A Review of Fuzzy Front End Studies

Dr. Dongmyung Park

Dyson School of Design Engineering
Imperial College London
Imperial College Road
South Kensington
London, SW7 2DB, UK
d.park14@imperial.ac.uk

Prof. Peter RN Childs

Dyson School of Design Engineering
Imperial College London
Imperial College Road
South Kensington
London, SW7 2DB, UK
p.childs@imperial.ac.uk

1 Appraisal Criteria for 266 Fuzzy Front End Studies

– Park, D, and Childs, PRN, Dyson School of Design Engineering, Imperial College London, UK

#	Criteria		Description
1	Study Taxonomy	1.1	Dependent FFE model • FFE models which depend on innovation (NPD and design) processes as parent processes. • FFE parts extracted from innovation (NPD and design) processes.
		1.2	Independent FFE model • FFE models which exist independently. • FFE models which are explicitly for one or two FFE tasks or activities, e.g. opportunity identification, ideation, requirements list, conceptual design, etc.
		1.3	FFE issue study • The given study does not provide the type of the process, model and framework • Given studies are related to FFE issues, e.g. attributes, roles, functions, uncertainty control, success factors, etc.
		1.4	Study related to the FFE issue study • Given studies affect (or apply to) FFE tasks or activities, e.g. reasoning system, adaptive system, problem-solving system, etc.
2	Model Type [1]	2.1	Technology-push • Emphasis on R&D (and engineering & manufacturing)
		2.2	Market-pull • Emphasis on marketing (and management)
		2.3	Coupling model • Simple integration of R&D and marketing
		2.4	Interactive model • Complex intertwined linkage of push and pull
		2.5	Network model • Interactive system, extensive networking and continuous innovation • Intertwined linkage of R&D, marketing and other fields such as product planning, industrial design, design management, etc.
		2.6	Data-driven model • Based on the network model, the model has a function: to collect and analyse information, to process and determine parameters, and to transform the information and parameters into knowledge assets which can be ustilsed for future projects.
		2.7	Not Included (N/I) • The directions above cannot be identified in the given model.
3	NPD Speed	○	Agile NPDs • The model pursues agile NPDs with particular structures or strategies.
		△	Agile NPDs • The model attempts to pursue agile NPDs to some extent, although its particular structures or systems are not equipped to do so.
		X	Non-agile NPDs • The model does not pursue agile NPDs.
4	NPD Attribute	4.1	Radical NPDs • The model is largely appropriate for Radical NPDs.
		4.2	Incremental NPDs • The model is largely appropriate for Incremental NPDs.
		4.3	Radical > Incremental NPDs • The model is moderately appropriate for radical NPDs, although it aims at both attributes.
		4.4	Radical < Incremental NPDs • The model is moderately appropriate for incremental NPDs, although it aims at both attributes.
		4.5	Radical = Incremental NPDs

[1] In the case of the second appraisal criterion, 'Model Type', sub-criteria '2.1' to '2.7' were defined based on studies by Eveleens (2010), Kotsemir and Meissner (2013), Rothwell (1994), Tidd (2005), Trott (2008), etc.

			• The model is largely appropriate for both radical and incremental NPDs.
		4.6	Not Included (N/I) • The model cannot be verified as a radical and/or incremental NPD.
5	Model Characteristic	5.1	Explicitness • The structure of the model pursues a robustly fixed structure.
		5.2	Responsiveness • The structure of the model pursues a variably flexible structure.
		5.3	Explicitness > Responsiveness • The structure of the model is more inclined to explicitness, although it aims at both structural characteristics.
		5.4	Explicitness < Responsiveness • The structure of the model is more inclined to responsiveness, although it aims at both structural characteristics.
		5.5	Explicitness = Responsiveness • The structure of the model is balanced between explicitness and responsiveness.
		5.6	Not Included (N/I) • The structure of the model cannot determined as to its focus between explicitness or responsiveness.
6	Model Structure	6.1	Procedure type • The model defines phases and relevant sub-phases.
		6.2	Performance type • The model has a physical and functional form where NPD-related input and output parameters are yielded.
		6.3	Procedure type > Performance type • The model is more inclined to the procedure type, although it aims at both types.
		6.4	Procedure type < Performance type • The model is more inclined to the performance type, although it aims at both types.
		6.5	Procedure type = Performance type • The model is a combination of both the procedure and performance types.
		6.6	Not Included (N/I) • The type of model is a casual model or consists of pure mathematical or engineering formulas, etc.
7	Task	The broadest units constructing the FFE phase	
		7.1	Opportunity identification and screening task • The following tasks can be regarded as corresponding to this task: e.g. problem/need identification and screening, preliminary uncertainty analysis of markets and technologies, product-related information research, feasibility studies of opportunities, analyse, etc.
		7.2	Idea generation and screening task • The following tasks can be regarded as corresponding to this task: e.g. ideation and competition, feasibility studies of ideas, synthesis and evaluation, hypothesis search and selection, etc.
		7.3	Mission statement task • The following tasks can be regarded as corresponding to this task. e.g. strategic formulation, product planning, task clarification, outline of design proposal, brief product definition, etc.
		7.4	Requirements List task • The following tasks can be regarded as corresponding to this task. e.g. product specification, specific product definition, specification and priority, etc.
		7.5	Conceptual design task • The following tasks can be regarded as corresponding to this task. e.g. conceptual product definition, product function and system structure definition, conceptual design principles, etc.
		7.6	Prototyping task
		7.7	Not Included (N/I) • The model does not define any FFE tasks.
8	Activity	The subordinate units under 'Task' to accomplish the purposes of 'Task' implementation, e.g. 'market and user research activity' in the opportunity identification task, 'convergent and divergent activity' in the idea generation task, 'functional and system design activity' in the conceptual design task.	
		○	The model defines FFE activities (n≥3) specifically for each FFE task.
		△	The model defines FFE activities (n≤2) briefly or defines them for some FFE tasks.

