IntechOpen

Operations Management and Management Science

Edited by Fausto Pedro García Márquez

Operations Management and Management Science

Edited by Fausto Pedro García Márquez

Published in London, United Kingdom

Operations Management and Management Science
http://dx.doi.org/10.5772/intechopen.96833
Edited by Fausto Pedro García Márquez

Contributors
Roberto Sarmiento, Kotomichi Matsuno, Jiahua Weng, Noriyuki Hosokawa, Takahiro Ohno, Nneoma Benita Amos, Edafe Bawa Dogo, John Kolade Obamiro, Wasiu Oluwasegun Kehinde, Jonathan Ehimen Ekpudu, Oluwasegun David, Yu Zhao, Yiannis Laouris, Alexsandro Silva Solon, Marcos Paulo Leite Silveira, Marcos J. Negreiros, Nelson Maculan, Augusto W.C. Palhano, Albert E.F. Muritiba, Pablo L.F. Batista, Ashok G. Verghese, Thalavaipillai Sudalaimuthu, Pon Ramalingam, Călin Corciovă, Robert Fuior, Doru Andriţoi, Cătălina Luca

First published in London, United Kingdom, 2023 by IntechOpen
IntechOpen is the global imprint of INTECHOPEN LIMITED, registered in England and Wales, registration number: 11086078, 5 Princes Gate Court, London, SW7 2QJ, United Kingdom

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Additional hard and PDF copies can be obtained from orders@intechopen.com

Operations Management and Management Science
Edited by Fausto Pedro García Márquez
p. cm.
Print ISBN 978-1-80355-982-7
Online ISBN 978-1-80355-981-0
eBook (PDF) ISBN 978-1-80355-983-4

Meet the editor

Fausto Pedro García Márquez has been a Full Professor at the University of Castilla-La Mancha (UCLM), Spain, since 2013, is an Honorary Senior Research Fellow at Birmingham University, UK and a lecturer at the Postgraduate European Institute. He was a Senior Manager at Accenture from 2013 to 2014 and is currently the director of Ingenium Research Group obtained his European Ph.D. with maximum distinction. Since 2021 he has been a Senior Member of IEEE and an Honoured Honorary Member of the Research Council of the Indian Institute of Finance. He became the Committee Chair of the International Society for Management Science and Engineering Management (ISMSEM) in 2020. Among his awards are the Nominate Prize (2022), Grand Prize (2021), Runner Prize (2020) and Advancement Prize (2018), Runner (2015), Advancement (2013) and Silver (2012) from the International Society of Management Science and Engineering Management (ICMSEM), and the First International Business Ideas Competition 2017 Award (2017). He has published more than 200 papers and is the author or editor of more than 45 books, over 100 international chapters, and six patents. He has been the principal investigator in four European projects, eight national projects, and more than 150 projects for universities and companies. His main interests are: artificial intelligence, maintenance, management, renewable energy, transport, advanced analytics, and data science.

Contents

Preface

Operations management may be defined as the efficient transformation of inputs to outputs, carried out according to customer needs and considering the limitations present in the process. It, therefore, involves process optimization, from design to future requirements, the management of materials and products, production, and such other areas as maintenance and quality control. The products may be considered goods or services, while the inputs may be human resources, financial support, information, materials, energy, and so on.

Industry uses a large amount of data which, with appropriate analytics, provides more information and leads to an increase in the efficiency of operations management. In the various disciplines such as forecasting, capacity planning, location, layout, and integration of activities, new methods are constantly evolving to solve problems related to operations management, for example, dynamic analysis, computational techniques, probabilistic methods, and mathematical optimization techniques. Most of these new methods are based on artificial intelligence, for example, machine learning, deep learning, natural language processing, expert systems, data mining, support vector machines, and so on. Heuristics and metaheuristics algorithms are often found in optimization problems, for example, genetic algorithms, colony optimization, cuckoo search optimization, greedy randomized adaptive search procedure, particle swarm optimization, etc. Hybrid algorithms that combine several methods are being used today to improve solutions or to solve complex and robust problems that cannot be solved in another way.

This book introduces the main concepts and theoretical frameworks in operations management, as well as the latest empirical research findings from around the world. It also presents case studies from several industries, in which standard and novel algorithms are used to solve problems. Finally, future applications, trends and future work are suggested to improve the solutions presented.

Fausto Pedro García Márquez
Ingenium Research Group,
University of Castilla-La Mancha,
Ciudad Real, Spain

Chapter 1

Differences between Universal-Deterministic and Probabilistic Hypotheses in Operations Management Research

Roberto Sarmiento

Abstract

Very few papers in the operations management (OM) field have taken the themes of universal-deterministic (UD) and probabilistic hypotheses as their main topics of investigation and discussion. Our investigation continues a recent line of research that focuses on a better understanding of these critical issues. Specifically, we attempt to respond to some pointed criticisms that experts in the field have made when the topic UD and probabilistic hypotheses have emerged in academic settings/discussions. A detailed analysis of those criticisms shows that they lack merit, thereby reinforcing our argument that it is most important to distinguish between the two types of scientific hypotheses in order to advance in the rigor of OM theoretical and empirical research. Ideas for future research are outlined.

Keywords: universal-deterministic hypotheses, probabilistic hypotheses, case study research, quantitative studies, qualitative studies

1. Introduction

Previous investigations (e.g., [1, 2]) have attempted to provide a better understanding and awareness vis-à-vis the two types of hypotheses that exist in all fields of empirical science: universal-deterministic (UD) and probabilistic. In particular, those papers emphasize the potential problems of not acknowledging the theoretical/empirical differences between these two types of scientific propositions. Continuing with this line of research, our paper deals with some objections that have

been made by experts in the operations management (OM) field[1]. More specifically, our paper discusses why those criticisms are not justified. This article strengthens the argument about the importance of acknowledging the distinct characteristics that UD and probabilistic hypotheses possess. This topic is important, not only in operations management research, but in all areas of empirical science.

In sections 2, 3, and 4, we present the aforementioned criticisms and explain why those objections lack justification. In Section 5, we further explore (based on Popperian logic and methodology) how falsified hypotheses can still be of practical use. Section 6 offers some concluding remarks.

2. Criticism (a): "measurement variability messes up deterministic hypotheses. This problem turns a deterministic relationship into a probabilistic one"

There is no question that variability in the measurement of individual observations is an important issue in the empirical sciences. Nevertheless, it is not accurate to say that measurement variability transforms a UD hypothesis into a probabilistic one. These are two separate issues: 1) the problems with the measurement of empirical evidence (e.g., individual observations) when testing a hypothesis of interest, and 2) the logical form and implications of UD hypotheses.

Popper (e.g., [7], p. 63) acknowledges the potential problems that exist with respect to measurement variability. His recommendation is that there should be "methodological rules" by which decisions regarding empirical evidence in support of or against a given hypothesis may be agreed upon: "... Inter-subjectively testable experiments are either to be accepted, or to be rejected in the light of counter-experiments." Or as Dienes ([8], p. 20, his italics) puts it,

[1] Ross [3] says "[I]t is often stated that, unlike classical physics, Quantum Physics is not deterministic. This statement is not really correct ...". With this assertion, Ross begins a detailed explanation of a concept that he calls "probabilistic determinism." Later in his treatise, Ross writes that "[T]his means we do indeed have determinism, but only determinism of probability distributions of positions and momentum, as opposed to determinism of their exact values...". "Thus, although Quantum Physics does not allow us to determine where a particular photon will land, it does allow us to determine where we will find dense and sparse regions – and in this sense it is deterministic," Ross concludes. To reinforce his point, Ross explains that "probabilistic determination" is a viewpoint/approach that is tacitly/implicitly accepted/used in other disciplines, such as the Social Sciences. In the process of publishing OM papers that deal with the topics of UD and probabilistic hypotheses, we have received criticisms from anonymous referees that are similar to Ross' arguments, e.g., "the probabilistic versus deterministic distinction is basically a red herring," "something that is impossible according to a deterministic hypothesis is basically the same as something that has a one-in-a-billion chance of happening according to a probabilistic hypothesis." Referees are supposed to have considerable expertise on the subjects that are presented in the investigations they evaluate. Therefore, it is reasonable to conclude that if expert reviewers are not aware of the differences between UD and probabilistic hypotheses, then it is possible that the rest of the field is also unaware of these themes. We also note that highly influential works that offer guidance about case study research methodology (e.g., [4–6]) do not offer a detailed discussion of the differences between UD and probabilistic hypotheses. Moreover, when these topics have been brought up in informal gatherings and discussions with colleagues in other areas of business management research, a lack of awareness/understanding of these types of scientific propositions has also been identified. We argue that these situations justify our investigation. We are quoting or paraphrasing the objections that are dealt with in the paper.

> According to Popper, observation statements are finally accepted only by decision or agreement. Finally, there comes a point where everyone concerned feels the observation statement is sufficiently motivated that no one wishes to deny it. Considerable work may be needed to reach that point; and even then the decision to accept an observation may be overturned by new considerations. [...] In the end we must decide which observation statements we will accept. The decision is fallible and amounts to tentatively accepting a low-level empirical hypothesis which describes the effect: For example, accepting an observation statement amounts to accepting a hypothesis that "Peter is an extrovert", or "This extrovert was asleep at 7 am" and so on.

To illustrate Popper's point, we recall the story of the experiments and events that corroborated Einstein's general theory of relativity. According to Folsing, ([9], p. 443),

> The numerical values obtained were 1.98 ± 0.12 seconds of arc for the Sobral pictures and 1.61 ± 0.30 seconds of arc for the pictures from Principe (which had been impaired by clouds). Both results ruled out the "Newtonian" value; their mean value was almost exactly equal to Einstein's prediction of 1.74 seconds of arc.

This famous episode in the history of science shows that irrespective of the variability/errors that sometimes are inevitable when measuring empirical evidence, scientists can still develop methodological rules/agreements in order to judge whether the predictions/implications of a UD hypothesis have been corroborated or refuted. Put differently, the variability in the measurement of empirical evidence does not turn a UD hypothesis (e.g., Einstein's) into a probabilistic one.

We now offer a more recent example. Overbye [10] reported that in September of 2011, a group of scientists announced that they had measured a batch of subatomic particles (neutrinos) traveling faster than the speed of light. This appeared to falsify the UD law that negates that specific occurrence ("no object can travel faster than the speed of light"). However, Overbye then quoted a scientist as saying that "[T]he evidence is beginning to point toward the (results showing falsifying evidence of the UD law) being an artifact of the measurement" (see also [11] for more reports about the same episode).

The neutrinos story was very interesting to follow because the whole process – from the initial claims of falsification to the conclusion that errors had been made during the experiments – was consistent with the logic and methodology that Popper proposed in order to test a UD law. It also serves to illustrate once more that regardless of the different potential difficulties that can be present when testing a UD hypothesis, scientists can still come to the conclusion (based on methodological rules/conventions) that a given UD proposition has been refuted or corroborated. This helps us to affirm that the different difficulties that might appear when testing a UD hypothesis do not turn it into a probabilistic one.

Response to criticism (a): potential measurement problems that exist when testing the implications of UD hypotheses do not turn them into probabilistic ones. Instead, scientists can/should arrive at methodological rules/agreements upon which decisions should be made about empirical evidence that appear to corroborate or refute a hypothesis of interest.

3. Criticism (b): "the probabilistic versus deterministic distinction is basically a red herring," "something that is impossible according to a deterministic hypothesis is basically the same as something that has a one-in-a-billion chance of happening according to a probabilistic hypothesis"

These criticisms arguably reflect the prevalent thinking among scientists that are familiar with the frequentist approach to probability and statistical hypothesis testing[2]. For the sake of argument, we will assume that this approach is an adequate way to apply Popperian falsificationism when testing a probabilistic hypothesis[3]. In this approach, researchers usually have to formulate a null hypothesis (Ho) and an alternative hypothesis (H1). We will use these assumptions and conventions to explain one of the theoretical/empirical differences between UD and probabilistic hypotheses.

