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Service Science & Engineering: Transdisciplinary Epistemology

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Abstract. In the absence of an axiomatic and rigorous foundation, Services risk, at best, being a narrow multi/inter-disciplinary domain At worst, it is a trade or a craft like plumbing or hairdressing. To address this weakness, we propose an *epistemological foundation* for a *transdisciplinary* Service Science and Engineering. The epistemology is predicated on a set of normative axioms, first principles, and a differential equation. We argue that a truly convincing transdisciplinary foundation must be able to derive and uncover new, novel, and quantitative transdisciplinary themes, which have escaped conventional qualitative analyses. To that end, we reveal and discuss the property of *chilarity* and the principle *takchronicity* for services. Physics, unlike services, has the laws of nature and mathematics to serve as a normative base. Similarly, mathematics is grounded on lemmas and theorems. This base enables new insightful theorems and novel mathematical theories like geometry and topology. All sciences require normative axioms, but they are not sufficient to frame a transdisciplinary science or engineering. There must be also a right way that legitimizes the praxis. For example, the Scientific Method. Hence, we will introduce our Services Method. Altogether, our epistemological base, analytic equations, new transdisciplinary themes, and Service Method help frame Services Science and Engineering more rigorously.

Keywords. Transdisciplinary Service Science. Service Science epistemology. Service Method. Service Science axioms. Service Value equations

Introduction

We use Services as a comprehensive term for the science, discipline, and practice. In contrast, a service refers to a specific instantiation and embodiment in a specific Services domain. (This is similar to the usage of data in the singular, although the singular is datum). We argue that the science of Services does not have the rigorous prerequisite foundations nor the hallmarks of science [1][2][3][4]. Therefore, to establish the rigor of Services as a science and engineering, we introduce a set of first principles [5]), normative axioms, and a Services Method for the praxis. Multidisciplinary or interdisciplinarity are prerequisites of transdisciplinary, they are not synonyms. Transdisciplinary requires new, useful, and insightful concepts of a higher-level synthesis than multidisciplinary or interdisciplinary ideas [6][7][8][9][10][11]. This is a new thinking that leads to a kind of *aufgehoben*, an original and creative Hegelian type synthesis. We introduce two key undiscovered fundamental transdisciplinary ideas, *chilarity* and *taktchronicity*. Normal science insists on frameworks for its practice, e.g., the Scientific Method [12]. Our proposed Service Method plays the same role as the Scientific Method for scientists and engineers [13][14]. We argue that in the absence of first principles, normative axioms, and a Services Method

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as a rigorous epistemological transdisciplinary foundation Services risks being like a trade or a craft rather than a rigorous science and engineering.

1. Gaps in Services Science and Engineering

A gap analysis of Services versus sciences like physics, mathematics, engineering, and the Sciences of the Artificial of Simon reveals fundamental gaps (Table 1)[15]. In the paragraphs that follow, we discuss them in more detail.

Table 1. Gaps in Services Science and Engineering.

science	goal	foundations	a method	disciplines	validation
natural science	understand nature	laws of science, math, logic	scientific method	physics, biology, chemistry, etc.	experiments, SI units, math, logic
mathematics	create consistent math theories	axioms, proofs, lemmas, and theorems	proofs, theorems, and theories	set theory. logic	proofs
engineering	conceive and develop useful products	natural sciences, social sciences	conceive, design, build, and operate	natural science marketing, finance, and management	supply & demand monetary & SI units
artificial products	create physical & non-physical artifacts	sciences of the artificial, and satisficing	adopt socio-tech. science methods	science of man-made artifacts, tangible, and intangible	adopted from socio- technical domains
services	create provider and customer benefits	co-creation first principles	**gap**	**gap**	**gap**

1.1 Absence of epistemological foundations

Services is a nascent science [16]. Science requires accumulated and epistemologically body of knowledge and learning, which are grounded on first principles, rigorous constructs, and mental models [4]. Science requires rigorous thinking and logical reasoning to systematically develop, communicate, validate, and accumulate valid and useful knowledge [17]. First principles, axioms, postulates, and rigorous logic establish the epistemological foundation for science and its praxis. Pseudoscience and superstition are without such firm foundations [4]. To support the praxis, correct *methods specify procedures to do science in the "right way"* [18][1][19][20]. The *right way* includes how to think, solve, and evaluate sociotechnical outcomes of Services problems. For Services, evaluation criteria must also include measurable technical factors like repeatability, homeostaticity, and reproducibility [21][15], satisfaction, affectiveness, and other benefits [22].

