

# Design Science Research

Aline Dresch · Daniel Pacheco Lacerda  
José Antônio Valle Antunes Jr.

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A Method for Science and Technology  
Advancement

 Springer

Aline Dresch  
Daniel Pacheco Lacerda  
GMAP | UNISINOS  
Porto Alegre/RS  
Brazil

José Antônio Valle Antunes Jr.  
UNISINOS  
Porto Alegre/RS  
Brazil

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# Foreword I

Design Science Research (DSR), also known as Constructive Research, is a methodological approach concerned with devising artifacts that serve human purposes. It is a form of scientific knowledge production that involves the development of innovative constructions, intended to solve problems faced in the real world, and simultaneously makes a kind of prescriptive scientific contribution. An important outcome of this type of research is an artifact that solves a domain problem, also known as solution concept, which must be assessed against criteria of value or utility.

The interest in this scientific research approach has emerged recently in different fields, such as information systems, business management, and management accounting, mostly due to the criticism that some of those academic communities have suffered for the lack of practical relevance of the scientific knowledge being produced. It occupies a middle ground between traditional scientific approaches, mostly descriptive, and context-related problem-solving knowledge produced in practical situations.

In fact, DSR has been pointed out as a suitable research approach when researchers need to work in close collaboration with organizations, for testing new ideas in a real context. Therefore, it can be used as a form of knowledge production for achieving two different purposes in research projects at the same time: producing scientific knowledge, and helping organizations to solve real problems.

The literature on DSR is still very scarce, and this book presents a comprehensive description of what this approach is about. It provides a historical perspective as well as introduces the main concepts involved in DSR, and compares it to descriptive research methods, normally used in the Natural Sciences or Social Sciences. Moreover, interesting discussions on the nature of the research process in DSR, and on the set of possible outcomes is also included in the book.

It is a great pleasure for me to introduce this book due to the fact that it is the results of the work of a team of people, Aline Dresch, Dr. Daniel Lacerda, and Dr. José A.V. Antunes Jr., who have attempted, through this research work, to make a contribution toward improving the quality of Engineering research, both in terms of rigor and relevance.

Interestingly, this book could be regarded as the main artifact produced by a research project that involved the three authors, being a useful resource for researchers interested in applying DSR. Although the book might call the attention of academics from several fields of research, it fills an important gap in the literature on research methods for engineering students. It is well founded in the literature, and some parts of the book present clarifying examples extracted from Industrial Engineering research projects.

Finally, it is necessary to recognize that this methodological approach is fairly new, and that further studies are necessary to understand and define it from the epistemological perspective. This can be partly achieved by discussing and reflecting on the outcomes of DSR projects. However, I am sure that this book makes an important contribution for this journey. For this reason, I strongly recommend it to be used in courses on research methods, especially for engineering and design students.

Carlos Torres Formoso  
Associate Professor at the Building  
Innovation Research Unit (NORIE)  
School of Engineering, Federal University  
of Rio Grande do Sul (UFRGS)  
Porto Alegre Brazil

# Foreword II

This book provides a valuable further step in the development and dissemination of knowledge on Design Science (DS) and Design Science Research (DSR). Briefly, DS can be conceptualized as a body of valid knowledge on designs and designing, produced by rigorous research and DSR as research producing this type of knowledge. In disciplines like engineering and medicine DSR is mainstream research, in others not yet. Nowadays, in more and more other academic disciplines DSR is getting more and more an accepted place in the domain of their research. Nevertheless, there still are misunderstandings in the nature of DS, different from the explanatory knowledge of much mainstream research, and of the research strategies producing DS. Many academics still feel that the mission of *all* academic research is to understand the world as it is and are wary of research aiming to develop valid knowledge to improve the world, thus dealing with the world that can be.

Therefore, it is important that books like this one are published. It aims to give insight into the developments of DS and DSR after Herbert Simon published in 1969 his seminal *The Sciences of the Artificial* and is written for an audience of researchers and students—from undergraduate to graduate and Ph.D. students—in the various management disciplines. It can also be of value to researchers and students in engineering disciplines to the extent that they are not only interested in designing material systems like machines, mobile telephone networks, or bridges, but also in the social context in which they are built and used.

The book starts with a discussion of some aspects of academic management research, bemoaning—as I also do—the gap between research and practice, leading to the promise of DS and DSR to bridge this gap. It is followed by a general discussion of approaches, strategies, and methods of academic research in general. Chapters 3 and 4 deal with the core business of the book, DS and DSR, which includes a discussion on the historical evolution of the ideas on DS and DSR.