We first discuss a situation where researchers are interested in testing whether a variable "A" (the cause) has an effect on variable "B". We model this relationship using the usual principles and assumptions of standard linear regression analysis. We state Ho as a general proposition: "A has no noticeable effect on B" (e.g., Ho: $\beta 1 = 0$). We also establish H1 as "A has a noticeable effect (e.g., "statistically significant") on B" (e.g., $\beta 1 \neq 0$). Let us also suppose that two different investigations are performed: one to test a probabilistic relationship between A and B, and the other one to test its UD version. To be clear that we are dealing with two different and separate situations, we will rename the variables as *Ap/Bp* in the case of a probabilistic relationship and *Ad/Bd* to model its UD version. We can now restate both H1's as "*Ap* is likely to have a positive and significant effect on *Bp*," and "the effect of *Ad* on *Bd* is positive and linear," respectively. **Figures 1** and **2** illustrate the results of the hypothetical investigations of the probabilistic and UD relationships:

These figures show evidence supporting the alternative hypothesis (e.g., H1: "A has a noticeable and positive effect on B") in both its probabilistic and UD forms. Based on this, the assertion that there are no practical differences between these two types of hypotheses would appear to be true. Put differently, since **Figures 1** and **2** support the idea that Ho ("A has no noticeable effect on B") in its probabilistic and UD forms has been "practically falsified" and "falsified," respectively, it does seem as if arguing that UD and probabilistic hypotheses are different in nature is indeed a red herring.

We now proceed to explain that, in spite of what was discussed previously, there are clear theoretical/empirical differences between UD and probabilistic hypotheses. To accomplish our objective, we again model a causal relationship between two different variables: C ("the cause") and D ("the effect"). We make the same assumptions as before, with only one difference: we now suppose that there is prior corroborating evidence showing a noticeable and positive effect of C on D. We state the probabilistic version of this relationship as "*Cp* is likely to have a positive and noticeable effect on *Dp*" (i.e., Ho: $\beta 1 \neq 0$). The UD form of this relationship could be phrased along the lines of "*Cd* has a linear and positive effect on *Dd*" (e.g., Ho $\beta 1 = 1$). This is a different situation to the one that was analyzed in the previous paragraphs (Ho: $\beta 1 = 0$). Let

[2] For a more technical discussion on those topics, we recommend Popper [7] and Miller [12].

[3] Popper ([7], p. 183n) affirms that due to their logical form, probabilistic hypotheses are not directly falsifiable. However, he also says that scientists can arrive at "...the adoption of a methodological rule..., which makes probability hypotheses falsifiable." In this way, probabilistic hypotheses can attain a scientific status, because once a methodological rule has been adopted, their implications can be tested empirically (i.e., their predictions can be contradicted by empirical evidence).

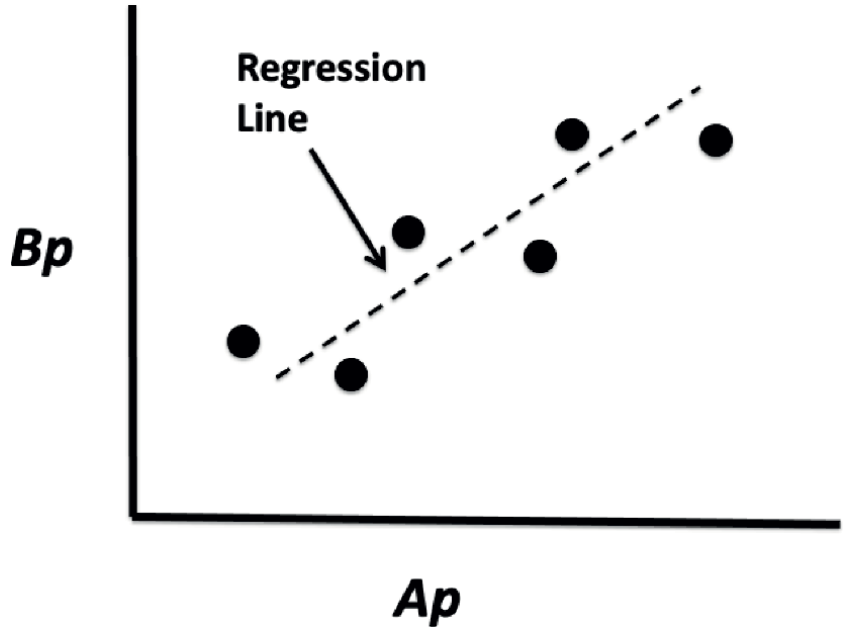

Figure 1.
Evidence supporting a probabilistic relationship between Ap and Bp.

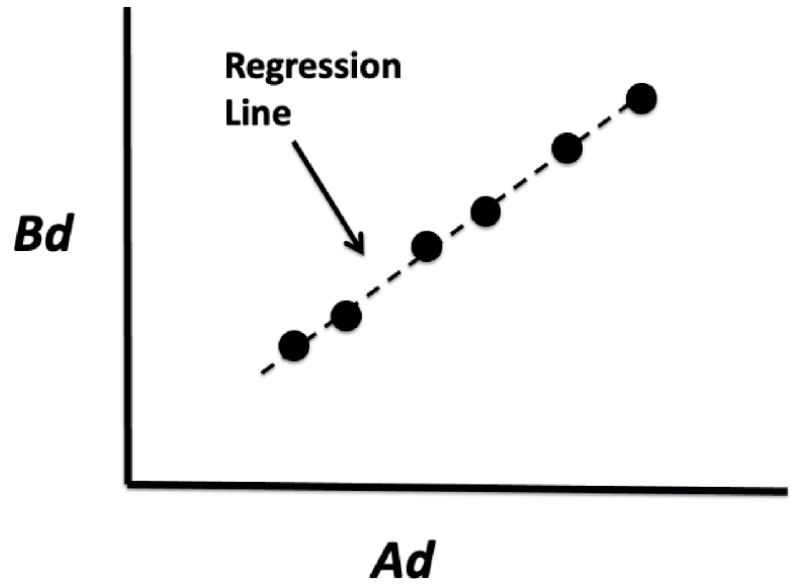

Figure 2.
Evidence supporting a UD relationship between Ad and Bd.

us also suppose that two investigations are run to examine these two relationships. **Figures 3** and **4** show the results of these hypothetical investigations.

These illustrations show one of the theoretical/empirical differences between UD and probabilistic hypotheses. **Figure 3** shows evidence that the probabilistic relationship

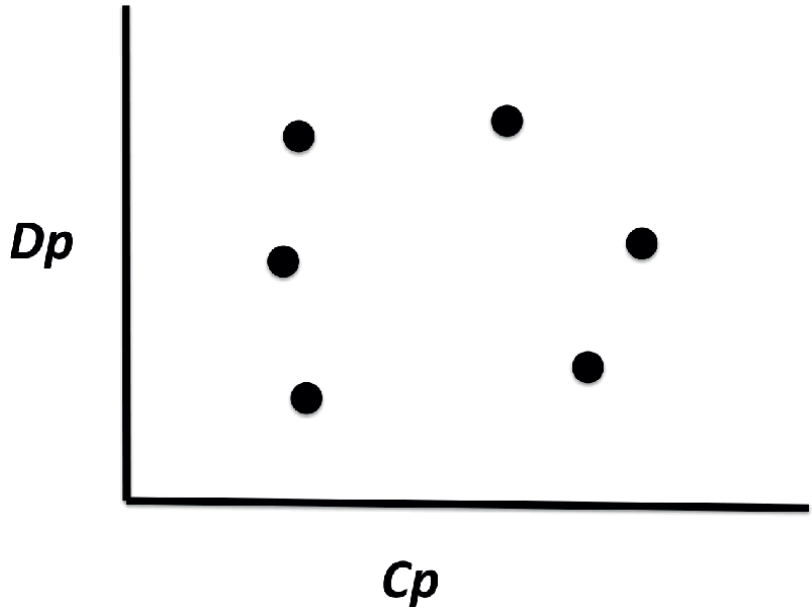

Figure 3.
Evidence that "practically falsifies" a probabilistic relationship between Cp and Dp.

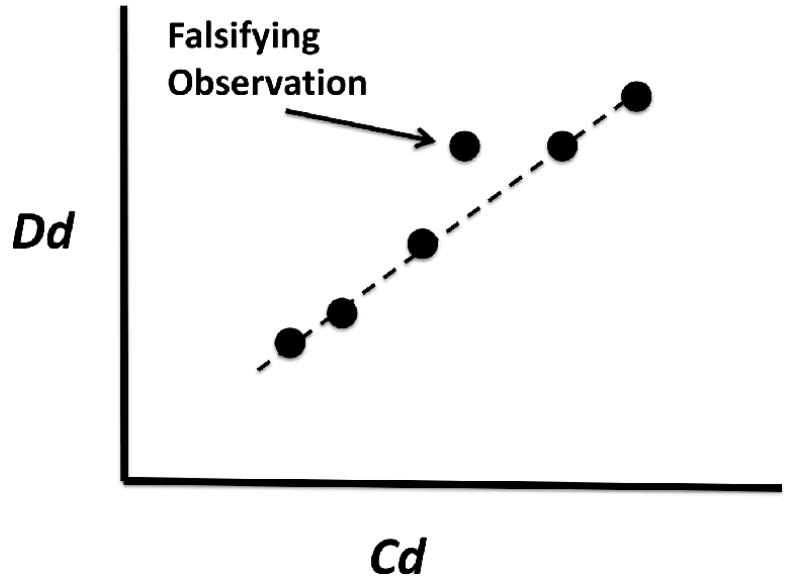

Figure 4.
Evidence that falsifies (logically and strictly) a UD relationship between Cd and Dd.

between *Cp* and *Dp* has been "practically falsified." Likewise, **Figure 4** shows evidence that the UD relationship between *Cd* and *Dd* has been falsified (logically and strictly). In short, Ho for both the probabilistic and UD forms of the causal relationship between C and D has been "practically falsified" and "falsified," respectively.

While it is true that in both cases there appears to be undermining/falsifying evidence against Ho *(when Ho establishes a noticeable and positive relationship between*

the variables), it is obvious that in theoretical/empirical terms, researchers finding evidence that "practically falsifies" a probabilistic hypothesis cannot continue to affirm that there is a noticeable and positive effect of *Cp* on *Dp*. **Figure 3** shows evidence of this non-relationship. Therefore, for all practical and theoretical purposes, researchers should be inclined to conclude that there is no evidence of a relationship between *Cp* and *Dp*. On the other hand, researchers who find falsifying evidence of the UD relationship between *Cd* and *Dd* should be inclined to say that even though the UD relationship has been (logically and strictly) falsified, there still appears to be a noticeable and positive relationship between *Cd* and *Dd*. In other words, the relationship between these two variables, for all practical and theoretical purposes, can still be considered as positive and noticeable. In short, the falsified UD relationship can now be stated as a probabilistic one: *Cd* is likely to have a noticeable and positive effect on *Dd*.

To complement the current discussion, we now offer an example of a relationship where the dependent and independent variables can be present or absent. To avoid repetition, now we will only model the situation where Ho states a prior noticeable effect of E (the cause) on F (the effect). The probabilistic form of this relationship can be phrased along the lines of "if E occurs/is present, then F is more likely to occur/be present than not." Its UD form can be stated as "If E occurs/is present, then F will always occur/be present." Once more we utilize *Ep* and *Fp* for a probabilistic relationship, and *Ed* and *Fd* for a UD one.