1.2 Absence of a Services Method

In science, there are accepted norms to do science in the "right way". The Scientific Method is such a universally accepted way of doing science [2][18]. The Scientific Method is a *normative* method, it is endowed with an epistemological foundation and rigorous rules for its use. For example, physics' epistemology is grounded on the laws of nature. Unanimous rules require confirming hypotheses, using experiments, and analyzing quantitative results for accuracy. Physics has first principles, axioms, postulates, and rigorous logic as the norms that establish legitimacy of the Scientific Method. Norms that consistently produce new knowledge and effective practices endow methods, with convincing epistemological

rigor and persuasiveness, justify their usage and findings. Science has a right way to do science.

Similarly, engineers have the engineering method to build useful artifacts [13][14]. The normative rules are grounded on physics, marketing, and economics. Systems that are multidisciplinary and interdisciplinary, in the sociotechnical sense, specifying the epistemological foundations for science. The conceptual task for transdisciplinary science is considerably more difficult. Systems engineering principles also appear in the literature [24]. *Satisfice* combines the words *satisfy* and *suffice*. *Satisficing* is a decision-making rule for sociotechnical sciences, engineering, and systems because optimality cannot or is impractical to be determined. For example, what is the optimal unemployment rate? Satisficing means *good enough*, neither maximized nor irrational, but doable and practical. Nobel laureate Simon [15] coined the term for decision-making for artificial man-made systems, which he called "artificial" because they do not appear in nature until they are made. Services are *artificial.*

1.3 Absence of a Services Metrology

Regrettably, Services' outcomes remain quantitatively unmeasurable except supported by qualitative, descriptive prose, and an abundance of examples. Services has no quantitative science of measurements with units and ratio scales. Metrology, the science of measurements is conspicuously absent in the service literature [25]. NIST Metrology is vital to understand and measure service value [26]. This measurement void has not escaped the attention of service scholars. "Value is perhaps the most ill-defined and elusive concept in service marketing and management" [27]. Badinelli writes that [28]:

> "… nobody has a precise definition of value, a model of its construction, or a methodology for evaluating it." … "Any research in cocreate processes provokes a host of questions about the very objective of co-creation." Indeed, there is an urgency "to advance the disciplines' knowledge of the definition and measurement of value." … "How can we measure something that has no precise definition?"

Unfortunately, this is the state of Services.

1.4 Transdisciplinary Weakness

There are many reasons why transdisciplinary is a challenging concept. There is a multitude of definitions [6][29][30][31], a plethora of selective case studies [32][33][34][36]. Transdisciplinary requires knowledge of Systems Engineering [10][30][37][7], demands technical skills and professional management expertise of SSME (Service Science, Management, and Engineering) [38][39]. Unfortunately, multidisciplinary, interdisciplinary, and transdisciplinary are frequently conflated. Multidisciplinary and interdisciplinary are prerequisites to transdisciplinary.

Transdisciplinary requires the integration of the different disciplines, into a converged holistic perspective [7][6]. What emerges are new ideas, insights, knowledge, and potentially disruptive findings. Transdisciplinary demands contributions from participants to create conceptual, theoretical, methodological, and transformational innovations that integrate and move beyond the discipline-specific domains of common problems. This is "a new way of thinking … beyond their traditional boundaries to identify and fill knowledge gaps and overcome incompatibilities" [40]. This requires a complex kind of Hegelian synthesis of complementary or even conflicting knowledge to reach a Hegelian type of ***aufgehoben***. Services as a sociotechnical discipline and also Sciences of the Artificial [15]. Man-made artifacts are artificial. They are conceived and made of tangible and intangible parts.

