatrix} \cdot \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix} \quad a) \quad \begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} a_{11} & & \\ a_{21} & a_{22} & \\ a_{31} & & a_{33} \end{bmatrix} \cdot \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix} \quad b) \quad \begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & \\ a_{31} & & a_{33} \end{bmatrix} \cdot \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix} \quad c) \quad (1)$$

Equation 1b shows a decoupled design, which are represented by a lower or upper triangular matrix. In these designs, DPs must be defined in a specific order to adjust their FRs without iterations. DP_1 is the first parameter to be adjusted to bring FR_1 into tolerance. DP_1 will influence the remaining FRs. The following DPs can adjust their FRs in order without taking any of the previous ones out of tolerance. In Equation 1b, DP_2 or DP_3 can be defined interchangeably to reach FR_2 and FR_3 , which would not be the case if a_{32} were non-zero.

If FRs depend on several DPs simultaneously, and the design matrix cannot be arranged to make it triangular, then the design is coupled. It is a poor design (Equation 1c). This type of design can produce unstable systems that might not be adjustable and that could produce unintended consequences.

New concepts in an innovation process can be evaluated for technical viability using Suh's two axioms. At any level of a decomposition, the design to choose should be uncoupled, if possible, or decoupled, if not. Then the Information Axiom should be applied. The information content (I) can be calculated from the probability of success (p), Equation (2). Information content ranks remaining DP candidates. The one with the least information in the functional domain would be the best and should be selected.

$$I = \ln\left(\frac{1}{p}\right) \quad (2)$$

4. AD frames of innovation

AD is more than a design theory. It is a tool, a method, for innovation. By defining FRs in a physically neutral environment, and by zigzagging decomposition, the designer creates a semantical representation selecting the best solutions at each level of detail. Moreover, AD explains reverse engineering by representing what gave rise to an entity in the previous domain.

Essential elements of AD are, Suh's axioms, independence, represented with DMs (Eq.1) and information content (Eq.2); structure consisting of domains and hierarchies; hierarchical decompositions in detail and physical integrations. These elements are used for innovating and designing.

The next subsections focus on innovation by defining problems in AD domains, developing hierarchical decompositions in detail by zigzagging, examining independence (axiom one) using DMs, and evaluating the information content (axiom 2).

4.1. Innovation by identifying the domains

Problem definitions generally start in the customer domain. However, innovation problems still belong to a broader organization, entity, or country. Before defining CNs, designers might need to check to which domain problems belong, by looking at a more comprehensive system. Therefore, the first step of innovation could be to define problems in the context of a larger system considering ethics and sustainability.

If the problem regards manufacturing, it could belong to the process domain of a larger system. By checking PVs, DPs, FRs, and CNs, new ideas can arise to define new CNs, FRs, DPs, or PVs for that problem. Figure 3. shows innovation regarding a problem in a manufacturing system, relating one PV to one DP and one FR. This relation occurs most clearly in an uncoupled system.

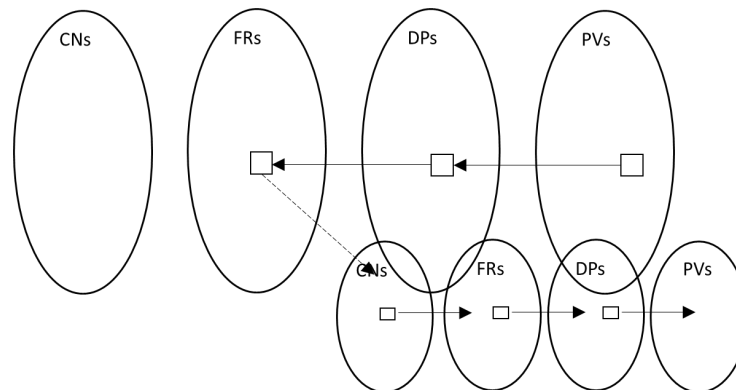


Figure 3. Zigzagging between the functional and the physical domains

In this example, a problem identified in a manufacturing system provides checks or redefines the corresponding DP and FR, in a reverse engineering context. Thus, it was possible to create a new design by defining a CN that defines the problem. However, a PV may influence many DPs, and each DP can influence many FRs, making the problem harder to define.