Let us suppose that we collect two different samples to test the two distinct hypotheses. In the case of the probabilistic relationship, let us assume that we found two cases where *Ep* and *Fp* are present, and three cases where *Ep* is present but *Fp* is absent. **Figure 5** illustrates these scenarios.

In the case of a UD hypothesis, let us suppose that we found four cases where *Ed* and *Fd* are present, and one case where *Ed* is present but *Fd* is absent.

Similar to the scenario disused before, it can be seen again that when researchers find evidence that "practically falsifies" a hypothesis stating that "if *Ep* occurs/is present, then *Fp* is more likely to occur/be present than not," for all pragmatic purposes, such a hypothesis should be discarded, as the evidence in **Figure 5** shows that in most cases, it does not hold. Therefore, researchers should be inclined to conclude that there is no evidence supporting the assertion that *Ep* and *Fp* are in some way associated. On the other hand, **Figure 6** shows that although the UD relationship "If *Ed* occurs/is present, then *Fd* will always occur/be present" has been logically and strictly falsified (i.e., one observation falsified this hypothesis), for all practical and theoretical purposes, researchers could still affirm that *Ed* is likely to be a causal agent for *Fd*, as the evidence shows that in most cases (four to one), the expected relationship does hold. Therefore, the falsified UD hypothesis between *Ed* and *Fd* can now be restated as a probabilistic hypothesis: "if *Ed* occurs/is present, then *Fd* is more likely to occur/be present than not."

The previous discussions show a clear difference between UD and probabilistic hypotheses: a "practically falsified" probabilistic hypothesis (*when Ho establishes a noticeable and positive relationship between the variables*) has no theoretical/empirical utility. On the other hand, a (strictly and logically) "falsified" UD hypothesis could still have pragmatic/empirical utility. In Section 5, we elaborate on the potential utility of hypotheses that have been falsified.

Response to criticism (b): a "practically falsified" probabilistic hypothesis (when Ho establishes a noticeable and positive relationship between the variables), for all theoretical/practical purposes, does not have predictive power/utility. On the other hand, a falsified UD hypothesis can still have predictive power/practical utility. Therefore, it is not a red herring to say that UD and probabilistic hypotheses are different in nature.

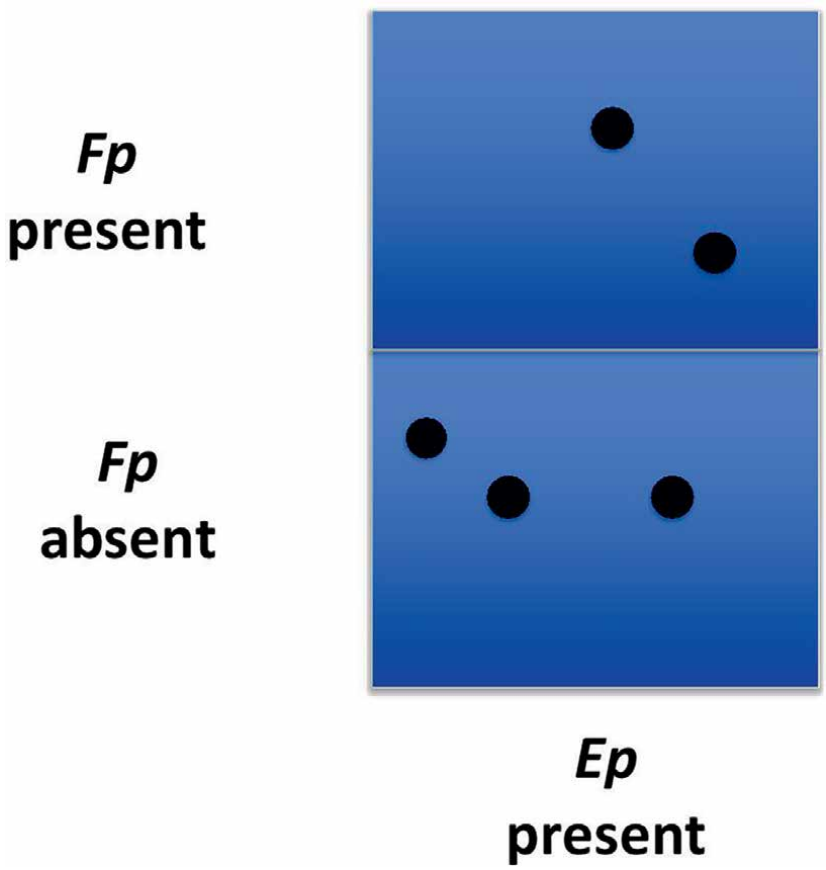

Figure 5.
Evidence that practically falsifies a probabilistic relationship between Ep and Fp.

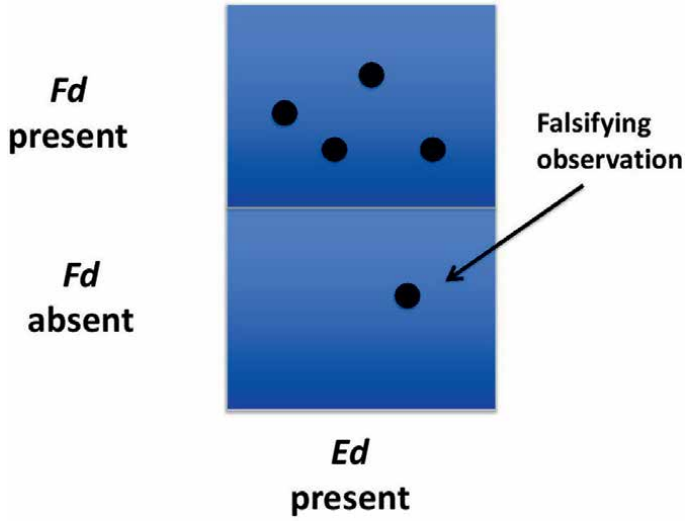

Figure 6.
Evidence that falsifies (logically and strictly) a UD relationship between Ed and Fd.

4. Criticism (c): "Few interesting relationships in operations management can be formulated as deterministic hypotheses"

The Cambridge Dictionary online[4] defines the word "interesting" as:

> Someone or something that is interesting keeps your attention because he, she, or it is unusual, exciting, or has a lot of ideas:

It could be validly argued that a UD relationship (e.g., something that always occurs) is far more interesting that something that takes place, for example, in most cases (e.g., a probabilistic relationship). Nonetheless, irrespective of why a researcher may deem a causal relationship interesting, we think that all scientists should be knowledgeable about the theoretical/empirical differences between UD and probabilistic hypotheses. This is important in order to avoid inaccuracies/omissions when hypothesis-testing and also when offering advice about research methodology (see [2] for a more detailed discussion about these issues in OM research).

Furthermore, while it is clear that the OM field (and arguably most of Social Sciences[5]) has been dominated by what could be called as "significance testing" [13], recently some scientists have also attempted to emphasize the importance and utility of UD hypotheses, for example, in the Business/Operations Management field [1, 14]. Likewise, Dienes ([8], p. 26, his italics) affirms that.

> Maybe many theories in psychology could effectively be written in the form, "In certain contexts, people always use this mechanism": "When my experimental procedure is set up in this way, all learning involves this sort of neural network."

Therefore, if UD hypotheses are to become more prominent in the Social Sciences, then it follows that scientists should be aware of their differences vis-à-vis probabilistic hypotheses, regardless of whether scientists (in their subjective views) think them interesting or not.

Response to criticism (c): whether a scientific proposition appears to be interesting or not, it is important for all scientists to be knowledgeable vis-à-vis the differences in the logical form and theoretical/empirical implications of UD and probabilistic hypotheses.

5. To be clear false theories can still be of use!

In Section 3, we explained that when a probabilistic hypothesis has been "practically falsified," researchers should be inclined to conclude that there is no evidence at all of a causal relationship between an independent and a dependent variable. We also explained that when a UD hypothesis has been logically and strictly falsified, it could still be of practical use, as a noticeable causal relationship between two variables could still be identified (see **Figures 4** and **6**).

It is not possible to be certain regarding the reasons that explain why expert researchers (see footnote 1) still opine that the differences between UD and probabilistic hypotheses are just a red herring and unimportant. Nevertheless, we think that a contributing factor might be the lack of awareness about the fact that falsified hypotheses can still be

[4] See https://dictionary.cambridge.org/dictionary/english/interesting [accessed 20 May 2022].

[5] See for example Hartmann and Sprenger [13] for a more detailed discussion on what they call "the mathematization of the social sciences."

of practical utility. It would appear as if researchers tend to equate the terms "falsified/false" with "useless," "meaningless" or "pointless." To support our contention that falsified hypotheses can still be of use, we quote Popper ([15], p. 74):

> ... false theories often serve well enough: most formulae used in engineering or navigation are known to be false, although they may be excellent approximations and easy to handle; and they are used with confidence by people who know them to be false.

Even though Newtonian physics have been "recognized as literally false" ([8], p. 5), "... scientists needed nothing more than Newton's equations to plot the course of the rocket that landed men on the moon" [16].

More specifically, in the OM field, the influential strategic trade-offs model [17] was put forward as a UD theory [2]. Even if empirical evidence were to falsify – logically and strictly – this proposition in the future, it would be difficult for researchers to affirm that Skinner's core argument ("*no product/service can be the best at everything*") does not reflect phenomena that occurs in the marketplace[6]. In short, even if Skinner's model were to be falsified, we argue that it would still be useful/have practical utility in the understanding – at least in some circumstances/situations – of the differences observed in the features/performance between pairs of rival products/services.

The fact that strictly and logically false/falsified (UD) hypotheses can still be of practical/empirical use should serve to strengthen our argument about the importance of acknowledging the differences that exist between UD and probabilistic hypotheses in empirical science.

6. Some concluding remarks

Investigations that deal directly with the topics of universal-deterministic and probabilistic hypotheses are not common in business management research in general, and operations management science in particular. Our hope is that this paper can contribute to a better understanding of the theoretical/empirical differences that exist between these two types of hypotheses.

[6] See [18] for a detailed discussion of strategic trade-offs between two competing products. Moreover, some authors (e.g., [19]) claim that in practice, the trade-offs model is not used. Sarmiento et al. [20] provide a detailed response to Singh et al.'s assertion.