2. Foundations – Service Science and Engineering

2.1 First Principles

Service-dominant logic articulates the defining idea of value co-creation [41][45][43][44][45]. The phenomenology of Service value is stipulated by ten foundational premises (FP). Specifically, FP7 states "The enterprise cannot deliver, but only offer value propositions." And FP10 states that "Value is always uniquely and phenomenologically determined by the beneficiary." We argue that these FPs cannot be "foundational".

Value co-creation appears in the literature as a monolithic phenomenological event. But value co-creation is an interactive *step-by-step* process *between* the provider and the customer intended to satisfy their independent objectives. Either the provider or the customer can unilaterally terminate this process at any time. For example, when the provider's price is too high for the customer, the customer can walk away. Or when the customer reneges its commitment, to the resources and skills required, to complete its part to implement a service, the provider can walk away. The principles of co-creation disclose a bias to one side of the service value co-creation coin. Co-creation also implies bi-partite activities [46], a set of interactions between a provider and a customer.

All this has profound implications on pricing, a key factor of value. A provider sets a *reservation price* for an expected return given the resources and skills to develop a service. This is the lowest price it will accept from a customer. The customer also has a reservation price, which is the highest price it is willing to pay for such a service. In general, these two reservation prices are different; for they represent two invisible win-lose situations, one from a provider and the other from a customer. Through a process of explorations, discussions, and negotiations, the provider and customer will move from their respective reservation prices to reach a *transaction* price that is simultaneously acceptable to both. This is a win-win *Nash Equilibrium price*.

Prices, whether reservation or transaction price, are determined as a function of a firm's financial model. The general equation for profit is Profit = revenues - (cost + expenses). [47]. Provider and customer profit equations are respectively:

$$\text{(provider profit)} = \text{(sell price)} - [\text{(provider cost)} + \text{(provider expenses)}] \quad (1)$$

$$\text{(customer profit)} = \text{(sell price)} - [\text{(customer cost)} + \text{(customer expenses)}] \quad (2)$$

Assume a contract price = $10K, then sell price = buy price. Assume provider cost = $6.5K, and provider expenses = $1.5K. Then, provider profit = $2.K

A sale is assumed, so buy price = sell price = $10K. Assume customer cost = $1.K, and customer expenses = $1.K. Then, customerr profit = $8.K

Equation (1) is the provider profit-benefit of value-**from**-use. Equation (2) is the customer profit-benefit of value-**in**-use. Though the *construct of both equations is identical*, their values for a given service will not be identical. This is true because the provider's and customer's business structures are distinct, their revenues, costs, and expenses will not be equal. We have two equations for value, we do not agree with PF7 and PF10 [48]. From example of equation (1) and (2), in general.

$$\text{value-from-use} \neq \text{value-in-use}, \quad (3)$$

This is an example of the **Chilarity** property of service value. Chilarity is like a pair of gloves. You need a pair for gloves to be useful. Both the left-hand glove and right-hand glove are constructed for a thumb and four fingers, they cannot be substituted *for use* or *in use*. Their intentions and socio-technical systems will always make equation (3) valid. *Chilarity* is a very important transdisciplinary services concept to understand Services.

Services exist to make ***both*** providers and customers "better off" (*e.g.,* [49][27][50][51]) by offering utility and benefits [52]. "Benefits, which emerge from goal satisfaction, and sacrifices …"[53]. Benefits produce value for providers and customers. A service produces benefits of varying intensity, it automatically produces commensurate levels of value.

Grőnroos advises [50] that "monetary effects should be studied and metrics required to do such measures should be developed." He directs our attention toward the activities, that result in monetary benefits. This "enables customers to fully understand the benefits; quantify the value of those benefits, and raise customers' willingness to pay for differentiating features and services"[54]. Gebauer *et al.* report specific activities that impact industrial services [55]. Partanen et al. decompose the actions that generate benefits, into 33 specific simple and small service activities [56]. Value is the "worth in monetary units of the set of economic, technical, service, and social benefits received by a customer firm in exchange for the price paid ...". Economics is the most salient, practical, and measurable for value. Economic value helps address two other very important questions. What is the "the worth of benefits"? And what are the measurement units for benefits? The answer is benefits are measurable in monetary units, a ratio scale. Though we concentrate on economic value as the dominant measure of value in B2B markets, we do not exclude trust, satisfaction, loyalty, quality, and other measures. All contribute, to different degrees, to a more detailed understanding of service-value measures. In this article, we focus on the economic value of B2B markets, and defer the others as future work.

