A Taxonomy for Process Improvement and Innovation Systems

Tobias Fehrer, Linda Moder, Maximilian Röglinger

Business & Information Systems Engineering (2025)

Appendix (available online via http://link.springer.com)

Appendix A – Iteration 1

Table A.1 Initial draft of the taxonomy in the beginning of Iteration 1

Layer	Dimension	Characteristics					
Input	Type of Input	Process execution data	Process fragments / models	Constraints / rules	Organizational data	Context-dependent domain knowledge	Context-agnostic domain knowledge
Process	Redesign Scope	Same value proposition	Enhanced value proposition	New value proposition			
	Design Generation	Manually created rules	Automatically derived rules	Simulate and test algorithms	Logical reasoning		
	Design Evaluation	Simulation	Economic evaluation	Experimental	None		
Output	Type of Output	Decision knowledge	Process fragments / models	Event log(s)	Organizational data	Specific improvement ideas	

Table A.2 Outlets examined in the unstructured literature search

Journals	Conferences
Business & Information Systems Engineering	Business Process Management Conference
Business Process Management Journal	European Conference on Information Systems
Communications of the Association for Information Systems	International Conference on Conceptual Modeling
Computers in Industry	International Conference on Information Systems
Data & Knowledge Engineering	International Conference on Process Mining
Decision Support Systems	
Enterprise Modelling and Information Systems Architectures	
Expert Systems with Applications	
International Journal of System Modeling and Design	

Appendix B – Iteration 2

Table B Artifacts used for the classification based on the systematic literature review

Source	ID	Scope		Input	Throughput				Output
		Focus of changes	Ambition		Design generation method	Knowledge acquisition	Design evaluation objectives	Level of human involvement	
Afflerbach et al. (2017)	37	Control-flow; Resource	Incremental	Process execution data; Process design data; Business rules; Process goal; Improvement objective	Rule-based	Explicit	Performance	Out of the Loop	Formalized
Assy et al. (2013)	24	Control-flow	Incremental	Process design data; Process goal	Rule-based	Explicit	All	Out of the Loop	Formalized
Bazhenova and Weske (2014)	28	Control-flow	Incremental	Process execution data; Process design data; Process context; Business rules; Process goal; Improvement objective	Rule-based	Explicit	All	Out of the Loop	Formalized
Chakraborti et al. (2020)	46	Control-flow; Resource	Incremental	Process design data	Rule-based	Explicit	All	On the Loop	Non-Formalized
Fakhfakh et al. (2022)	57	Control-flow; Resource	Incremental	Process design data; Business rules; Process goal; Improvement objective	Randomness-based	Explicit	All	Out of the Loop	Formalized
Fehrer et al. (2022)	61	Control-flow; Resource	Incremental	Process design data; Business rules	Rule-based	Explicit	Performance	In the Loop	Formalized
Havur et al. (2019)	41	Control-flow	Incremental	Process design data; Business rules; Improvement objective	Rule-based	Explicit	All	Out of the Loop	Formalized
Heinrich et al. (2009)	13	Control-flow	Radical	Process context; Process goal; Improvement objective	Rule-based	Explicit	Feasibility	Out of the Loop	Formalized
Heinrich and Schön (2015)	11	Control-flow	Radical	Process design data; Process context	Randomness-based	Explicit	All	Out of the Loop	Formalized
Hoesch-Klohe and Ghose (2010)	15	Control-flow	Incremental	Process design data; Process context	Randomness-based	Explicit	Feasibility	Out of the Loop	Formalized
Jaeger et al. (1994)	1	Control-flow	Radical	Process design data; Process context	Randomness-based	Explicit	Feasibility	Out of the Loop	Formalized