The broader the system, the better, because a more comprehensive DM can be achieved. However, larger systems can require greater knowledge to understand all the relations.

Moreover, by knowing the DP of a design solution, a new PV can be innovated. It is a widespread process in the industry. More seldom, an innovation department knows a company's FR and decides to implement a new DP. The impact in the organization will be higher if the FR is a child of the company mission. These approaches apply to problems other than industry. Many universal issues occur due to the lack of a global vision. The next examples show some huge mistakes that have compromised the entire society.

In the Republic [12] Plato discussed "Who must govern?". He applied this question to timocracy, oligarchy, democracy, and tyranny. "Who" belongs to the PV domain, so Plato discussed the design of regimes in the process domain! If instead of "who?", Plato had asked "how to govern?", or "what do we

want?”, the solution would have been different [9]. It would have avoided a lot of historical errors. Now CNs are the freedom and prosperity of people. We want to be live in peace and freedom in sustained environments. Thus, extreme conflicts are avoided by providing access to the government to different parties with different ideas.

This, 2020, has been the year of the COVID pandemic. Facing the disease, governments looked at medicine and epidemiology as the DPs. They focused the problem in the physical domain, e.g., hospitals, treatments, and vaccines. If they had started by defining CNs and FRs, they might have realized that hospitals are a piece of the problem. The problem involves more than medicine. The union between political power and medical power create unintended consequences, like economic issues, ethical issues based on eugenics or personal incomes, social repression and disruption, and psychological problems [13].

4.2. Innovation by zigzagging

The zigzagging decomposition process at each new level develops FRs in a solution neutral environment. Child FRs and DPs can be imagined in a vast space of solutions, as long as they comply with their parents, axioms, upper level DPs, and constraints, like sustainability [1].

Thus, once the innovation process reaches the functional domain, by direct or reverse engineering (Figure 3), many possibilities can match the requirements.

Urban electric mobility is a trend in any city for reducing pollution and global emissions. Suppose a DP is a bus with an electric motor, then a child FR will be “provide electrical energy”. Electricity may be provided by overhead wires, as in the trams of old cities. Batteries can be an alternative, which has been the solution for electric cars.

On-line electric vehicles (OLEVs) include a bus developed at KAIST that receives energy by electromagnetic induction from a buried cable at high tension. The OLEV design team developed the project using AD and reached a completed new innovative solution, supply electric energy by induction. OLEV receives power from new municipal infrastructures, cables buried in roads for a significant part of the route. Moreover, vehicles have small batteries that charge at stops, allowing the bus to run for a while on ordinary roads. Trams, trucks, and other heavy transports can use a similar approach.

Therefore, the same FR “provide electrical energy” can have many physical solutions. Getting power through induction from cables in the road required generating new knowledge. If instead of discussing bus mobility, the FR is about electrical mobility for people, the number of solutions will be enormous. We might see all those solutions coming to the market soon.

4.3. Innovation by checking the DM

A good design must be uncoupled or decoupled. Realizing a design is coupled is the first step for changing it.

History is a useful repository of AD applications. Implementation of a new, innovative FR decided the naval battle of Hampton Roads in 1862, in the American Civil War. The CSS Virginia, a confederate ship, was advanced for that time. The steam ship had a significant firepower, was protected by metal plates, and had a configuration that deflected direct shots. In turn, the Union had the USS Monitor, a low-profile steam ship with only one cannon. This was the first ship to have a rotating turret to aim its cannon independently of the ship’s direction. In this way, the FR: “aim the cannon” became independent of: “navigate in a direction”. CSS Virginia was neutralized by a smaller, slower, and outgunned Monitor. The Virginia retreated up a river, where it remained under the protection of land-based cannons. The independence of satisfying CNs with a new FR fulfilled by a new, independent DP, decoupled a design solution and allowed a smaller ship with less firepower to pose a lethal threat to the CSS Virginia. This Navy example is about creating a new uncoupled solution. Sadly, many things in life are coupled, and difficult to uncoupled. An example of coupled designs are relationships between countries that, moreover, vary with time.