Inseparability is the idea that production and consumption are inextricably linked to services [34]. This is a temporal attribute that separates services from the manufacturing of physical goods. Unfortunately, discussions on this temporal dimension are entirely absent in the literature. It is conspicuously silent about the properties of inseparability. The key missing idea is *takt time*. Takt time is the rate at which the provider needs to complete a service step to meet specific or general customer demands. The crux of inseparability is **taktchronicity.** Taktchronicity is like tango, both dancing partners must move in complementary and synchronicity to perform their art to the music. Taktchronicity is the crux of inseparability. It is also a service's transdisciplinary property.

2.2 Service Axioms.

- Axiom 1. Value is the result of benefits obtained

Purpose of services is to produce benefits.
Provider *Value* = *f* (provider benefits). Customer *Value* = *g* (customer benefits).
Let Value = $\boldsymbol{V}$ and Benefits = $\boldsymbol{B}$
and $\boldsymbol{\Delta B / B}$ = *benefit increase*
and $\boldsymbol{\Delta V = \Delta B / B \Rightarrow \int dV = \int k*dB / B}$
$\therefore$ $\boldsymbol{V = k * log\ B + c}$ and ***without*** loss of generality let $\boldsymbol{c = 0}$ (4)
Equation (4) is the value equation in its most general form.

- **Axiom 2.** More value is good, but it decelerates

Provider value equation is $V_p = k_p * logB_p$ and customer value equation is $V_c = k_c * logB_c$.
The derivative of a log function is monotone decreasing.

- Axiom 3. Benefit Intensity

When a service is in use, the provider's and client's benefits are **not** equal.

$$B_p = \text{provider benefit intensity} = \frac{\$(\text{provider benefits}) + (\$\text{sell price})}{\$(\text{provider costs}) + \$(\text{provider expenses})}$$

$$B_c = \text{customer benefit intensity} = \frac{\$(\text{customer benefits}) - \$(\text{buy price})}{\$(\text{customer costs}) + \$(\text{customer expenses})}$$

Using data from equations (1) and (2,). We get: Bp=(2K+10K)/(6.5K+1.5K)=1.5. And we get for Bc=(8K+10K)/(1K+1K)=9K. Customer's "buy" is right "make or buy" decision.

- **Axiom 3.** Parity and Chirality

Parity. All axioms to providers and customers, albeit differently.

Per First Principles in 2.1, distinct social-technical mechanisms produce *provider-value* and client-value, we have:

*value-**from**-use* = f_p (provider *socio-tech sys)*

*value-**in**-use* = f_c (client *socio-tech sys)*

it follows that *value-**from**-use* ≠ *value-**in**-use.*

This is another instance of Services transdisciplinary **chirality** property. Although *provider-value* and *client-value* have identical analytic constructs, they are not equal.

- **Axiom 4.** No free lunch

It takes the provider's socio-tech systems and skills to **develop** a service. Similarly, it takes customer's socio-tech systems and skills to **use** a service. The demands are necessarily different. However, between provider and client, their use of resources and know-how must be *complementary, synergistic, and fair.*

2.3. Transdisciplinary Postulates.

The following are Services **transdisciplinar**y postulates whose roots are grounded in sociotechnical physical and intangible disciplines.

Postulate 1. Experience of Losses and gains.

For provider and customers losses are perceived more severely than gains. (prospect theory [57]). Gains and losses for providers and customers are not equally intense.

Postulate 2. Losses and gains are logarithmic functions.

This is the Weber-Fechner Law of people perceiving changes based on neural effects that logarithmic functions [58][59].