Jia-Xing Wang et al. (2021)	54	Control-flow; Resource	Radical	Process design data; Process context; Process goal	Rule-based	Explicit	All	Out of the Loop	Formalized
JIMÉNEZ et al. (2013)	25	Control-flow	Radical	Process design data	Rule-based	Implicit	Feasibility	In the Loop	Formalized
Jimenez-Ramirez et al. (2012)	22	Control-flow	Incremental	Process design data; Business rules; Process goal; Improvement objective	Randomness-based	Explicit	None	Out of the Loop	Formalized
Khan et al. (2020)	47	Control-flow	Incremental	Process execution data; Process design data; Business rules; Improvement objective	Rule-based	Both	All	In the Loop	Formalized
Lincoln et al. (2010)	16	Control-flow; Resource	Incremental	Process design data; Process context; Business rules; Process goal; Improvement objective	Randomness-based	Explicit	All	Out of the Loop	Formalized
Lohmann (2013)	26	Control-flow	Radical	Process design data	Rule-based	Explicit	Feasibility	In the Loop	Formalized
Mahammed et al. (2021)	56	Control-flow; Resource	Incremental	Process design data; Business rules; Process goal	Rule-based	Explicit	All	Out of the Loop	Formalized
Mahammed et al. (2019)	42	Control-flow; Resource	Radical	Business rules; Process goal	Rule-based	Explicit	All	In the Loop	Formalized
Mahammed and Benslimane (2016)	34	Control-flow	Incremental	Process design data	Rule-based	Explicit	None	Out of the Loop	Formalized
Min et al. (1996)	5	Control-flow	Incremental	Process design data; Process context	Rule-based	Explicit	All	Out of the Loop	Formalized
Mustansir et al. (2022)	59	Control-flow	Incremental	Process design data; Process context	Rule-based	Explicit	All	Out of the Loop	Formalized
Nagel et al. (2014)	30	Control-flow	Incremental	Process design data; Process goal; Improvement objective	Randomness-based	Explicit	All	Out of the Loop	Formalized
Nahabedian et al. (2019)	43	Control-flow	Incremental	Process execution data; Process design data	Rule-based	Explicit	Feasibility	In the Loop	Formalized
Netjes et al. (2007)	9	Control-flow	Incremental	Process design data; Process context; Process goal; Improvement objective	Randomness-based	Explicit	All	Out of the Loop	Formalized

Ng (2018)	39	Resource	Incremental	Process execution data; Process design data	Randomness-based	Explicit	All	Out of the Loop	Formalized
Niedermann and Schwarz (2011)	19	Control-flow	Incremental	Process execution data; Process design data; Process goal; Improvement objective	Rule-based	Explicit	All	Out of the Loop	Formalized
Nissen (1998)	7	Control-flow; Resource	Radical	Process design data; Process goal	Rule-based	Explicit	All	Out of the Loop	Formalized
Nordemann et al. (2020)	50	Control-flow	Incremental	Process design data; Business rules; Process goal; Improvement objective	Randomness-based	Explicit	All	Out of the Loop	Formalized
Paszun et al. (2019)	44	Control-flow	Incremental	Process design data; Process context; Business rules; Process goal	Rule-based	Explicit	All	Out of the Loop	Formalized
Rungworawut and Senivongse (2010)	18	Control-flow	Radical	Process design data; Business rules; Process goal; Improvement objective	Rule-based	Explicit	Feasibility	Out of the Loop	Formalized
Salomie et al. (2012)	23	Control-flow	Radical	Process design data	Rule-based	Explicit	All	In the Loop	Formalized
Sbai et al. (2013)	27	Control-flow	Incremental	Process design data; Business rules	Rule-based	Explicit	Feasibility	Out of the Loop	Formalized
Scholta et al. (2019)	45	Control-flow	Incremental	Process execution data; Process design data	Rule-based	Explicit	All	On the Loop	Formalized
Seeliger et al. (2018)	40	Control-flow	Incremental	Process design data; Improvement objective	Rule-based	Explicit	All	Out of the Loop	Non-Formalized
Seyffarth and Raschke (2020)	52	Control-flow	Incremental	Process design data; Business rules; Process goal	Rule-based	Explicit	None	In the Loop	Formalized
St. Kirn and Wanka (1994)	3	Control-flow	Incremental	Process design data	Rule-based	Explicit	All	On the Loop	Formalized
Stelling et al. (2009)	14	Control-flow	Incremental	Process design data	Rule-based	Explicit	All	On the Loop	Non-Formalized
Tealeb et al. (2014)	31	Control-flow; Resource	Incremental	Process design data; Business rules; Process goal	Randomness-based	Explicit	All	Out of the Loop	Formalized