Consultancy aims to improve a specific situation through developing and applying specific interventions, but academic research aims to develop generic knowledge. So also DSR aims to develop generic knowledge. Therefore, a following chapter discusses classes of problems and classes of artifacts, the basis for

developing generic knowledge. The authors proceed with developing a 12-step procedure for doing DSR.

A separate chapter discusses a method to do systematic literature reviews, on the one hand because a systematic literature review was one of the bases of the book, on the other hand because it is, together with research synthesis, an important component of DSR. In explanatory research one can give several explanations next to one another, but in acting to improve one has to make a definite choice of action. In evidence-based, or research-informed practice, one bases this choice on a synthesis of the results of a systematic review of the literature on the field problem at hand. The book concludes with a reflection on the developments since the publication of Simon's seminal book and on their own contribution to this.

I wish this book a large readership. Good for these readers, good for the dissemination of insights into DS and DSR, and through this good for academic management research and for its potential to inform practice.

Prof. Joan van Aken Ph.D.  
Professor Emeritus of Organization Science  
School of Industrial Engineering  
Eindhoven University of Technology  
Netherlands

# Acknowledgments

First, I thank the opportunity for writing this book. We sincerely hope that it contributes to the advancement and strengthening of scientific and technological researches. I would like to point out that many people were fundamental to the development and accomplishment of this book, but I would like to highlight some special thanks here. First, I would like to thank Prof. Ricardo Cassel (School of Engineering/UFRGS) for encouraging me to advance in the academic career. This important step in my career put me into contact with bright people, and with challenging activities (the development of this book among them). I also thank the many contributions of Prof. Adriano Proença (GPI/DEI/COPPE/UFRJ), Prof. Carlos Torres Formoso (NORIE/PPGEC/UFRGS), and Prof. Michel Thiollent (UNIGRANRIO/PPGA), which were very relevant to the consolidation of this research. I also thank the following colleagues from the Modeling for Learning Research Group (GMAP | UNISINOS); our daily discussions were essential for carrying out this book: Prof. Dieter Brackmann Goldmeyer, Prof. Douglas Rafael Veit, Prof. Luis Felipe Riehs Camargo, Profa. Maria Isabel Wolf Motta Morandi, and Prof. Secundino Luis Henrique Corcini Neto. Each one of them helped to implement this book in their own special way. In particular, I would like to thank Prof. Luis Henrique Rodrigues (General Coordinator of the GMAP | UNISINOS) for generously having me in the research group, for his words of friendship, laughs, and especially for all the learning. I also take this opportunity to thank Prof. Junico Antunes for his contributions, criticisms, and suggestions which guided the development of this book. Also, I thank him for being a great supporter of this cause. Last but not least, I would like to especially thank Prof. Daniel Pacheco Lacerda for proposing me the challenge of writing this book in 2011 and, above all, for making me believe that it would be possible. I am and will always be very grateful for the opportunity, for the trust, and for all the learning. Daniel, you are definitely an example to be followed. I'm also gratefully thankful to my family, to my Mom and to my Dad. Thank you for the unconditional support you have always given me. I even thank you for having encouraged me to read and write when I was still in my childhood (that was essential for this challenge to become



pleasurable). Finally, I would like to thank my love, Natanael, for all the patience, good humor, and dedication to me. Thank you for helping me in becoming a better person!