Author details

Roberto Sarmiento
Faculty of Engineering, Autonomous University of San Luis Potosi, Mexico

*Address all correspondence to: sarmientoroberto@yahoo.com.mx

References

[1] Dul J, Hak T. Case Study Methodology in Business Research. Oxford UK, and Burlington, MA, USA: Butterworth-Heinemann; 2008

[2] Whelan G, Sarmiento R, Sprenger J. Universal-deterministic and probabilistic hypotheses in operations management research: A discussion paper. Production Planning & Control. 2018;**29**(16):1306-1320

[3] Ross D. I don't Understand Quantum Physics. Available from: https://www.southampton.ac.uk/~doug/quantum_physics/quantum_physics.pdf. Southampton, UK: University of Southampton; 2018 [Accessed: May 20, 2022]

[4] Eisenhardt KM. Building theories from case study research. Academy of Management Review. 1989;**14**(4): 532-550

[5] Voss C, Tsikriktsis N, Frohlich M, M. Case research in operations management. International Journal of Operations and Production Management. 2002;**22**(2):195-219

[6] Yin RK. Case Study Research: Design and Methods. London: Sage; 2014

[7] Popper K. The Logic of Scientific Discovery. London and New York: Routledge Classics, Taylor & Francis Group; 2002

[8] Dienes Z. Understanding Psychology as a Science: An Introduction to Scientific and Statistical Inference. Basingstoke and New York: Palgrave-Macmillan; 2008

[9] Folsing A. Albert Einstein: a biography. Viking (published by the Penguin Group), London: Penguin Books Ltd; 1997

[10] Overbye, D. 2012. The Trouble With Data That Outpaces a Theory. Available from: http://www.nytimes.com/2012/03/27/science/the-trouble-with-neutrinos-that-outpaced-einsteins-theory.html. [Accessed: December 13, 2015]. Available from: https://www.nytimes.com/2012/03/27/science/the-trouble-with-neutrinos-that-outpaced-einsteins-theory.html. [Accessed: May 18, 2022]

[11] Cartlidge E. BREAKING NEWS: Error Undoes Faster-Than-Light Neutrino Results. 2012. Available from: http://news.sciencemag.org/2012/02/breaking-news-error-undoes-faster-light-neutrino-results?ref=hp. [Accessed: December 13, 2015]. Available from: https://www.science.org/content/article/breaking-news-error-undoes-faster-light-neutrino-results. [Accessed: May 18, 2022]

[12] Miller D. Popper's contributions to the theory of probability and its interpretation. In: Shearmur J, Stokes G, editors. The Cambridge Companion to Popper. Cambridge: Cambridge University Press; 2016. pp. 208-229

[13] Hartmann S, Sprenger J. Mathematics and statistics in the social sciences. In: Jarvie IC, Zamora Bonilla J, editors. The SAGE Handbook of the Philosophy of Social Sciences. London: SAGE; 2011. pp. 594-612

[14] Dul J, Hak T, Goertz G, Voss C. Necessary condition hypotheses in operations management. International Journal of Operations & Production Management. 2010;**30**(11):1170-1190

[15] Popper K. Conjectures and Refutations: The Growth of Scientific Knowledge. London and New York:

Routledge Classics, Taylor & Francis Group; 2002

[16] Green B. The Elegant Universe: Episode 1 - Einstein's Dream. Available from: https://www.youtube.com/watch?v=5vUzzCoArCo. [Accessed: May 20, 2022]

[17] Skinner W. Manufacturing-missing link in corporate strategy. Harvard Business Review. 1969;**47**(3):136-145

[18] Sarmiento R, Thurer M, Whelan G. Rethinking Skinner's model: Strategic trade-offs in products and services. Management Research Review. 2016;**39**(10):1199-1213

[19] Singh PJ, Wiengarten F, Nand AA, Betts T. Beyond the trade-off and cumulative capabilities models: Alternative models of operations strategy. International Journal of Production Research. 2015;**53**(13): 4001-4020

[20] Sarmiento R, Whelan G, Thürer M. A note on 'beyond the trade-off and cumulative capabilities models: Alternative models of operations strategy'. International Journal of Production Research. 2018;**56**(12): 4368-4375

Chapter 2

Design and Planning Robust and Competitive Supply Chains

Kotomichi Matsuno, Jiahua Weng, Noriyuki Hosokawa and Takahiro Ohno

Abstract

In recent years, supply chains in the manufacturing industry have become more and more complicated, and many cases of supply chain disruptions due to natural disasters have been confirmed. It is necessary for manufacturers to build a system that can help them alleviate losses and shorten recovery periods due to supply chain disruptions. Supplier diversification, as well as supplier evaluation and selection, are discussed as risk aversion measures in many papers. However, even if the procurement source has been evaluated enough, there are problems, such as opportunity loss during recovery periods and soaring procurement costs during normal periods. In this chapter, to help Japanese manufacturers to alleviate opportunity loss under component procurement disruption situations and keep cost competitiveness in normal periods, decision-making models of supply chain structure assessment, supplier selection, procurement allocation, and trading contracts are designed and verified.

Keywords: supply chain disruption, supply chain structure, supplier selection, procurement allocation, contract

1. Introduction

The supply chain structure in the manufacturing industry is getting more and more complex due to the acceleration of globalization. It makes the impact of disruptions on the whole supply chain greater than ever before. Many natural and man-made disasters, such as Hurricane Katrina 2005, Great East Japan Earthquake 2011, Thailand Flood 2011, Kumamoto Earthquake 2016, COVID-19 2019, and the recent Russia-Ukraine war 2022, have resulted in large-scale supply chain disruptions. Manufacturers had a large amount of opportunity losses due to production interruptions caused by the shortage of components. Moreover, a number of manufacturers were unable to get survived anymore due to component procurement disruptions.

In the past, how to reduce procurement costs, shorten procurement lead time, and maintain good relationships with suppliers are considered the most important matters when manufacturers make their decisions on procurement. Since the Great East Japan Earthquake of 2011, the development of an effective business continuity plan (BCP) has been considered one of the most important matters to Japanese manufacturers. As a part of BCP development, sourcing decision-making with consideration of supply

chain disruption risks is becoming the most important process. In the increasingly competitive global environment, manufacturers should not only focus on the efficiency of their own production and logistics operations but also take measures, such as understanding the location of risks in the supply chain and diversifying procurement sources to reduce the risks of procurement shortages due to supply chain disruptions [1].

As known to all, BCP defines the activities for business continuity. It should be carried out under both normal and emergency situations to enable the business continuation or early recovery of core business operations in the event of natural disasters, major fires, terrorist attacks, or other emergency situations. With the aim of increasing the development rate of BCP in Japan, the Small and Medium Enterprise Agency has published a BCP development manual on its website, which explains how to develop a BCP for each business in detail. The process of BCP development is shown in **Figure 1** [2].

There are five steps for BDP development and operation, including (1) understand business operations, (2) consider BCP preparations and prior measures, (3) formulate BCP, (4) establish BCP culture, and (5) test, maintain, and update BCP. Step 2 and step 3 are considered the most important and difficult steps among all the five steps. The significance of BCP and its economic effects are mentioned to show that BCP should be a system that also could generate economic effects even in normal periods compared to conventional disaster prevention measures [3]. However, many manufacturers are stuck between step 2 and step 3. Lacking visibility of benefits under normal situations

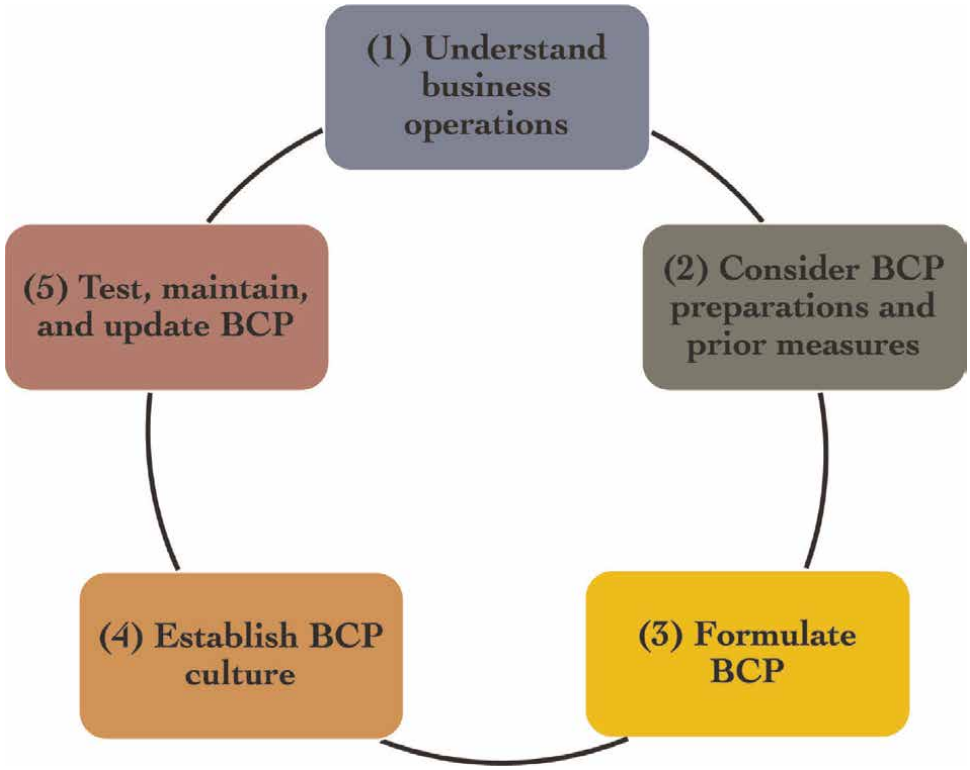

Figure 1.
BCP development and operation cycle.

and lacking mitigation effects against losses due to supply chain disruptions are cited as the main reasons for lacking progress in BCP development.

To help manufacturers to make their decision-making on risk mitigation measures creation as well as effectiveness evaluation, research on supply chain disruption risk management (SCDRM) to deal with supply chain disruptions has been attracting much attention and the number of papers has been increasing rapidly in recent 10 years. Proposals of these papers could be broadly divided into two types which are pre-measures and post-measures. Risk assessment of supply chain structures, supplier evaluation, and procurement allocation is considered the pre-measures. On the other hand, switching to alternative components and switching procurement sources are considered the post-measures. In addition, since most of the post-measures are ineffective without any pre-measures, pre-measures can be considered as plans for post-measures.

Based on the levels of decision-making, risk mitigation measures could be divided into strategic level, tactical level, and operational level. Assessing supply chain risks and determining what kind of supply chain structure should be built is considered the strategic level of decision-making. As a part of supply chain building, evaluating and selecting suppliers based on the decided supply chain structure is also considered the strategic level of decision-making. Concluding risk-hedging trading contracts, including procurement agreements, supply and penalty terms between upstream and downstream companies are considered the tactical level of decision-making. How to make post-measures more efficient is considered an operational level of decision-making. **Figure 2** shows the risk mitigation measures by different decision-making levels. In this chapter, decision-making models of risk mitigation measures at the strategic level and tactical level are mainly discussed.

The remainder of this chapter is organized as follows. Section 2 provides an introduction to the risk assessment of supply chain structures. Section 3 provides a study on the decision-making of manufacturers on suppliers selection and procurement allocation based on the risk assessment of supply chain structures. Section 4 presents a robust and competitive contract model for manufacturers. The chapter is concluded in Section 5.

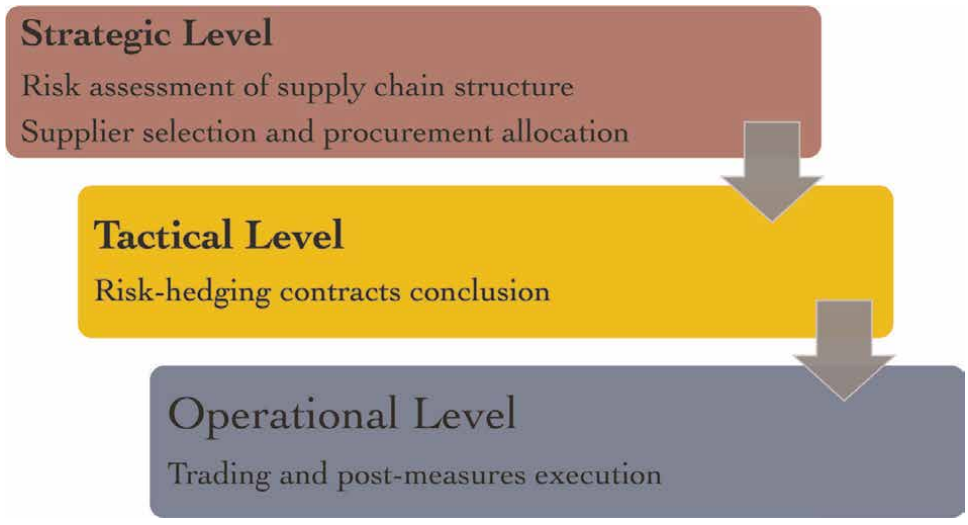

Figure 2.
Risk mitigation measures at different decision-making levels.