Postulate 3. Satisficing is the correct heuristic for Services**.**

Satisfice combines the words *satisfy* and *suffice*. *Satisficing* is a decision-making rule for sociotechnical sciences, engineering, and systems because optimality cannot or is impractical to be determined. For example, what is the optimal unemployment rate? Satisficing means *good enough*, neither maximized nor irrational, but doable and practical. Nobel laureate Simon coined the term for decision-making for artificial man-made systems, are "artificial" because they do not appear in nature until they are made [15]. Services are *artificia*l.

Postulate 4. A life-cycle Service Method.

Science largely progresses of knowledge accumulation through valid mental models, paradigms, disciplined and accepted processes to answer questions. A life cycle method

covers the span of service an idea from end-to-end does not appear to exist. There is no Service Method to do science in the "right way" like the Scientific Method [2][18]. A method with established norms is a *normative* method. For science, first principles, axioms, postulates, and rigorous logic are the norms that establish the epistemological foundation for normative methods. Norms that consistently produce new knowledge and effective practices endow methods with strong and convincing epistemological persuasiveness to justify their usage and findings. For complex systems, it is to understand, develop, and operate systems of technical and social rational organizations [24]. Systems that are multidisciplinary and interdisciplinary, in the sociotechnical sense, specify the epistemological foundations for science. The conceptual task for transdisciplinary science is considerably more difficult.

Table 2. Phases of the Service Method

complementary needs and capabilities	**Φ1 issue**	**e**ngage? needs and expectations compatible?
	process	explore, interact until "meeting of the minds"
	decision	if compatible commit to engage
reservation prices to a transaction price	**Φ2 issue**	formalize commitment? reservation prices negotiable?
	process	negotiate until agreed T's & C's
	decision	if transaction prices = NE, sign contract
commit resources and know-how	**Φ3 issue**	formulate a plan? resources sufficient & complementary?
	process	commit a doable plan with resources
	decision	if resources complementary, develop a plan
joint effort, adhere to T&Cs	**Φ4 issue**	implement plan? schedule, resources, risks, ok?
	process	develop the deliverables, review quality
	decision	develop the plan
joint effort, produce deliverables on schedule, & quality	**Φ5 issue**	operationalize plan? sociotechnical systems operable?
	process	sociotechnical systems flexible and resilient?
	decision	homeostatic & contingency processes
		execute the process

3. Summary of Original Contributions to Service Science and Engineering

3.1 Equations for provider and customer

Service Value Equation. V = k * log B + c
Benefit Equation. Same construct but chiral.
Identified major Gaps.

3.2 Lack of an articulated epistemological foundation for service science.

Lack of a Service Science and Engineering for the praxis.
Lack of Metrology as the measurement science for service value

3.3 New transdisciplinary findings. Chilariy and Taktchronicity.

3.4 Axiomatic & epistemological base for providers and customers

Axiom 1. Value is the benefits obtained.
Axiom 2. More value is good, but it decelerates.
Axiom 3. Axioms apply equally. Parity and Chilarity
Axiom 4. No free lunch.
Axiom 5. Chirality property of service value.

4. Research Implications

4.1 Service value Metrology.

Feynman said, "Unless a thing can be defined by measurement, it has no place in a theory." This is conspicuous in the literature. It is not a priority research subject. This is a serious deficiency in service science and a defect in the rigorous understanding of service value. It is said that if you're not measuring, you don't care and you don't know. Or, what you do know is superficial. We insist that measurements use ratio scales and avoid the more ambiguous and imprecise ordinal and weaker scales. Purely qualitative narratives and prose descriptions of case studies will not be enough to understand or manage Services.

4.2 Service Method

Most of the sciences and scientific practices have their discipline-unique methods. We have sketched a framework for the Service Method (Table 1). Further work on this must address each phase's critical issue, entry criteria, exit criteria, decision factors, service principles, commit mechanism, value and price implications.

4.3 Transdisciplinarity Challenges

Rigorous normative rules for transdisciplinary research should be developed. We uncovered chilarity and taktchronicity as transdisciplinary. A transdisciplinary property is one that uncovers or elevates disciplinary properties or interdisciplinary interactions to a higher level so that it resolves an apparent contradiction or produces new ways of thinking that substantially changes conventional frameworks or models of thought and analysis. We argue that its paradigmatic or Hegelian aufgehoben.