Truong and Lê (2016)	36	Control-flow; Resource	Incremental	Process design data; Business rules; Process goal; Improvement objective	Randomness-based	Explicit	All	Out of the Loop	Formalized
van Dun et al. (2023)	63	Control-flow; Resource	Both	Process execution data	Randomness-based	Implicit	None	In the Loop	Non-Formalized
Vergidis et al. (2007)	10	Control-flow; Resource	Incremental	Process design data; Improvement objective	Rule-based	Explicit	All	In the Loop	Formalized
Vergidis et al. (2006)	8	Control-flow; Resource	Incremental	Process design data; Improvement objective	Rule-based	Explicit	All	In the Loop	Non-Formalized
Vergidis and Tiwari (2008)	12	Control-flow	Radical	Process execution data	Randomness-based	Implicit	None	In the Loop	Non-Formalized

For archetype analysis, we only considered the characteristics that occurred in the sample for the clustering. For focus of changes, we therefore used “control-flow”, “resource” and “both” to determine combinations, so that we could analyze the dimension with mutually exclusive characteristics.

References

Afflerbach P, Hohendorf M, Manderscheid J (2017) Design it like Darwin - A value-based application of evolutionary algorithms for proper and unambiguous business process redesign. Inf Syst Front 19:1101–1121. https://doi.org/10.1007/s10796-016-9715-1

Assy N, Chan NN, Gaaloul W (2013) Assisting Business Process Design with Configurable Process Fragments. In: 2013 IEEE International Conference on Services Computing. IEEE, pp 535–542

Bazhenova E, Weske M (2014) A Data-Centric Approach for Business Process Improvement Based on Decision Theory. In: van der Aalst W, Mylopoulos J, Rosemann M, Shaw MJ, Szyperski C, Bider I, Gaaloul K, Krogstie J, Nurcan S, Proper HA, Schmidt R, Soffer P (eds) Enterprise, Business-Process and Information Systems Modeling, vol 175. Springer Berlin Heidelberg, Berlin, Heidelberg, pp 242–256

Chakraborti T, Agarwal S, Khazaeni Y, Rizk Y, Isahagian V (2020) D3BA: A Tool for Optimizing Business Processes Using Non-deterministic Planning. In: Del Río Ortega A, Leopold H, Santoro FM (eds) Business Process Management Workshops, vol 397. Springer International Publishing, Cham, pp 181–193

Fakhfakh F, Cheikhrouhou S, Dammak B, Hamdi M, Rekik M (2022) Multi-objective approach for scheduling time-aware business processes in cloud-fog environment. J Supercomput. https://doi.org/10.1007/s11227-022-04690-2

Fehrer T, Fischer DA, Leemans SJ, Röglinger M, Wynn MT (2022) An assisted approach to business process redesign. Decis Support Syst 156:113749. https://doi.org/10.1016/j.dss.2022.113749

Havur G, Haselböck A, Cabanillas C (2019) Automated Multi-perspective Process Generation in the Manufacturing Domain. In: Di Francescomarino C, Dijkman R, Zdun U (eds) Business Process Management Workshops, vol 362. Springer International Publishing, Cham, pp 81–92

Heinrich B, Schön D (2015) Automated Planning of Context-aware Process Models. In: ECIS 2015 completed reseaech papers, AIS Electronic Library

Heinrich B, Bolsinger M, Bewernik M (2009) Automated planning of process models: the construction of exclusive choices. In: H. Chen, S. A. Slaughter (eds) Doing IT Research That Matters, Proceedings of the 30th International Conference on Information Systems (ICIS). Springer, Berlin, pp 1–18

Hoesch-Klohe K, Ghose A (2010) Business Process Improvement in Abnoba. In: Maglio PP, Weske M, Yang J, Fantinato M (eds) Service-Oriented Computing, vol 6470. Springer Berlin Heidelberg, Berlin, Heidelberg, pp 193–202

Jaeger T, Prakash A, Ishikawa M (1994) A framework for automatic improvement of workflows to meet performance goals. In: Proceedings Sixth International Conference on Tools with Artificial Intelligence. TAI 94. IEEE Comput. Soc. Press, pp 640–646

Jia-Xing Wang J-XW, Jia-Xing Wang S-BG, Si-Bin Gao C-EY, Cong-Er Yuan D-PT, Da-Peng Tan JF (2021) Service Process Improvement Based on Business Process Management. Journal of Internet Technology 22:1117–1128. https://doi.org/10.53106/160792642021092205015