2. Risk assessment of supply chain structure

This section presents literature reviews and a previous study about risk assessment of supply chain structures [4].

The economic impact of supply chain disruptions immediately after the Great East Japan Earthquake was examined and the amount of production losses caused by the supply chain disruptions to at least 0.35% of the GDP was estimated in [5]. In ref. [6], the responses of Japanese manufacturing firms to natural disasters, such as earthquake, tsunami, and nuclear disasters, were discussed. Based on case studies, several supply-chain recovery processes after natural disasters as well as humanitarian disruptions were discussed and reflection points in terms of disaster planning, and recovery responses were summarized. In ref. [7], several supply-chain structural models were built and the tradeoff relation between supply-chain efficiency and robustness under supply-chain disruption risks was discussed. Countermeasures for mitigating supply-chain disruption risks in terms of redundancy, robustness, and flexibility were discussed after the research work on supply-chain visualization in ref. [8].

As typical natural disasters, earthquakes cause significant damage to supply chains. Since earthquakes occur frequently in Japan, procurement disruptions due to earthquakes also occur frequently. Occurrence probability, as well as impact, are two main evaluation indicators of earthquakes. In this study, the recovery period of the supply chain from the earthquake is considered as the earthquake impact. A model of procurement disruptions due to earthquakes is developed to clarify the loss difference among different supply-chain structures in Japan.

2.1 Model of procurement disruptions due to natural disasters

Although the probability of an earthquake cannot be expressed accurately, as a general thought, occurrence probability could be estimated based on historical data on earthquakes. Since earthquakes less than seismic intensity 7 only have little impact on production and procurement activities, only earthquakes with a seismic intensity of 7 or over are considered in this study.

Table 1 shows the data about earthquakes over seismic intensity 7 in the last 10 years (2011–2021) which was collected from the website of the Japan Weather Association [9]. With the data in **Table 1**, the average annual probability of an earthquake which seismic intensity is 7 could be estimated. Since seismic intensity 7 earthquakes occurred 4 times in 11 years including 2021, the average annual occurrence probability is 0.36 and the average monthly occurrence probability should be 0.03.

Date and time	Epicenter	Magnitude	Max seismic intensity
2018/9/6 3:08	Eastern Iburi of Hokkaido	M6.7	7
2016/4/16 1:25	Kumamoto region of Kumamoto	M7.3	7
2016/4/14 21:26	Kumamoto region of Kumamoto	M6.5	7
2011/3/11 14:46	Sanriku offshore	M7.9	7

Table 1.
Earthquakes over seismic intensity 7 in the last 10 years (2011–2021) in Japan.

Chapter 6

Managing Large-scale Societal Change

Yiannis Laouris

Abstract

In this chapter, we discuss three decisive parameters for successful large-scale societal interventions: 1. The selection of the most representative and relevant stakeholders; 2. The application of an appropriate systemic problem-structuring methodology; and 3. The process used to convert the results of a structured deliberation into a clear strategy accompanied by a roadmap consisting of the most effective actions. We claim that the structured democratic dialog process emerges as an excellent tool for managing diverse types of societal interventions. Two models of intervention for large-scale societal reforms are briefly presented and discussed. The first is based on a quasi-synchronous process using the same intervention delivered at multiple localities. The second starts with one intense focal intervention and a process design that allows it to replicate and expand by creating spin-off agents or communities of change. The chapter concludes with recommendations.

Keywords: societal reforms, structured democratic dialog, problem structuring methods, community operations research, collective intelligence, collective wisdom

1. Introduction

As our world is constantly evolving, it will, of course, always be in need of changes and reforms. However, the increasing rate of change in combination with the rapidly increasing complexity renders the need for effective large-scale reforms a pressing emergency [1–3]. International bodies such as the UN, the EU, the G7/20, etc., as well as scientists, philosophers, and activists, alert us to the need for positive change in virtually all aspects of our lives. Reforms are especially critical in (global- and local scale) governance, peace, education, economy, and health. However, we still lack solid scientific models on how to plan and successfully implement large-scale reforms. Also, the number of successful and scientifically validated large-scale interventions is still small. On the other hand, the advances in technology and especially social media render changes previously thought as unachievable entirely feasible. The question is, however, whether we, as a society, must passively welcome changes just because of their feasibility? Does the fact that they are possible mean that they are also desirable or inevitable? Although not the focus of this chapter, humanity is at a point from which it could design and construct positive futures in the realm of what we call conscious evolution [4, 5]. To be able to achieve this, we need visionary leaders but, more importantly, appropriate science, methods, and tools. Effective leaders engaging in large-scale reforms rely on the triad, *will*, *ideas*, and *execution* for guidance [6, 7]. Clear, quantifiable, and ambitious vision and goals are crucial to

building will. Those leading should express confidence in their people's creative potential and goodwill and know when and how to celebrate success. They should put systems and procedures in place to empower those whose lives will be influenced by any reforms to offer their ideas without fear of criticism. They should also allow them to hear or experience others' innovations and success stories. The execution, vis-à-vis, implementation, requires strategy, roadmaps, continuous attendance to processes, and willingness to adapt to new situations. Finally, the encouragement of cooperation and dialog among groups pursuing similar or identical goals increases the speed and quality of the change process.

In practice, there are many approaches to implementing a desired change. The first is by executive order coming from a gifted leader or from the management/government. Such interventions do not need the "acceptance" of the public, nor do they require lengthy approval processes. They are typical in hierarchical organizations and in emergency situations, such as the recent COVID-19 pandemic, and are often temporary or serve a short-term purpose. Sometimes, they are unwelcome and might even create societal unrest.

The most typical scenarios of societal change are through some form of policies or legislation, which could take place with or without the participation of all relevant stakeholders. In the latter case, the path can be rough (see next section). In this chapter, we are concerned with the case when relevant stakeholders are invited to define the problem collectively but also deliberate to come up with a consensus as to what actions are required to move forward. Thus, the first challenge is the selection of the most *representative* and *relevant* stakeholders.

The second challenge for achieving positive change is the availability and application of an *appropriate systemic problem-structuring methodology* and *relevant tools*. And the third and probably greatest challenge is how to convert the results of any process of deliberation into a clear strategy accompanied by a roadmap consisting of the most effective actions. We claim that the structured democratic dialog (SDD) process emerges as an excellent tool for addressing these three challenges and successfully managing diverse types of societal interventions.

In this chapter, we present and discuss two models of intervention for large-scale societal reforms. The first is based on a quasi-synchronous process using the same intervention delivered at multiple places. The second starts with one intense focal intervention and a process design that allows it to replicate and expand by creating spin-off agents or communities of change. The chapter concludes with recommendations.

1.1 Stakeholder participation: authenticity, diversity, and equity

Researchers [8] have identified factors that impact large-scale change already in the 90s and they mostly point to human factors. The lack of support by the top management, their attempt to force change, inconsistent actions, unrealistic expectations, absence of meaningful participation, poor communication, unclear purpose, and misplacement of responsibility were found to have a highly negative impact. Factors with a highly positive impact include the management's tangible and visible support and commitment, good preparation, encouragement of stakeholder participation, a high degree of communication, a reward system, etc. Methods for stakeholder identification and engagement have been well described by Gregory et al. [9]. All of the above boil down to what we call *authentic participation*. Indeed, the law of requisite action [10] of the science of SDD[1] predicts that "action plans to redesign complex

[1] For a brief introduction to the first six laws see [23].

socio-technical systems without the authentic and true engagement of those whose futures will be influenced by the change are bound to fail." One can think of countless empirical examples.

In many cases reported in the literature, the "type" of stakeholders engaged was not made explicit, and their role was not specified [11]. Also, certain (possibly marginalized) groups might be excluded for justified or unjustified reasons [12]. A diversity of stakeholders is imperative if all perspectives are to be considered, in line with the law of requisite variety [10, 13–15].

In sum, the effective, democratic, and equal participation (i.e., equity criterion) of all those who have a stake has the great advantage that assuming consensus is reached, the great majority backs up the decisions for change. Consequently, the change has a higher chance of surviving for extended periods. Some ways by which the application of the SDD methodology guarantees the above are briefly explained in the next sections.

1.2 Choosing an effective problem structuring methodology

The management of complex social problems requires the application of a systemic problem-structuring method (PSM). Matching an appropriate PSM and tools to a specific system is of paramount importance [16]. Polls, surveys, interviews, focus groups, etc. might be appropriate to access the "general attitudes" of the stakeholders or the wider public. If, however, the aim is to enable them to exchange points of view, increase trust between conflicting groups, attempt an in-depth analysis of the issue or challenge at hand, deliberate, consider pros and cons of different solutions, and make choices or informed decisions, then participatory methods, such as world cafés, citizens assemblies, operation research and management science (OR/MS) methods, SDD, etc. become a must. In most cases, different methods and tools need to be used in different phases of the process. Operation research scientists [17] argue that OR/MS methods and tools are often used not so much because of their effectiveness but more for "prestige." They observe that there is an inverse relationship between the importance of social reforms and the use of OR/MS techniques for their management. Those in charge of change prefer to use political tools (which also serve their "masters") to avoid addressing the real conflicts, or dealing with the low degrees of bureaucratization. In this chapter, we argue that the structured democratic dialog process has emerged as an excellent PSM capable of managing any type of large-scale socio-technical reforms, exactly, because on the one hand, it relies on well-founded and repetitively validated tools and processes, and on the other hand, it is particularly effective in interconnecting different points of view and positionalities, thus resolving multiple conflicts of purpose and values and generating consensus [18, 24].

1.3 Converting strategies and roadmaps to tangible change

Probably the most significant challenge toward achieving an envisioned societal (or any other type of) positive future is that strategies and plans fail to produce the desired results. The problem lies in what we could call the conversion of a vision and associated strategy and individual steps of action toward achieving the desired goals into a coherent and effective sequence. The orderly (typically timewise) arrangement of sub-actions is called roadmaps, i.e., plans that articulate a specific course of action [19]. In our context, roadmaps could be orderly sequences consisting of goals, phases, processes, or milestones, collectively referred to as steps, each supporting the subsequent ones. A roadmap can also be defined as the compilation of views of a group of stakeholders as to what to do, when, who, and how to get where they want to go [20]. A plan must be supported

and backed up by all stakeholders to be effective. In this paper, we argue that interpretive structural modeling (ISM) [21] in connection with the multi-parameter evaluation [22] of impact, feasibility, and probability of happening without intervention serves to help organize the most effective ordering of a roadmap's steps.

2. Models of intervention

We present two models of large-scale interventions. In the first (**Figure 1** left), the same type of intervention is delivered more or less synchronously to multiple groups that are distributed. The term distributed refers to either spatial (i.e., similar stakeholders but in different geographic locations) or contextual (i.e., stakeholders in different communities/sectors or with different perspectives or group interests). In the second model (**Figure 1** right), the process begins with one intense focal intervention and a process design that allows it to replicate and expand by creating spin-off agents or communities of change. The premise of both models is that the will, ideas, and pragmatics of implementing the change are generated (or facilitated vis-à-vis "implanted") and allowed to grow at multiple (spatial or contextual) localities. Awareness, perceptions, identified challenges, visions, and actions grow around each locality and assuming they are strong enough, they gradually connect to each other and eventually embrace the wider community of stakeholders. The approach resembles the metaphor of multiple forest fires (in our example in a positive sense) in which independent fires join forces to form an unstoppable fire. In the next sections, we present examples for both models from our own experience.