Aline Dresch

At this moment, we should thank those who played an important role in the development of this work. I would like to thank Prof. Dr. Ricardo Cassel (School of Engineering/UFRGS) for calling our attention to this theme by initially disseminating an article related to Design Science (DS). I thank the colleagues from the Pro-Engineering Program, funded by CAPES, in the Operation Management Model in Innovative Organizations—MGOOI Project. This project had the participation of many graduate programs, namely: PPGEPS/UNISINOS, PEP/COPPE/UFRJ, PEP-PE/UFPE, AI/INPI, and Poli/USP. This project was led by Prof. Dr. Adriano Proença (GPI/DEI/COPPE/UFRJ), an enthusiast of the theme. His intellectual brilliance, his reflections, and contributions were central to the development of our research. I also thank Prof. Carlos Formoso (NORIE/PPGEC/UFRGS) for the important comments and articles related to DS. I thank the colleagues at COPPE/UFRJ, which was decisive institution in my education, André Ribeiro (UERJ), Édison Renato (UNIRIO), Guido Vaz (UFF), Prof. Domício Proença Jr. (COPPE/UFRJ), Priscilla Ferraz (Bio-Manguinhos), and my advisor Prof. Dr. Heitor Caulliroux (COPPE/UFRJ), my undying respect and admiration. Certainly, this book would have not become real if I was not in a stimulating environment. Therefore, I need to thank those who are the basis of this environment. I thank Prof. Dr. Ione Bentz (PPGD/UNISINOS) for believing and decisively contributing for the formation of the GMAP | UNISINOS (Modeling for Learning Research Group). Her vision about the research, science, and academic doings inspire me today and in the future. I thank all colleagues from GMAP | UNISINOS (we are almost at our fifth year, who knew?). In particular, I thank Prof. Luis Felipe Camargo, Prof. Maria Isabel Morandi, and Prof. Secundino Luis Henrique Corcini Neto. I am deeply thankful to Prof. Dr. Luis Henrique Rodrigues (General Coordinator of the GMAP | UNISINOS) for all the teachings and learnings. Yesterday, my advisor; today, a great companion and mainly a friend-brother. As you would say, “We are together!” I thank Prof. Junico Antunes for the steady partnership, the great discussions, and intellectual constructs that are so good to our Master and Ph.D. students of PPGEPS/UNISINOS (unfortunately, increasingly rare in the academia). I deeply thank Aline Dresch for believing and giving her best to the development of this research and work. Over these 4 years, you have acquired my admiration and appreciation. As the fans of the immortal (*Grêmio Porto Alegrense*) would say: “*O sentimento não se termina*” (“The feeling never ends”). Finally and most importantly, I thank my family Carina (Xuxu), Caio and soon, Serena Lacerda. Carina, you are the co-author of the major “works” of my life. These “works” originated from and were built with much love. Our children have taught us the real meaning of a word that is so vulgarized and in which I believe so much: love. Thank you for your companionship, support, and inspiration

since the beginning, today, and ever, as I intend to. I love you more than you can understand! Finally, I will leave a popular wisdom of life in which I strongly believe: “*Só o amor constrói*” (“Only love builds”). This guides me both personally and professionally. Be assured that this book was developed with my best.

Daniel Pacheco Lacerda

Initially, I would like to recognize that the Design Science Research (DSR) theme came to my attention through a series of papers passed on by Prof. Ely Paiva. As Production Engineering lacks methods that can contribute to the development of prescriptive nature works, the reflections on the DSR method were essential to complement and advance in relation to the methods that we have often used, which are the Case Study and the Action Research. Undoubtedly, Prof. Ricardo Cassel was also essential as he sought to disseminate articles associated with the Design Science (DS) among PPGEPS/UNISINOS students and teachers.

Due to our historic partnership with GPI/COPPE, we immediately passed on the articles and initiated reflections on the DSR Method with our longtime partners, Profs. Adriano Proença and Heitor Mansur Caulliraux. In addition, we encouraged PPGEPS/UNISINOS students to address the issue with the maximum depth possible, being that the dissertations developed in the last few years were fundamental for making it possible to carry out this project.

Also, we immediately dealt with the subject in the “Operation Management Model in Innovative Organizations—MGOOI” Project, funded by CAPES, in the Pro-Engineering Program context. Several relevant discussions took place in the scope of this project, with the participation of the PPGEPS/UNISINOS, PEP/COPPE/UFRJ, PEP-PE/UFPE, AI/INPI, and Poli/USP institutions, in particular with Profs. Adriano Proença and Mário Sérgio Salerno, discussions which significantly pro-actively contributed to the preparation of this book.

Our contacts with Prof. Carlos Formoso, who is developing and coordinating several research works using the principles of the DS in the NORIE/PPGEC/UFRGS, were also relevant.

My objective insertion in the method theme was during my Ph.D. studies in Business Administration at UFRGS (1996/1999), particularly encouraged by Prof. Francisco Araújo Santos. Since late 90s, I have been lecturing the scientific method subject in Masters and Ph.D. programs in Management and Production Engineering: PPGEU/UFRGS, PPGEPS/UNISINOS, and PPGA/UNISINOS. In this context, I would like to highlight the partnership with Prof. Yeda Swirsky, with whom I have exchanged several conversations and ideas over the last 13 years on the method theme, which is really multifaceted, fascinating, and relevant. Moreover, it is worth highlighting the effective contribution of the UNISINOS environment, particularly the Business School/PPGA and PPGEPS, to the set of scientific and technological nature works recently developed.

I also appreciate the partnership with Prof. Daniel Lacerda, with whom I have had constant and systematic theoretical debates, and made relevant practical constructions in the PPGEPS/UNISINOS environment over recent years. Aline Dresch,

a professional with a future in Production Engineering, we recognize the essential efforts that led to the design, consolidation, and operationalization of this book.