5. Management Implications

5.1 Disruptions to required skills.

Required skills, will change at all levels of the organization. The emphasis on science and engineering at the quantitative level will place a premium on hard science and soft science. Unequal command of science, management, and economics of sociotechnical systems like services will place a new level of stress at all levels.

Disruptions to required thinking. Skills. A new kind of sociotechnical thinking ike SSME will be required at every management and working level [38]. Brute force and old thinking will not be effective or competitive. Providers must show expertise in business and sociotechnical systems thinking. And the clients must understand the provider's service offering beyond a superficial task level, and leverage complex system effects to transform their own business processes within and across multiple and diverse functions.

References

[1] P. Caws, *Scientific Method, Encyclopedia of Philosophy. Volume*7. Macmillan, New York, 1966.
[2] R. Feynman, R. Leighton, M. Sands, *The Feynman Lectures on Physics: The New Millennium Edition: Mainly Mechanics, Radiation, and Heat, vol. 1*, Basic Books, 1963.
[3] T.S. Kuhn, *The structure of scientific revolutions*. University of Chicago Press, Chicago, 2012.
[4] S.O. Hansson, Science and Pseudo-Science. *Stanford Encyclopedia of Philosophy* (Summer 2017 Ed.), E.N. Zalta (ed.), https://plato.stanford.edu/archives/sum2017/entries/pseudo-science/. Accessed March 3 2023.