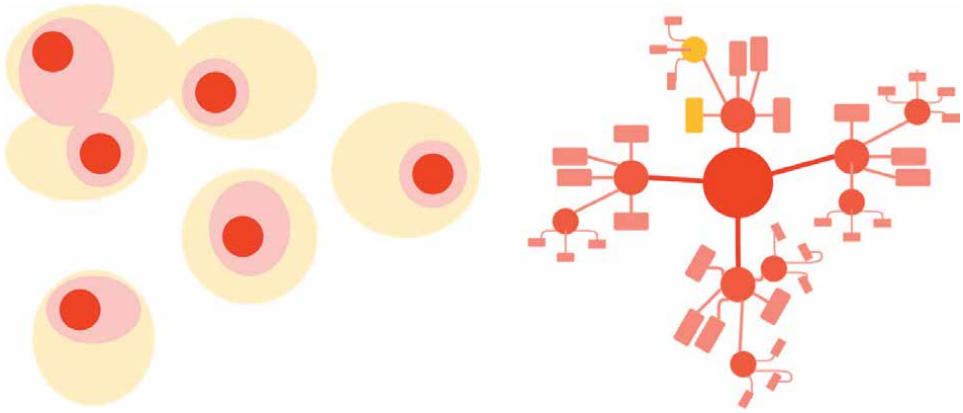

Figure 1.
Models of intervention for large-scale social changes.

3. The SDD methodology

The methodology and process of implementing either a single SDD or an array of parallel or sequential processes have been described elsewhere [14, 23]; for arrays of SDDs see [24, 25]. Here we provide a brief overview just sufficient to acquaint our audience with the key steps of a single SDD (**Figure 2**) or an array (for examples see **Figures 3** and **4**) of SDDs.

DOI: http://dx.doi.org/10.5772/intechopen.1000220

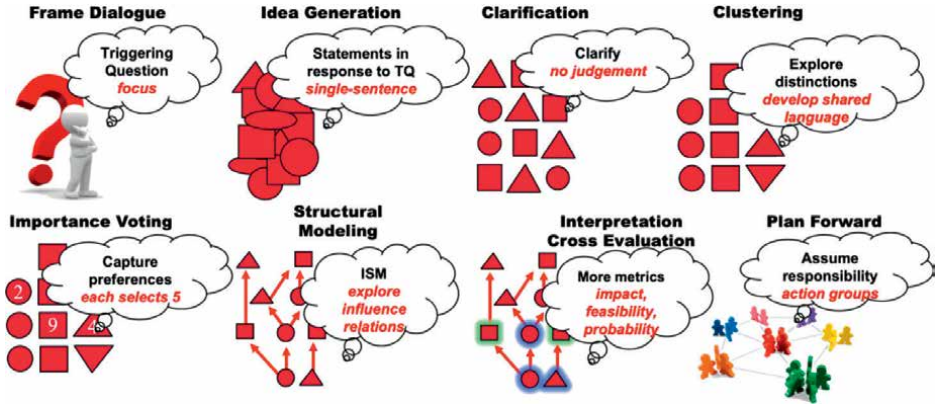

Figure 2.
Steps of a typical single SDDP implementation.

The first step of any SDD (**Figure 2**) is the generation of observations concerning the problematic situation in response to a triggering question (TQ). Each participant is invited in a round-robin manner to contribute only one response at a time in the form of a single statement, which should contain only one[2] specific observation. Contributions are numbered and their authors are registered. Giving individuals space to generate their ideas without criticism from others helps to counter group-think and clanthink [27]. This approach satisfies not only the equity criterion (see 1.1) but also facilitates active listening and learning.

In a second step each participant clarifies her idea. This can be conducted through synchronous (f2f or virtual) processes, or asynchronously using the IdeaPrism[3] (or equivalent) app to record short videos, or through a collaboratively developed cloud-based document where everyone can edit, comment, or ask for further clarifications. During the clarification process, others can ask questions about meaning, but no judgment is allowed. This facilitation technique is intended to protect the autonomy and authenticity of participants so that no participant is discouraged, and no idea is prematurely evaluated and/or rejected. The so-called law of requisite autonomy in distinction making guarantees that "during the dialogue, the autonomy and authenticity of each person contributing ideas are protected" [28].

The next step involves the categorization of observations using a bottom-up approach. This process takes much longer than top-down clustering methods because it encourages discussion. Evolutionary learning takes place as the participants are encouraged to explore how specific aspects of their ideas might make them similar to other ideas; a process that forces them to draw further distinctions. The Law of Requisite Evolution of Observations asserts that "The elemental observations made by stakeholders in the context of a complex design situation, are interdependent" [10, 14, 23]. During the above steps, the participants are invited to reconsider the importance they assign to various observations. While the authors are liberated to clarify their observations with even inventing their own language and collectively searching for similarities in their effort to create categories, they better understand each other's positions. Only after this,

[2] This is important because, when observations are examined for similarity between them or influence on one another, if one statement contains several ideas or is too general, the process is compromised.

[3] IdeaPrism is a free app available in app stores.

individual participants are requested to choose typically five out of the total set of ideas according to their perceived importance. Known as Boulding's [29; see also 8, 10, 14] law of requisite saliency, the law refers to the range of importance that people assign to observations relative to other observations. The relative importance of an idea can be understood only when it is compared with the ideas of others (it is rare for people to choose only their own ideas as most important). All the ideas that receive a threshold number of votes (i.e., those that participants consider the most important) enter the ISM process, which comes next. The threshold number of votes is determined as as a function of the amount of time available to conduct the ISM.

In ISM, participants are confronted with two ideas at a time (to reduce cognitive load in recognition of our human limitations; i.e., Miller's Law of Requisite Parsimony; [30]) and are requested to decide whether one influences the other. In a synchronous implementation, they are invited to present arguments pro or against a relationship and engage in discussion. In our newly developed asynchronous models [31] participants may conduct parts of this process individually.

A relation is established only when it is supported by a large majority (typically 75%) following the constructive deliberation. The application of Warfield's [21] ISM algorithm reduces the number of questions that the software will ask. The binary connections that are established by the group are used to build up an influence map (see the example in **Figure 3**). Meaning and wisdom are produced only when the participants begin to understand the relationships (such as similarity, priority, influence, etc.) among their different ideas. The influence map reflects the shared understanding and the consensus of the participants.

Since challenges at the bottom of the structure correspond to the root causes of the problem, the method is also referred to as "root cause mapping." When the SDD is about exploring actions, the factors at the root are referred to as "deep drivers." The factors that end up at the root of the map are the ones with the greatest influence.

Participants engage in further discussions on how to resolve the obstacles at the root, and as these influence all the problems further up the structure, the idea is that addressing the root causes should have positive knock-on effects throughout the interlinked system of issues that the participants want to tackle. Analogously, factors at the root of an actions' SDD should be given priority when developing action plans. This form of problem structuring helps to minimize the erroneous priorities (first observed by Kevin Dye; see [24]) effect, which comes into play when strategic actions are targeted at isolated aspects of the problematic situation without their interconnections being considered.

Our team has applied the SDD in more than 100 different contexts, including peace and conflict resolution [32–34]; government and societal challenges (e.g., "Wine Villages" [25] and "Merging of taxation systems," conducted by CAPA [35]); discovering and collectively agreeing on research agenda priorities, thus influencing European Commission funding [36]; the support and capacity building of youth and civil society [37]; Uniting for Citizenship and Participation [38]; envisioning and designing new educational systems (Reinventing Education, [39]); and reinventing democracy [18, 26, 40]. For a complete list of Future Worlds SDDP applications, see Footnote.[4]

[4] https://www.futureworlds.eu/wiki/Chronological_List_of_SDDPs_by_Future_Worlds_Center_and_Associates

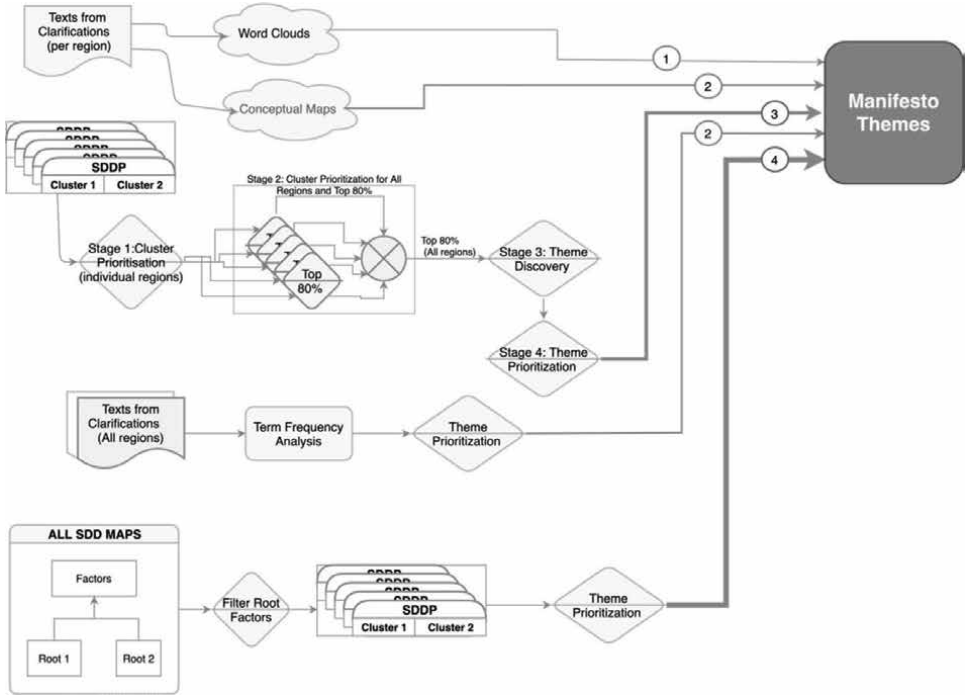

Figure 3.
Reprinted from reinvent democracy manifesto [26].

4. Real-world examples of large-scale interventions

In the following sections, we briefly introduce two examples, one international and one national, for each type of intervention.

4.1 Quasi-synchronous, spatially distributed interventions

4.1.1 Reinventing democracy bottom-up

The "Reinventing Democracy in the Digital Era" project [18, 26, 40] was a global project funded by the UN Democracy Fund. The aim was to identify shortcomings of our current systems of governance that could be improved through technology, and come up with concrete actions, policies, etc. capable of alleviating them. The process engaged about 1000 youth, from about 50 countries, in structured, face-to-face as well as virtual deliberations (**Figure 3**).

Selection of participants: Eleven weighted criteria were applied to the evaluation of a few hundred applicants in order to choose ca 20 Core Participants per region (i.e., five regions: Africa, Europe, Latin America, MENA, and Australasian; a total of 100). Gender (weight .2) and age (.15; young people 18–30 years old) had the largest weights. Four (i.e., anti-discrimination criteria; years of relevant experience or/and prior relevant activities; potential for organizing follow-up activities; availability of sponsors) had a weight of .1, and the remaining five (i.e., belonging to associations with wide networks; communication skills; reliability/commitment; country of origin/nationality; uninterrupted access to social networking) were weighted with .05.

Each core participant had to use similar criteria to invite 10 so-called shadow participants (who contributed throughout the 2-year period virtually), thus bringing their number to ca. 1000.

Methodology: Five identical interventions have taken place in the five different regions over a period of two years with the core participants. Week-long sessions followed the same format: Two days were spent on a critical systemic examination of shortcomings, with a view to considering the potential for improving democracy in the digital age. Then two days were spent on developing a collective understanding of the "deep drivers for change," which could serve as an inspiration for significant action to be pursued (by the participants or by others inspired by the maps), which were later made accessible on the internet via a Manifesto [26]. On the fifth day, participants formed groups to create action plans for themselves to pursue, springing from the collective work in locating leverage points for significant types of action while working on the second TQ. The last day was reserved for exploration of the city and joint activities to facilitate bonding.