JIMÉNEZ A, BARBA I, Del VALLE C, WEBER B (2013) OptBPPlanner: Automatic Generation of Optimized Business Process Enactment Plans. In: Linger H, Fisher J, Barnden A, Barry C, Lang M, Schneider C (eds) Building Sustainable Information Systems. Springer US, Boston, MA, pp 429–442

Jimenez-Ramirez A, Barba I, Del Valle C, Weber B (2012) Generating multi-objective optimized configurable business process models. In: 2012 Sixth International Conference on Research Challenges in Information Science (RCIS). IEEE, pp 1–2

Khan R, Azam F, Maqbool B, Anwar MW (2020) A Framework for Automated Reengineering of BPMN Models by Excluding Inefficient Activities. In: Proceedings of the 2020 9th International Conference on Software and Computer Applications. ACM, New York, NY, USA, pp 147–151

Lincoln M, Golani M, Gal A (2010) Machine-Assisted Design of Business Process Models Using Descriptor Space Analysis. In: Hutchison D, Kanade T, Kittler J, Kleinberg JM, Mattern F, Mitchell JC, Naor M, Nierstrasz O, Pandu Rangan C, Steffen B, Sudan M, Terzopoulos D, Tygar D, Vardi MY, Weikum G, Hull R, Mendling J, Tai S (eds) Business Process Management, vol 6336. Springer, Berlin, Heidelberg, pp 128–144

Lohmann N (2013) Compliance by design for artifact-centric business processes. Information Systems 38:606–618. https://doi.org/10.1016/j.is.2012.07.003

Mahammed N, Benslimane SM (2016) Toward Multi Criteria Optimization of Business Processes Design. In: Bellatreche L, Pastor Ó, Almendros Jiménez JM, Aït-Ameur Y (eds) Model and Data Engineering, vol 9893. Springer International Publishing, Cham, pp 98–107

Mahammed N, Benslimane SM, Ouldkradda A, Fahsi M (2019) Evolutionary Multi Optimization Business Process Designs Using MR-Sort NSGAII. In: Renault É, Boumerdassi S, Bouzefrane S (eds) Mobile, Secure, and Programmable Networking, vol 11005. Springer International Publishing, Cham, pp 24–31

Mahammed N, Bennabi S, Fahsi M (2021) Application of Multiple Population Genetic Algorithm in Optimizing Business Process. In: Hatti M (ed) Artificial Intelligence and Renewables Towards an Energy Transition, vol 174. Springer International Publishing, Cham, pp 847–855

Min DM, Kim JR, Kim WC, Min D, Ku S (1996) IBRS: Intelligent bank reengineering system. Decision Support Systems 18:97–105. https://doi.org/10.1016/0167-9236(96)00021-8

Mustansir A, Shahzad K, Malik MK (2022) Towards automatic business process redesign: an NLP based approach to extract redesign suggestions. Autom Softw Eng 29. https://doi.org/10.1007/s10515-021-00316-8

Nagel B, Gerth C, Engels G (2014) Goal-Driven Composition of Business Process Models. In: Hutchison D, Kanade T, Kittler J, Kleinberg JM, Kobsa A, Mattern F, Mitchell JC, Naor M, Nierstrasz O, Pandu Rangan C, Steffen B, Terzopoulos D, Tygar D, Weikum G, Lomuscio AR, Nepal S, Patrizi F, Benatallah B, Brandić I (eds) Service-Oriented Computing – ICSOC 2013 Workshops, vol 8377. Springer International Publishing, Cham, pp 16–27

Nahabedian L, Braberman V, D'ippolito N, Kramer J, Uchitel S (2019) Dynamic Reconfiguration of Business Processes. In: Hildebrandt T, van Dongen BF, Röglinger M, Mendling J (eds) Business Process Management, vol 11675. Springer International Publishing, Cham, pp 35–51

Netjes M, Mansar SL, Reijers HA, van der Aalst. WMP (2007) AN EVOLUTIONARY APPROACH FOR BUSINESS PROCESS REDESIGN - Towards an Intelligent System. 2184-4992. https://doi.org/10.5220/0002356900470054

Ng CY (2018) Business process optimization using the ant colony system. Manage Decis Econ 39:629–637. https://doi.org/10.1002/mde.2933