At the end of World War II, the US State Department comes with a proposal for creating an international structure to ensure peace and security. In 1941 US President Roosevelt and the UK Prime

Minister Churchill made the first draft of The United Nations (UN). They defined an executive branch, the International Assembly, and an intervention force called the four policemen (US, UK, USSR, and China). The relationships of nations have always been coupled. Decoupling high levels of international relationships is accomplished by creating international political organizations. That is the case of the EU and African Union, the Arab Maghreb Union, and many more international organizations. All are intellectual creations to help to establish good relationships between countries.

Reducing, or eliminating, the role of international organizations exacerbates unwanted couplings between countries, violates Suh's independence axiom and the unintended consequences that could lead to disasters.

4.4. Innovation by evaluating the information content

Design managers decide on solutions often based on intuition or on a weighted decision process. Depending on the weights, any solution could be the chosen one. Computing the innovation content in the functional domain avoids psychologism when FRs are correctly defined. In such situations, FRs have bounds making it possible to evaluate the system performance against an acceptable range. At high-level definitions of designs, information content can be computed in a fuzzy way, to choose between two or more global options.

5. Conclusions

The first law of innovation defines the necessary conditions for innovation to occur. "For innovation to occur, there can be no lack of any element or link in the innovation continuum". The elements are "fundamental research and technological invention; financial community willing to provide capital and take the risk; industry with the necessary knowledge to develop, manufacture and commercialize the products of the invention."

Once the first law of innovation is satisfied, it is possible to think about several solutions by defining "what is the problem?". The innovation process of AD uses domains, zigzagging decomposition, design matrices, and evaluations of information content.

The process of innovation starts by identifying the AD domain in which the problem arises in a more global architecture. The higher the entity is in the abstraction hierarchy in which the innovation starts, the greater the impact on the process, organization, system, or artifact.

Acknowledgements

The first author acknowledges *Fundação para a Ciência e a Tecnologia* (FCT-MCTES) for its financial support via the project UIDB/00667/2020 (UNIDEMI).

References

- [1] Brown C A and Rauch E 2019 Axiomatic Design for Creativity, Sustainability, and Industry 4.0 *The 13th Int Conf on Axiomatic Design (Sydney)* vol 301 (MATEC Web of Conferences, EDP Science) p 00016
- [2] Le Masson P, Weil B and Hatchuel A 2017 *Design theory* (Springer International Publishing)
- [3] Mourão A, Cavique M and Gonçalves-Coelho A M 2011 Different Perspectives in Engineering Education According to the Mission – The Balance between analysis and synthesis *The 17th Int. Scientific Conf. Knowledge-Based Organization (Sibiu, România)* pp 496-501
- [4] Stilgoe J, Owen R and Macnaghten P 2013 Developing a framework for responsible innovation *Research Policy* **42** 1568– 1580
- [5] Eelko K.R.E. Huizingh 2011 Open innovation: State of the art and future perspectives, *Technovation* **31** 1 2-9
- [6] Sheu D D and Hei-Kuang Lee H-K 2011 A proposed process for systematic innovation, *International Journal of Production Research* **49** 3 847-868.
- [7] Furrer O, Sudharshan D, Tsiotsou R H and Liu B S 2016 A framework for innovative service design *The Service Industries Journal* **36** 9-10 452-471

- [8] Suh N P 1990 *The Principles of Design* (New York: Oxford University Press)
- [9] Suh N P, Cavique M and Foley J (Eds.) 2021 *Design Engineering and Science* (Springer International Publishing)
- [10] Suh N P 2010 A Theory of Innovation and Case Study *International Journal of Innovation Management* **14** 5 893–913
- [11] Gutierrez E, Olundh Sandstrom G, Janhager J and Ritzen S 2008 Innovation and decision making: Understanding selection and prioritization of development projects *The 4th IEEE Int. Conf. on Management of Innovation and Technology*, Bangkok, pp. 333-338
- [12] Plato – translated by Cornforf F M 1970 *The Republic of Plato* (New York: Oxford University Press)
- [13] Lévy B-H 2020 *The virus in the age of madness* (Yale University Press)