Action: To compile the hundreds of shortcomings and actions (from a total of 10 SDDs) proposed by the participants into a short and clear actionable whole, we applied a novel multi-methodology for data compression (**Figure 3**). Five, weighted, data processing methods (the numbers on the arrows pointing toward the "Manifesto Themes" box in **Figure 3** correspond to the weights) were applied to extract seven prevailing themes, which were summarized in the Manifesto [26], where also the details of the methodological process are explained.

4.1.2 Reforming local authorities in Cyprus

The objective of the "Provision of Services for the Diagnosis of Learning and Development Needs for the Local Authorities of Cyprus" project was to improve the skills of the human resources of the Cypriot Local Government Authorities (LGAs). The overarching goal was to strengthen their administrative and leadership capacity with the view of facilitating the clustering of services and the eventual merging of LGAs to optimize the services offered to the public. The project was implemented between 2009 and 2015 under the special objective "enhancing administrative abilities in services provided in the public sector." The Cyprus Ministry of Finance supported this initiative using a palette of European funding, including structural and social cohesion funds.

Selection of stakeholders: The participants were selected from local communities. They included mayors, local authority employees, local educators, local and global business people and developers, local agricultural and other producers, repatriated citizens, older people, and youth. To secure requisite variety of their conflicting interests and objectives, particular emphasis was placed on conflicts between central and local governments, conflicts between neighboring local authorities, and conflicts between different stakeholders within the same local community.

Methodology: In this model, the diagnosis of the learning and development needs of the LGAs was embedded within a rich set of activities (**Figure 4**). It was preceded by identifying best practices in the EU member states and face-to-face interviews with LGA officials (left boxes in **Figure 4**). These actions informed the selection of the most relevant stakeholders and supported the framing of the TQ.

Action: Following the implementation of 10 SDDPs across the country, a network was set up comprising regional learning management groups and a coordinator for each group to support the management of learning in LGAs (see right side of **Figure 4**). Learning

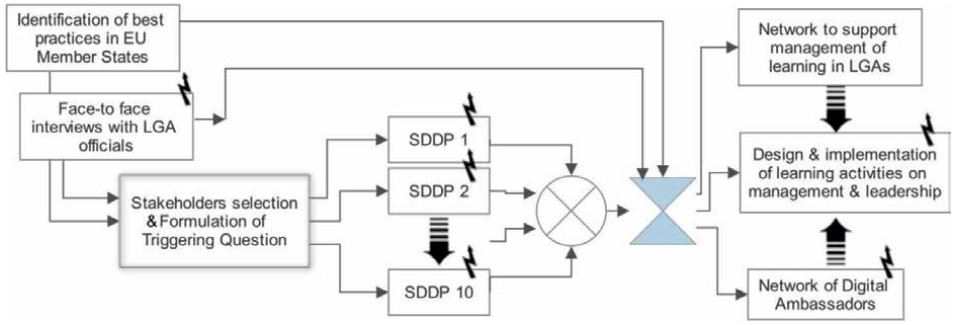

Figure 4.
Reprinted from [24].

activities were designed and implemented to enhance management and leadership. The overall intervention was supported by a strong awareness campaign, the engagement of political and government agencies, the expertise of technical advisors, and a network of digital ambassadors, many of them visiting foreign countries to research best practices. The intervention has eventually facilitated political decisions (in 2021/2022) for reforming the local authorities [24].

4.2 Single-focal intervention followed by evolutionary replication

4.2.1 Facilitating peace dialog across war zones

The "Civil Society Acts Beyond Borders" project [34] was funded by the European Instrument for Democracy and Human Rights of the European Commission. The aim was to empower civil society actors, youth, and local authorities in Israel and Palestine to actively promote human rights and democratization.

Selection of stakeholders: Participants were selected from diverse local communities by expert informants. The key criterion was to secure a mixture of peace activists but also a few who were against any peace "rapprochement."

Methodology: The project was designed as participatory action research grounded on the science of dialogic design. The project began with three consecutive (within a week) SDD processes (develop shared vision, identify obstacles, and explore actions) outside the conflict zone (in this case, Cyprus) engaging committed, already active peacebuilders (see left side of **Figure 5**). Between the second and the third SDD, the participants co-organized an international peace conference together with Greek and Turkish Cypriot actors. Having identified four target groups (business, informal education, students, and women) they created action groups (i.e., AG labels in **Figure 5**).

Action: Each AG selected and invited additional participants and organized their own SDD process, which was then followed by a comprehensive set of participatory intra-communal nonformal workshops (NFWS boxes in **Figure 5**). In parallel, a number of other activities were taking place. Following a training of trainers (top of **Figure 5**), those trained implemented a number of (up to 10) civil society strengthening pieces of training (purple boxes with a "W" in **Figure 5**), as well as multi-communal public debates (blue boxes with a "PD" in **Figure 5**), and a conference (purple box in **Figure 5**).

The above design offered the conditions for the objectives of the project to go viral, engaging several thousand people in various activities, i.e., to continue through self-replicating processes beyond the lifetime of the project.

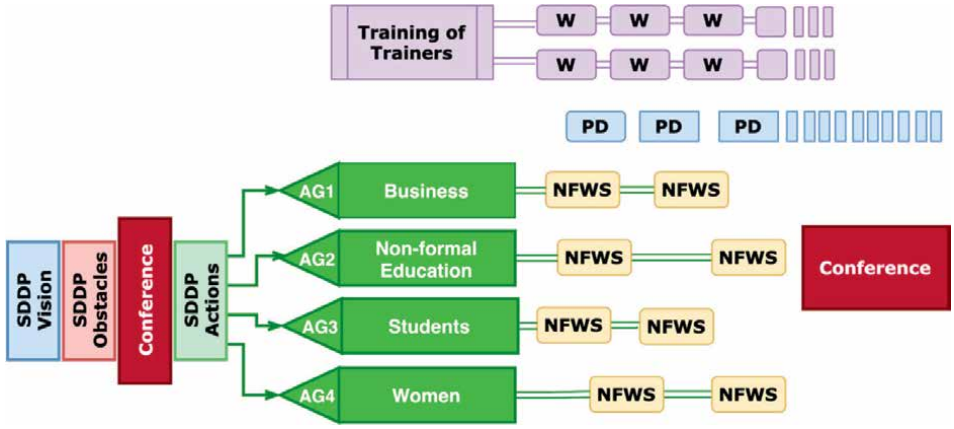

Figure 5.
Organization of activities in the CSABB project (from [34]).

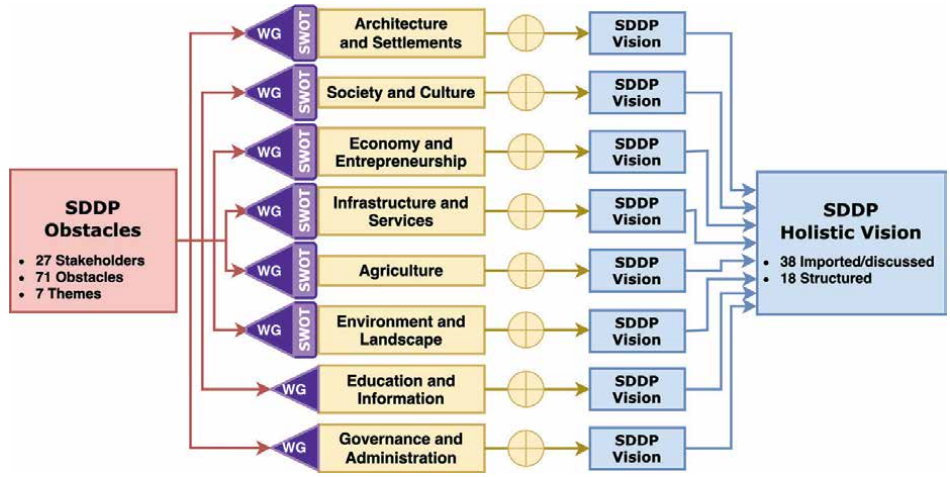

Figure 6.
Organization of activities in the wine villages project.

4.2.2 Local development of the wine villages in Limassol, Cyprus

The "Limassol Wine Villages Local Development Pilot Project: the contribution of heritage to local and regional development" was implemented through funding given by the Council of Europe's Local Development Pilot Projects Program[5] to the Department of Town Planning and Housing, Ministry of Interior of the Republic of Cyprus.

Selection of stakeholders: This project was implemented in phases. For the first SDD, 29 participants, representing many stakeholders' organizations were selected following standard stakeholder identification techniques [9]. In the following phases, a total of more than 150 stakeholders 'entered the scene' when they were acknowledged as stakeholders by other stakeholders [41].

Methodology: The intervention began with an SDD using TQ: "Which are the obstacles to the development of the Wine-villages of Limassol?" The participants

[5] https://www.coe.int/en/web/culture-and-heritage/ldpp

identified 71 obstacles (**Figure 6**; left), which they clustered into 7 themes of sectoral (thematic) or strategic nature (society and culture; architecture and settlements; economy and entrepreneurship; infrastructure and services; agriculture, environment, and landscape; education and information; and governance and Administration; second column in **Figure 6**). In order to develop each theme, a respective working group was created, which engaged further stakeholders thus allowing the base to drastically enlarge. Most working groups conducted a SWOT analysis (to obtain a better understanding of the area's real limitations and potentials at the local and macro-regional level) followed by a Vision-SDD using as TQ "What are the descriptors of the desired situation for the sustainable development of the wine villages in the field of… (relevant thematic)? " aiming to develop a shared vision. In a concluding SDD, the most influential factors from each Thematic SDD were selected and structured to develop an overall vision across all thematic areas (**Figure 6**, right).

Action: In total 150+ individuals from ca 75 different stakeholders' groups were involved in 10 SDDPs and 5 SWOT analysis workshops. The intervention allowed stakeholders to get involved in the policy process and in the formulation of the vision along with the strategy and its objectives. The model promoted territorial sensitivity and fostered identity and heritage. Most importantly, the intervention began with only 29 actors and ended up engaging actively more than 150.

5. Discussion

A large-scale societal intervention aims to support a community of stakeholders to develop a shared understanding of their problematic situation, converge on a clear shared vision, and ultimately generate collaborative action toward a desired future. This chapter proposed two models for large-scale interventions and presented examples of applications. Both models replace the hierarchical management of change in the design arena (i.e., relying predominantly on leaders or experts) in favor of models that include all parties with a stake (i.e., the stakeholders) in the definition and resolution of complex issues confronting them. Our first model applies the same intervention delivered at multiple places quasi synchronously. The term "places" could denote geographical or communal localities, but it could also denote corporate, religious, secular, local or international groups, etc. Our second model begins with one intense focal intervention using SDD and a design that allows the momentum generated to replicate, migrate, and/or expand by creating spin-off agents or communities of change. Assuming the momentum is strong enough, the waves of change will gradually reach each other and merge to embrace the wider community of stakeholders.

Both models presented here have not achieved extensive social change. The first reason is that the number of stakeholders engaged was a few hundred; i.e., too small compared to the total population. Second, some interventions were not extensive enough to generate a robust social wave toward change, because they lack the necessary political support and will. Nevertheless, eventually reforms did take place, even with a delay. To accelerate the process and achieve positive social change in a fraction of the time, we should probably utilize more social media and virtual-hybrid applications. We also need a new theoretical grounding of massive collaboration. Challenges of scalability and applications that made the participation of large numbers of participants possible are discussed only scarcely (e.g., [15, 42]) in the literature. A recent example of a large-scale project combined SDD with an interactive software called "Pathways to Wellbeing," [43] where the latter was aimed at facilitating citizen

involvement in thinking together about choices being made to move toward inclusive well-being. In other examples utilizing virtual communications, the author's team has experimented with organizing SDDs in Second Life[6] and/or engaging participants in asynchronous processes using asynchronous ISM and IdeaPrism [31]. Such attempts may violate to some degree Laws of SDD. For a critical review see [31]. An additional bottleneck is trust. Of course, when the envisioned change is constrained within a local environment, the issue of trust might be lessened because the participants might already know each other [44].