Finally, I thank my wife Verônica Verleine Horbe Antunes, my mother Maria da Graça Moraes Antunes, my father José Antônio Valle Antunes (*in memoriam*), and my son Juandres Horbe Antunes, who is now studying Production Engineering at UFPEL, for the unrestricted support to my academic activities developed over the past 30 years.

Junico Antunes (José Antônio Valle Antunes Junior)

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# Presentation

What does society expect from technology research?

This issue has always risen for this scribe during studies and research works in Production Engineering/Operations Management, along with the prospect of an upcoming research project or during the design of a research initiative; or when defining the theme, object and method in Master's Degree dissertations and Ph.D. Thesis. It is from this standpoint that this preface is written.

Through the voice of communities, organizations, businesses, leaders, managers, and students, what comes to us in the academia is the demand for designing, developing, planning, and implementing appropriate solutions. The issues raised involve whether such and which ways are indeed the most efficient, efficacious, and effective among the viable ones in situations 'a' or 'b'. The information and knowledge about the most advanced solutions and their degree of success in the existing implementations and their contexts, and the implication of this success on the progress of the technology in question as a whole; the possibility of developing a new solution to create, to push the technological frontier a bit further; all of this should be considered as alternatives, contemplated as a route, and works should always be informed to meet the final criteria of its performance in the real world, in different dimensions.

Maybe thousands of academic studies in Operations Management, taken here as an illustration of a technological area, have been conducted, in Brazil, as descriptions of real running solutions and analysis of the causality of results achieved by them, through case studies; or on what happened in a certain industrial sector through surveys relying on questionnaires and interviews. What happens/happened is studied, or the opinion/perception of large numbers is mapped. Analysis is developed to explain what was found and predict what would happen in such and which situations, according to this or that model, this or that "theory." The social sciences methods are emulated, the ambition of Nature sciences are mirrored. It is an agenda.

The "breakthrough" this book brings is to regain and affirm that this is not the only, and perhaps this is not "the" research agenda, for example, in Operations Management. This book starts from the recognition that there are Design Sciences.

A Design Science (DS) holds specific goals and ambitions; it seeks to establish artifacts of different natures for the solutions of problems (of “problem classes”—refer to Chap. 4 of this book).

Researching in a DS—in the terms of this book: to perform Design Science Research (DSR)—is unlike researching in the scope of a social or a natural science. Under the tentatively pragmatic understanding of this preface writer, DS is not “Applied Science<sup>1</sup>,” for starters. Its purpose is not the mere translation in practice of the explanatory statements of the social or natural sciences, but yet the formulation and validation of design rules—conception, design, and implementation in defined circumstances—to be driven by the field professionals when they judge them relevant.

In addition, a DS recognizes, from its definition, that professionals in the field are not reduced to mere enforcers of the results of their findings—in other words, they are not mere applicators of stabilized technological rules. Given the multitude of situations they may encounter, and the complexity and dynamism of the real world, professionals as the ones of Operations Management trigger their “toolbox,” or in accordance with what B. Koen defines what engineering is (refer to Chap. 5 of this book), trigger the “heuristics [that they know] to cause the best change possible in a poorly understood situation, with the resources available.”<sup>2</sup>

Providing this professional in the field of reliable, tested, and validated technology rules (or technological propositions—refer to Chap. 4 of this book), of tangible or intangible artifacts whose behaviors are scientifically—that is, logical (expressed in theories, models or frameworks, for instance), and empirically—validated, is the direction of research in a DS. In this context, the research turns to achieve theoretical, experimental, and empirical results, which inform the act of designing. These will be added in the field to the insights derived from the social and natural sciences; to the current design practices of the profession; to the creativity of the professional (i.e., to what he/she invents); and to what he eventually only tacitly deduces from his/her practical experience.<sup>3</sup>

The DS in Operations Management will play a key role not only in the conception and designing processes, but also in questioning, testing, and validating cognitive or structured artifacts (design methods; organization and management solutions; operational policies; procedures, for example). In fact, they sometimes are presented to professionals and scholars under fanfares and exalted descriptions in publications of various kinds, as if they were universal panaceas—in not few cases in the so-called “airport literature,” for example. It is for the DSR to unravel the actual scope of such claims, and if possible move into new proposals derived from their findings.

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<sup>1</sup> Cf. Silva, E.R., & e Proença Jr., D. (2012) *Não ser não é não ter: Engenharia não é Ciência (nem mesmo ciência aplicada)*. Mimeo.