[5] V. Tang, First-principles for services and product-services-systems: An R&D agenda. In *DS 58-6: Proceedings of ICED 09, the 17th International Conference on Engineering Design, Vol. 6, Design Methods and Tools (pt. 2), Palo Alto, CA, USA, 24.-27.08.* 2009, pp. 461-472.
[6] M.G. Lawrence, S. Williams, P. Nanz and O. Renn, Characteristics, potentials, and challenges of transdisciplinary research. *One Earth*, 2022, Vol. 5(1), pp. 44-61.
[7] B. Mesmer, D. McKinney, M. Watson and A.M. Madni, Transdisciplinary Systems Engineering Approaches. In *Recent Trends and Advances in Model Based Systems Engineering*, Springer International Publishing, Cham, 2022, pp. 579-590.
[8] J.T. Klein, The transdisciplinary Momentum, *Integral Review, special issue International Symposium: Research Across Boundaries*, Part 1, 2013, Vol. 9, No. 2, pp. 189–199.
[9] U. Wiesmann, S. Biber-Klemm, W. Grossenbacher-Mansuy, G.Hirsch Hadorn, H. Hoffmann-Riem, D. Joye and E. Zemp, Enhancing transdisciplinary research: a synthesis in fifteen propositions.in G.Hirsch Hadorn et al. (eds.) *Handbook of transdisciplinary research*, 2008, pp. 433-441.
[10] N. Wognum, Transdisciplinary engineering systems, in R.S. Kenett (ed.) *Systems Engineering in the Fourth Industrial Revolution: Big Data, Novel Technologies, and Modern Systems Engineering*, 2020, pp. 483-510.
[11] S. Bondar, et al., Globalized OEM and tier-1 processes at SKF, *Adv Concurrent Eng*, 2012, pp. 789-800.
[12] O. Kuhn, Methodology for knowledge-based engineering template update, *IFIP Advances in Information and Communication Tech.,* Vol. 355, Springer, Berlin, 2011, pp. 178-191.
[13] W.P. Seering, Redefining Engineering. *MIT Faculty Newsletter*. MIT, Cambridge, 2003.
[14] E.F. Crawley, J. Malmqvist, S. Östlund, D.R. Brodeur, K. Edström, *Rethinking engineering education: The CDIO approach,* Springer, Cham, 2014, pp. 11-45.
[15] H.A. Simon, *The Sciences of the Artificial*. 3rd edition. MIT Press, Cambridge, 2001.
[16] H. Chesbrough, Toward a science of services. *Harvard Business Review*, 2005, Vol. 83, pp. 16-17.
[17] H. Poincaré, In George Bruce Halsted (trans.) *Science and Hypothesis* (1905), 101. From the original French, in *La Science et l'Hypothèse* (1908), *168*.
[18] B. Hepburn and H. Andersen, Scientific Method, *The Stanford Encyclopedia of Philosophy* (Summer 2021), E.N. Zalta (ed.), https://plato.stanford.edu/archives/sum2021/entries/scientific-method/ , Acc March 3 2023.
[19] P. Voima, K. Heinonen and T. Strandvik, *Exploring customer value formation: a customer dominant logic perspective.* Hanken School of Economics. Finland, 2010.
[20] E.O. Voit, Perspective: Dimensions of the scientific method. *PLOS Computational Biology.* 2019, Vol. 15(9), e1007279.
[21] MSA, *Measurement Systems Analysis. Ref. Manual* 3rd ed. AIAG. 2002.
[22] M.A. Ruiz et al., Development and Validation of the "Treatment Satisfaction with Medicines Questionnaire" (SATMED-Q)©. *Value in Health*, 2008, Vol. 11, pp. 913-926.
[23] R.F. Lusch and S.L. Vargo, *The service-dominant logic of marketing: Dialog, debate, and directions.* Routledge, Armonk, 2014.
[24] M. Watson, A. Madni, B. Mesmer and D. McKinney, Envisioning Future Systems Engineering Principles Through a Transdisciplinary Lens. *INCOSE International Symposium*, 2020, Vol. 30, No. 1, pp. 1517-1532.
[25] NIST Metrology. (2021). https://www.nist.gov/metrology, Accessed March 1 2023.
[26] J. Achterbergh and D. Vriens, *Organizations: Social systems conducting experiments*. Springer, Berlin, Heidelberg, 2009.
[27] C. Grönroos and P. Voima, Critical service logic: making sense of value creation and co-creation. *Journal of the academy of marketing science*, 2013, Vol. 41(2), pp. 133-150.
[28] R.D. Badinelli, Defining and measuring value. *Service Science,* 2015, Vol. 7(3), iii-viii.
[29] S. Bondar, et al., Network-centric operations during transition in global enterprise, *International Journal of Agile Systems and Management*, 2015, 8(3-4), pp. 355-373.
[30] H. Sillitto, J. Martin, R. Griego, D. McKinney, E. Arnold, P. Godfrey and S. Jackson, Envisioning systems engineering as a transdisciplinary venture. *Insight*, 2018, Vol. 21(3), pp. 52-61.
[31] C. Pohl, From Transdisciplinarity to Transdisciplinary Research. *Transdisciplinary Journal of Engineering & Science*, 2010, 1. https://doi.org/10.22545/2010/0006.
[32] S. Lattanzio et al., Concepts of transdisciplinary engineering: a transdisciplinary landscape. *International Journal of Agile Systems and Management*, 2021, Vol. 14(2), pp. 292-312.
[33] V. Martinez and T. Turner, Designing competitive service models. In M. Macintyre, G. Parry, J. Angelis (ed.) *Service design and delivery*, Springer, Boston, 2011, pp. 61-81.
[34] G. Parry, L. Newnes, X. Huang, Goods, products and services. *Service design and delivery*, 2011, pp. 19-29.
[35] M. Wever, Managing risks in knowledge exchange: Trade-offs and interdependencies, *Advances in Transdisciplinary Engineering*, 2016, Vol. 4, pp. 15-24.
[36] E.K. Chew, Service science: a reflection from telecommunications service perspective. *Handbook of Service Science*, 2010, pp. 359-385.