6. Conclusions and recommendations

Contemporary liberalism has progressed to the point that it inhibits collective decision-making that serves the common good. It also undermines collective responsibility. Everyone agrees that we can be free and diverse only to the extent that our freedom and diversity do not undermine the rights of others. We, however, lack models of governance capable of balancing individual vs. collective needs and interests. This chapter proposes that the SDD methodology, embedded within a larger framework of OR methodologies, is ideal for engaging large groups of stakeholders in productive and efficient dialogs for the collective and systemic definition, as well as the resolution of their issues. It ensures that the deliberation produces high-quality observations by imposing structure and discipline and not allowing them to converge prematurely to preconceived choices of issues, options, and solution alternatives. It also creates an environment that facilitates openness to the ideas of others, which is vital for next-generation democracy.

Agents of change can choose from a wide range of strategic designs for large-scale improvement, considering available resources and constraints. Examples range from executive mandates, which may be appropriate for specific, small-scale changes that can be immediately implemented in a hierarchical system, to campaigns, which may be applicable for medium-scale interventions that rely on broad will-building [45, 46], to large-case change, which requires bringing together teams of stakeholders from numerous, often interdependent sectors, for structured interactions and learning [47]. The SDD approach addresses complex challenges, including sustainability, climate change, democratic deficiencies, pandemics, etc., all of which require new forms of stakeholders' engagement to work across conceptual and spatial boundaries [48, 49]. Some of the examples presented here have failed to reach the threshold for achieving extensive social change, primarily not because of theoretical limitations but because they were not supported by those who have the power. Democracy will rise to the level of collective wise decision-making that serves the common good only when the people manage to hold their leaders accountable for their choices and actions and put novel systemic approaches, instruments, and tools in all democratic processes.

Acknowledgements

The implementation of the projects has been the result of a team effort of dozens of experts and associates acknowledged in cited project pages and/or publications.

[6] Second Life is a virtual 3D environment that allows participants choose their own avatars and work collaborative in virtual spaces that resample conference rooms.

The specific case studies received funding as follows: Reinventing Democracy in the Digital Era was funded by the UN Democracy Fund (Contract number: UDF-GLO-13-532), "Provision of Services for the Diagnosis of Learning and Development Needs for the Local Authorities of the Cyprus" was funded by the Republic of Cyprus (Contract number 6/2009), "Human Rights and Reconciliation – Civil Society Acts Beyond Borders" was funded by European Commission, European Instrument for Democracy and Human Rights (Contract Number EIDHR/2009/167-502), and "Limassol Wine Villages Local Development Pilot Project: the contribution of heritage to local and regional development" was funded through structural funds managed by Marios Michaelides, acting head of the Cyprus Academy of Public Administration and various Ministries.

Author details

Yiannis Laouris
Future Worlds Center, Nicosia, Cyprus

*Address all correspondence to: laouris@futureworldscenter.org

References

[1] Fullan M. The return of large-scale reform. Journal of Educational Change. 2000;**1**(1):5-27

[2] McCannon CJ, Berwick DM, Massoud MR. The science of large-scale change in global health. Journal of the American Medical Association. 2007;**298**(16):1937-1939

[3] Christakis AN. A retrospective structural inquiry of the predicament of humankind. In: Rescuing the Enlightenment from Itself. Boston: Springer; 2006. pp. 93-122

[4] Harris LD, Wasilewski J. Indigeneity, an alternative worldview: Four R's (relationship, responsibility, reciprocity, redistribution) vs. two P's (power and profit). Sharing the journey towards conscious evolution. Systems Research and Behavioral Science: The Official Journal of the International Federation for Systems Research. 2004;**21**(5):489-503

[5] Marx HB. Conscious evolution: The next stage of human development. Systems Research and Behavioral Science: The Official Journal of the International Federation for Systems Research. 2003;**20**(4):359-370

[6] Nolan TW. Execution of Strategic Improvement Initiatives to Produce System- Level Results. Cambridge, MA: Institute for Healthcare Improvement; 2007

[7] Resar R. Will, ideas, and execution: Their role in reducing adverse medication events. The Journal of Pediatrics. 2005;**147**(6):727-728

[8] Covin TJ, Kilmann RH. Participant perceptions of positive and negative influences on large-scale change. Group & Organization Studies. 1990;**15**(2):233-248

[9] Gregory AJ, Atkins JP, Midgley G, Hodgson AM. Stakeholder identification and engagement in problem structuring interventions. European Journal of Operational Research. 2020;**283**(1): 321-340

[10] Laouris Y, Laouri R, Christakis A. Communication praxis for ethical accountability: The ethics of the tree of action: Dialogue and breaking down the wall in Cyprus. Systems Research and Behavioral Science: The Official Journal of the International Federation for Systems Research. 2008;**25**(2):331-348

[11] Degeling C, Carter SM, Rychetnik L. Which public and why deliberate?–a scoping review of public deliberation in public health and health policy research. Social Science & Medicine. 2015;**131**:114-121

[12] Caroline W. Lee Five Assumptions Academics Make about Public Deliberation, and Why They Deserve Rethinking

[13] Ashby WR. Requisite variety and its implications for the control of complex systems. In: Facets of Systems Science. Boston: Springer; 1991. pp. 405-417

[14] Christakis AN, Bausch KC. How people harness their collective wisdom and power to construct the future in co-laboratories of democracy. In: IAP. 2006

[15] Laouris Y, Dye K, Michaelides M, Christakis AN. Co-laboratories of democracy: Best choices for designing sustainable futures. In: Social Systems and Design. Tokyo: Springer; 2014. pp. 167-183

[16] Solomon S, Abelson J. Why and when should we use public deliberation? The Hastings Center Report. 2012;**42**(2):17

[17] Papoulias DB, Tsoukas H. Managing reforms on a large scale: What role for OR/MS? Journal of the Operational Research Society. 1994;**45**(9):977-986

[18] Laouris Y, Romm NR. Structured dialogical design as a problem structuring method illustrated in a Re-invent democracy project. European Journal of Operational Research. 2022;**301**(3):1072-1087

[19] Kappel TA. Perspectives on roadmaps: How organizations talk about the future. Journal of Product Innovation Management: An International Publication of the Product Development & Management Association. 2001;**18**(1):39-50

[20] Phaal R, Farrukh CJ, Probert DR. Technology roadmapping—A planning framework for evolution and revolution. Technological Forecasting and Social Change. 2004;**71**(1-2):5-26

[21] Warfield JN. Toward interpretation of complex structural models. IEEE Transactions on Systems, Man, and Cybernetics. 1974;**5**:405-417

[22] Linstone HA, Turoff M, editors. The Delphi Method. Reading, MA: Addison-Wesley; 1975

[23] Laouris Y. The ABCs of the science of structured dialogic design. International Journal of Applied Systemic Studies. 2012;**4**(4):239-257

[24] Laouris Y, Michaelides M. Structured democratic dialogue: An application of a mathematical problem structuring method to facilitate reforms with local authorities in Cyprus. European Journal of Operational Research. 2018;**268**(3):918-931

[25] Wine Villages Cyprus; Series of SDDPs https://www.futureworlds.eu/wiki/Wine_Villages_Cyprus_Series_of_SDDPs

[26] Manifesto: Reinventing Democracy in the Digital Era. 2016. Available from: https://www.futureworlds.eu/wiki/Manifesto:_Democracy_in_the_Digital_Era. [Accessed: May 30, 2022]

[27] Warfield JN. Spreadthink: Explaining ineffective groups. Systems Research. 1995;**12**(1):5-14

[28] Tsivacou I. The rationality of distinctions and the emergence of power: A critical systems perspective of power in organizations. Systems Research and Behavioral Science: The Official Journal of the International Federation for Systems Research. 1997;**14**(1):21-34

[29] Boulding KE. The Impact of the Social Sciences. New Brunswick, NJ: Rutgers University Press; 1966

[30] Miller GA. The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological Review. 1956;**63**(2):81

[31] Laouris Y. Method to integrate asynchronously produced individual influence maps into an extrapolated population influence map following the face-to-face stage of a structured democratic dialogue. Systems Research and Behavioral Science: The Official Journal of the International Federation for Systems Research. 2022

[32] Laouris Y, Michaelides M, Damdelen M, Laouri R, Beyatli D, Christakis A. A systemic evaluation of the state of affairs following the negative outcome of the referendum in Cyprus using the structured dialogic design process. Systemic Practice and Action Research. 2009;**22**(1):45-75

[33] Laouris Y, Erel A, Michaelides M, Damdelen M, Taraszow T, Dagli I, et al. Exploring options for enhancement of social dialogue between the Turkish and Greek communities in Cyprus using the structured dialogic design process. Systemic Practice and Action Research. 2009;**22**(5):361-381

[34] Civil Society Acts Beyond Borders. 2010. Available from: https: // www.futureworlds.eu/wiki/Act_Beyond_ Borders. [Accessed: June 01, 2022]

[35] Merging of TAX - VAT Services in Cyprus. 2013. Available from: https:// www.futureworlds.eu/wiki/Merging_of_ TAX_-_VAT_Services_in_Cyprus. [Accessed: June 01, 2022]

[36] CARDIAC - Advancing Research & Development in the area of accessible & Assistive ICT [Internet] 2010. Available from: https://www.futureworlds.eu / wiki/CARDIAC. [Accessed: June 01, 2022]

[37] Capacity and Synergy building among NGDOs and LAs in Greece, Cyprus and Malta for development [Internet] 2011. Available from: https:// www.futureworlds.eu/wiki/MeDevNet. [Accessed: June 01, 2022]

[38] UCYVROK - Uniting for Citizenship and Participation. 2008. Available from: https://www.futureworlds.eu/wiki/ UCYVROK__Uniting_for_Citizenship_ and_Participation. [June 01, 2022]

[39] Reinventing Education. 2018. Available from: https://www. futureworlds.eu/wiki/Reinventing_ Education. [Accessed: June 01, 2022]

[40] Reinventing Democracy in the Digital Era. 2016. Available from: https:// www.futureworlds.eu/wiki/Reinventing_ Democracy_in_the_Digital_ Era_(UNDEF). [Accessed: June 01, 2022]

[41] Goodman LA. Snowball sampling. The Annals of Mathematical Statistics. 1961;**1**:148-170

[42] Rosenhead J. Past, present and future of problem structuring methods. Journal of the Operational Research Society. 2006;**57**(7):759-765

[43] McIntyre-Mills JJ, Christakis AN. Social and environmental justice. In: From Polarisation to Multispecies Relationships. Singapore: Springer; 2021. pp. 283-307

[44] Ahlqvist T, Bäck A, Heinonen S, Halonen M. Road-mapping the societal transformation potential of social media. foresight. 2010

[45] Berwick DM, Calkins DR, McCannon CJ, Hackbarth AD. The 100 000 lives campaign: Setting a goal and a deadline for improving health care quality. Journal of the American Medical Association. 2006;**295**(3):324-327

[46] Wachter RM, Pronovost PJ. The 100,000 lives campaign: A scientific and policy review. The Joint Commission Journal on Quality and Patient Safety. 2006;**32**(11):621-627

[47] McCannon CJ, Berwick DM, Massoud MR. The science of large-scale change in global health. Journal of the American Medical Association. 2007;**298**(16):1937-1939

[48] Midgley G, editor. Systems Thinking. London: Sage; 2003

[49] Midgley G. Theoretical pluralism in systemic action research. Systemic Practice and Action Research. 2011;**24**:1-15