<sup>2</sup> Koen, B.V. (2003) *Discussion of the method: conducting the engineer’s approach to problem solving*. New York: Oxford University Press, 28.

<sup>3</sup> This list reflects the discussion undertaken by Vincenti, W.G. *What engineers know and how they know it: analytical studies from aeronautical history*. Baltimore: John Hopkins University Press, 1990, apud Silva, E.R. e Proença Jr., D. (op. cit.).

The DSR, for example, followed the hint offered by the real success of Toyota in Japan and in the U.S. at the end of the 70s to systematically describe the operation of the Toyota Production System (TPS) in books and articles; to then establish the circumstances and the contexts in which the policies and structures component of this system would satisfactorily work, making records of where its superiority in results was effectively verifiable; and then going deeper, grasping and describing the method by which Taiichi Ohno and Shigeo Shingo thought and responded to emerging challenges during the development of the TPS.<sup>4</sup> This last one is the best starting point for translating what has been learned from the TPS to the temporal/spatial reality faced by the designer/planner in charge of dealing with a real situation: its ill understood problem, to be solved under various constraints. Method, context, and circumstances of success, policies, and robust solutions: here is an example of a tested and validated artifact till where it is humanly possible. Always under the recognition that this artifact does not “automatically” bring the solution itself, but rather informs, as an available powerful heuristics, the process of creating a “new solution” in a given context, by definition strictly singular (spatially and temporally).

This book structures how a rigorous research is done within a DS, particularly in those that are identified with the broader field of Management, where this approach is not yet widely accepted. A solid bibliographic review allows identifying the convergence points presented in this literature, particularly in its most recent dimensions. It further seeks to (re)situate the methods of going to the field so that one can understand what is its best use in the DSR context. It is about discussing and reviewing how to develop a case study or survey when the objects and research objectives relate to cognitive and practiced artifacts, how to design them, the circumstances of its use and the expectable results (refer to Chap. 2 of this book).

To the judgment of this scribe, Brazil brutally lacks progress in this field. There are signs of massive resistance to the acceptance of such a perspective. An article on the subject, which was submitted for publication in a prestigious national academic journal, became, certainly in a large part by its own deficiencies, the target of strongly negative comments by the anonymous referees who refused it. However, among them there was a surprising identification of the whole issue of Management as a DS with a mere list of matters already resolved by product development techniques (!); and manifested perplexity and strong criticism to the importance given in the article to the contribution of Hebert Simon (Nobel Laureate in Economics and author of the seminal book on the Design Sciences.<sup>5</sup> To dimension what such criticism seemed to imply in terms of the referee ignorance on the subject, refer to Chaps. 1 and 2 of this book).

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<sup>4</sup> For a pioneer presentation of this aspect, refer to Antunes Jr., J.A.V. “*O Mecanismo da Função Produção: análise dos Sistemas Produtivos do ponto de vista de uma rede de processos e operações*”, in *Produção*, vol. 4, no. 1, Julho, 1994, pp. 33–46. A similar cognitive nature operation apparently took shape when the MIT team that established the “lean production” term later developed the idea of “lean thinking”.

<sup>5</sup> Simon, H.A. (1969) *The Sciences of the Artificial*. Cambridge, MA: MIT Press.



This and other signals coming from the Brazilian Academy suggest that this book can fill an important gap, and contribute to enlarge the necessary debate on the policies and practices of research in technological development in the country, among others. In fact, at a time when at least apparently there is a national consensus being forged on the need to increase the productivity of the Brazilian economy, the incorporation of the remarkable recent advances in technology, be it in the information and communication technologies level or in the materials and biotechnology level, among many to consider, will need to be made in a smart, methodical, and discerning way, if intended to be efficient, efficacious, and effective.

There is no historical time available for us to fall behind in this path. The best conception, design, and implementation heuristics available should be incorporated, and then move forward to the frontiers of the state of the art when possible. To test, learn, incorporate, move forward. To develop our local Design Sciences and expand the boundaries of possibilities for Brazil's future with them. I think that what society is asking for research on technology is not less than fulfilling its historic role of concretely contributing to the development of the country. This book will help the academia in particular to participate effectively in this process.

Adriano Proença  
Ph.D. in Production Engineering, COPPE/UFRJ  
Professor of the Industrial Engineering  
Department at Polytechnic School of UFRJ and  
collaborator of the Production Engineering and  
Nanotechnology Engineering Programs at COPPE/UFRJ  
Professor of the Integrated Production  
Group at COPPE and EP/UFRJ