Niedermann F, Schwarz H (2011) Deep Business Optimization: Making Business Process Optimization Theory Work in Practice. In: Halpin T, Nurcan S, Krogstie J, Soffer P, Proper E, Schmidt R, Bider I (eds) Enterprise, Business-Process and Information Systems Modeling, vol 81. Springer Berlin Heidelberg, Berlin, Heidelberg, pp 88–102

Nissen ME (1998) Redesigning Reengineering through Measurement-Driven Inference. MIS Quarterly 22:509. https://doi.org/10.2307/249553

Nordemann F, Tönjes R, Pulvermüller E, Tapken H (2020) Graph-based Multi-Criteria Optimization for Business Processes. In: Shishkov B (ed) Business Modeling and Software Design, vol 391. Springer International Publishing, Cham, pp 69–83

Paszun T, Wiśniewski P, Kluza K, Ligęza A (2019) Automated Generation of Business Process Models using Constraint Logic Programming in Python. In: Proceedings of the 2019 Federated Conference on Computer Science and Information Systems. IEEE, pp 733–742

Rungworawut W, Senivongse T (2010) AUTOMATING A DESIGN METHODOLOGY FOR REUSABLE BUSINESS PROCESS COMPONENTS THROUGH A GENETIC ALGORITHM. Int. J. Soft. Eng. Knowl. Eng. 20:1151–1207. https://doi.org/10.1142/S0218194010005109

Salomie I, Chifu VR, Pop CB, Suciu R (2012) Firefly-based business process optimization. In: 2012 IEEE 8th International Conference on Intelligent Computer Communication and Processing. IEEE, pp 49–56

Sbai H, Fredj M, Kjiri L (2013) Towards a Process Patterns based Approach for Promoting Adaptability in Configurable Process Models. In: Proceedings of the 15th International Conference on Enterprise Information Systems. SciTePress - Science and and Technology Publications, pp 382–387

Scholta H, Niemann M, Delfmann P, Räckers M, Becker J (2019) Semi-automatic inductive construction of reference process models that represent best practices in public administrations: A method. Information Systems 84:63–87. https://doi.org/10.1016/j.is.2019.03.001

Seeliger A, Stein M, Mühlhäuser M (2018) Can We Find Better Process Models? Process Model Improvement Using Motif-Based Graph Adaptation. In: Teniente E, Weidlich M (eds) Business Process Management Workshops, vol 308. Springer International Publishing, Cham, pp 230–242

Seyffarth T, Raschke K (2020) BCIT: A Tool to Recommend Compliant Business Processes based on Process Adaption. In: Wil M. P. van der Aalst, Jan vom Brocke, Marco Comuzzi, Claudio Di Ciccio, Félix Garc\'ıa, Akhil Kumar, Jan Mendling, Brian T. Pentland, Luise Pufahl, Manfred Reichert, Mathias Weske (eds) Proceedings of the Best Dissertation Award, Doctoral Consortium, and Demonstration & Resources Track at BPM 2020 co-located with the 18th International Conference on Business Process Management (BPM 2020), Sevilla, Spain, September 13-18, 2020, vol 2673. CEUR-WS.org, pp 107–111

St. Kirn RU, Wanka U (1994) MAMBA: Automatic customization of computerized business processes. Information Systems 19:661–682. https://doi.org/10.1016/0306-4379(94)90035-3

Stelling M, Roy R, Tiwari A (2009) A Novel Modelling and Optimisation Technique for Business Processes: An Evolutionary Computing Based Approach. In: Avineri E, Köppen M, Dahal K, Sunitiyoso Y, Roy R (eds) Applications of Soft Computing, vol 52. Springer Berlin Heidelberg, Berlin, Heidelberg, pp 75–85

Tealeb A, Awad A, Galal-Edeen G (2014) Context-Based Variant Generation of Business Process Models. In: van der Aalst W, Mylopoulos J, Rosemann M, Shaw MJ, Szyperski C, Bider I, Gaaloul K, Krogstie J, Nurcan S, Proper HA, Schmidt R, Soffer P (eds) Enterprise, Business-Process and Information Systems Modeling, vol 175. Springer Berlin Heidelberg, Berlin, Heidelberg, pp 363–377