[37] Y. Wang and E. Tunstel, The emergence of abstract sciences and transdisciplinary advances: Developments in systems, man, and cybernetics. *IEEE Systems, Man, and Cybernetics Magazine*, 2019, 5(2), pp. 12-19.
[38] J. Spohrer, Services sciences, management, and engineering (SSME) and its relation to academic disciplines. In B. Stauss et al. (eds.) *Services Science: Fundamentals, challenges and future developments*, Springer, Berlin Heidelberg. 2008, pp. 11-40.
[39] M.E. Gorman, Service science, management and engineering: A way of managing sociotechnical systems. In B. Hefley et al. (eds.) *Service Science, Management and Engineering Education for 21st Century.* Springer, New York, 2008, pp. 77-82.
[40] A.M. Madni, Transdisciplinarity: Reaching Beyond Disciplines to Find Connections, *Journal of Integrated Design & Process Science*, 2007, Vol. 11, no. 1, pp. 1-11.
[41] S.L. Vargo, and R.F. Lusch, Evolving to a New Dominant Logic for Marketing, *Journal of Marketing*, 2004, Vol. 68(1), pp. 1–17.
[42] S. L. Vargo and R.F. Lusch, Service-dominant logic: continuing the evolution. *Journal of the Academy of Marketing Science*, 2008, Vol. 36(1), pp. 1–10.
[43] S.L. Vargo and R.F. Lusch, It's all B2B...and beyond: Toward a systems perspective of the market. *Industrial Marketing Management*, 2011, Vol. 40(2), pp. 181–187.
[44] S.L. Vargo and R.F. Lusch, Institutions and axioms: an extension and update of service-dominant logic. *Journal of the Academy of Marketing Science*, 2016, Vol. 44(4), pp. 5-23.
[45] S.L. Vargo and M. A. Akaka, Service-dominant logic as a foundation for service science: clarifications. *Service Science*, 2009, Vol. 1(1), pp. 32-41.
[46] S. Gallagher, What is phenomenology?. In S. Gallagher (ed.) *Phenomenology*, Springer, Cham, 2022, pp. 1-10.
[47] F. Weston and E.F. Brigham, *Managerial Finance*. 10th print. Dryden Press, Hinsdale, 1993.
[48] S.L. Vargo, P.P. Maglio and M.A. Akaka, On value and value co-creation: A service systems and service logic perspective. *European Management Journal*, 2008, Vol. 26(3), pp. 145–152.
[49] I.C. Ng, S.S. Nudurupati and P. Tasker, Value co-creation in the delivery of outcome-based contracts for business-to-business service. *AIM working paper series,* No. 77 (May 2010). http://www.aimresearch.org/index.php?page=wp-no-77. accessed 1 March 2021.
[50] C. Grönroos, Service logic revisited: who creates value? And who co-creates?. *European business review*, 2008, Vol. 20(4), pp. 298-314.
[51] I. Mitrouchev, *Reconciling Normative and Behavioural Economics: A Critical Survey*. 2021, http://www.ivanmitrouchev.com/research.html, accessed July 6 2023
[52] M.K. Lee, R. Verma and A. Roth, Understanding customer value in technology-enabled services: A numerical taxonomy based on usage and utility. *Service Science*, 2015, Vol. 7(3), pp. 227-248.
[53] T.P. Sales, F. Baião, G. Guizzardi, J.P.A. Almeida, N. Guarino and J. Mylopoulos, The common ontology of value and risk. *International conference on conceptual modeling*, 2018, Oct., pp. 121-135
[54] T.T. Nagle and G. Müller, *The strategy and tactics of pricing: A guide to growing more profitably*. 6th e, Routledge, New York, 2017.
[55] H.Gebauer et al., Service-driven manufacturing: Provision, evolution and financial impact of services in industrial firms, *Journal of Service Management*, 2012, Vol. 23, No. 1, pp. 120-136.
[56] Partanen et al., Developing and validating a multi-dimensional scale for operationalizing industrial service offering, *Journal of Business & Industrial Marketing*, 2017, Vol. 32, No. 2, pp. 295-309.
[57] D. Kahneman and A. Tversky, Prospect theory: An analysis of decision under risk. In D. Kahneman and A. Tversky (Eds.), *Choices, values and frames*. Cambridge Univ Press, Cambridge, 2000, pp. 17-43.
[58] S. Dehaene, The neural basis of the Weber–Fechner law: a logarithmic mental number line. *Trends in cognitive sciences*, 2003, Vol. 7(4), pp. 145-147.
[59] E.N. Dzhafarov and H. Colonius, The Fechnerian idea. *American Journal of Psychology*, 2011, 124(2), 127-140.