Truong T-M, Lê L-S (2016) Towards a Formal Framework for Business Process Re-Design Based on Data Mining. In: Schmidt R, Guédria W, Bider I, Guerreiro S (eds) Enterprise, Business-Process and Information Systems Modeling, vol 248. Springer International Publishing, Cham, pp 250–265

van Dun C, Moder L, Kratsch W, Röglinger M (2023) ProcessGAN: Supporting the creation of business process improvement ideas through generative machine learning. Decis Support Syst 165:113880. https://doi.org/10.1016/j.dss.2022.113880

Vergidis K, Tiwari A, Majeed B (2006) Business process improvement using multi-objective optimisation. BT Technol J 24:229–235. https://doi.org/10.1007/s10550-006-0065-2

Vergidis K, Tiwari A, Majeed B, Roy R (2007) Optimisation of business process designs: An algorithmic approach with multiple objectives. International Journal of Production Economics 109:105–121. https://doi.org/10.1016/j.ijpe.2006.12.032

Vergidis K, Tiwari A (2008) Business process design and attribute optimization within an evolutionary framework. In: 2008 IEEE Congress on Evolutionary Computation (IEEE World Congress on Computational Intelligence). IEEE, pp 668–675

Appendix C – Iteration 3

In Iteration 3, we first conducted five semi-structured, qualitative interviews with leading process mining vendors. We used the following interview guideline.

Table C.1 Interview guideline for the semi-structured interviews with process mining vendors

Part 1 – Introduction	• Welcome and brief introduction of the research team
	• Brief introduction of the interviewee
	    o What is your current role?
	    o What experiences do you have?
	    o How much experience do you have in BPM (in years)?
	    o What is your background?
	• Presentation of the interview objective and schedule
	• Questions regarding confidentiality
	    o Are we allowed to provide the name of your organization in the paper?
	    o Are we allowed to record the interview?

Part 2 Exploratory Questions	• Questions regarding product development
	    o Are you currently working on PII systems?
	    o If yes, how do these PII systems work (e.g., in terms of input, throughput, and output)?
	• Questions regarding visions and expectations
	    o Can you imagine other PII systems?
	    o What kind of PII systems do you expect to be developed in the upcoming years?
	    o How could these PII systems work (e.g., in terms of input, throughput, and output)?

Part 3 Confirmatory Questions	• Presentation and explanation of the taxonomy
	• Questions regarding the taxonomy
	    o For each dimension:
	        ▪ Is the dimension understandable?
	        ▪ Is the dimension useful?
	        ▪ Are the included characteristics understandable?
	        ▪ Are the included characteristics useful?
	        ▪ Should any characteristic(s) be changes (e.g., added, merged, split, adapted, or eliminated)?
	    o Should any dimension be changed (e.g., added, merged, split, adapted, or eliminated)?
	    o Do you see any areas for improvement?

Part 4 Conclusion	• Appreciation for participation • Questions regarding further interviewees • Outlook on the next steps regarding our research

Concluding Iteration 3, we conducted 11 additional evaluation interviews with experienced researchers as well as an evaluation survey with 12 practitioners experienced in BPM and/or process mining in a workshop in the context of a research project. The interviewees and survey participants were presented with each dimension, the included characteristics, as well as the textual description, before rating statements on a 5-point Likert scale from 1 ("strongly disagree") to 5 ("strongly agree"). The researchers involved in the interviews also had the chance to provide qualitative feedback for the open-ended questions.

Table C.2 Questionnaire and survey items for the evaluation interviews and the survey

For each dimension	• Quantitative assessment: ○ The dimension is understandable. ○ The dimension is useful. ○ The dimension is complete. • Qualitative assessment: ○ Are there any other characteristics that we should consider? ○ Do you have any further feedback, comments, or suggestions on this dimension?
For the entire taxonomy	• Quantitative assessment: ○ I consider the taxonomy understandable. ○ I consider the taxonomy concise. ○ I consider the taxonomy robust. ○ I consider the taxonomy comprehensive. ○ I consider the taxonomy extendible. ○ I consider the taxonomy explanatory. • Qualitative assessment: ○ Are there any further dimensions that we should consider? ○ Do you have any further feedback, comments, or suggestions on the taxonomy at a global level?

Appendix D – Raw Data

The raw data on the taxonomy development process can be found online at https://figshare.com/s/7cdac68cbd5094191bad (de-anonymized link will be provided after acceptance).