		X	The model does not define any FFE activities (n=0) for any FFE task.	
9	Performance Method	The manual instructions (with basic knowledge/relevant frameworks) describing how to conduct each FFE activity or task.		
		○	The model describes specific performance methods. • Users can understand the provided performance methods without difficulty, using the given descriptions only.	
		△	The model briefly describes provides performance methods. • Users have difficulties understanding the provided performance methods with the given descriptions only.	
		X	The model does not describe how to conduct each FFE activity.	
10	Toolkit	A structural and functional frameset in which input and outputs related to product development parameters, variables and constrains are yielded.		
		1 Materiality	How much detail is provided to structure and operate the toolkits?	
			○	The provided toolkits are specific, so that users can understand and use them step by step without difficulty.
			△1	Self-development type (the process developed its own toolkits) • The toolkits provided are basic, so that users have difficulties not only understanding the methods of implementation but also in using the toolkits, step by step.
			△2	Representative toolkit type (the process borrowed well-known toolkits) • Representative toolkits which are broadly used in academia and industry are presented with brief instructions or the names of toolkits only.
			X	Toolkits are not specific, so that users cannot understand and use them step by step.
		2 Functionality	How much do the toolkits cover the various functional areas?	
			○	Toolkits are devised for diverse functional areas (at least two areas), e.g. marketing, R&D, design, etc.
			△	The toolkits provided target one functional area only.
			X	The toolkits provided do not target any functional areas, e.g. toolkits are aimed at managing FFE issues.
		3 Contextuality	How well do the toolkits interlock with each other for contextual performance?	
			○	The toolkits are well devised with respect to contextual performance. • The input of the subsequent toolkit can be directly inferred, based on the input of the previous toolkit.
			△	Toolkits provided are partially devised with contextual performance in mind. • The input of the subsequent toolkit cannot be directly inferred, based on the output of the previous toolkit.
			X	Toolkits provided are not devised with contextual performance in mind. • Each toolkit exists independently and thus the input of the subsequent toolkit cannot be inferred based on the output of the previous toolkit. • Toolkits are enumerated in a fragmented list.
		4 Cooperability	How are the toolkits structured and operated for collaboration?	
			○	The toolkits are devised, widely used, and are integrated with considerations for collaboration. • The inputs and outputs of toolkits can be physically and functionally yielded from multiple functional domains.
			△	Toolkits are devised with limited considerations for collaboration. • The inputs and outputs of toolkits can be yielded from two functional areas only.
			X	No toolkits are provided which consider collaboration. • The inputs and outputs of toolkits cannot be yielded from the collaboration aspect.
		X	The FFE study does not provide any toolkits for any FFE task, activity, and performance method.	
*	N/A	The case where the study does not offer any corresponding model type so that cannot be appraised using criteria above.		

2) Analysis Table of 266 Fuzzy Front End Studies

– Park, D, and Childs, PRN, Dyson School of Design Engineering, Imperial College London, UK

	Appraisal Criteria												
Model #	1 Taxo-nomy	2 Model Attribute	3 NPD Speed	4 NPD Attribute	5 Model Autonomy	6 Model Type	7 FFE Task	8 FFE Activity	9 Performance Method	10 Toolkit 1	10 Toolkit 2	10 Toolkit 3	10 Toolkit 4
– 1970s													
M001	1.4	2.7	X	4.6	5.1	6.1	7.1, 7.2	X	X	X			
M002	1.4	2.7	X	4.6	5.1	6.1	7.1, 7.2	X	X	X			
M003	1.4	2.7	X	4.6	5.1	6.1	7.2	X	X	X			
M004	1.4	2.7	X	4.6	5.1	6.1	7.1, 7.2	X	X	X			
M005	1.4	2.7	X	4.6	5.1	6.1	7.2	X	X	X			
M006	1.4	2.7	X	4.6	5.1	6.1	7.1, 7.2, 7.5, 7.6	X	X	X			
M007	1.1	2.1	X	4.2	5.1	6.3	7.1, 7.2, 7.4	△	△	○	△	○	X
M008	1.1	2.1	X	4.2	5.1	6.1	7.1, 7.2, 7.4	○	△	X			
M009	1.4	N/A	N/A	N/A	N/A	N/A	7.7	X	X	X			
M010	1.4	2.7	X	4.6	5.1	6.1	7.1, 7.2	X	X	X			
M011	1.1	2.1	X	4.2	5.1	6.1	7.1, 7.2, 7.4	○	○	○	△	△	X
M012	1.1	2.1	X	4.2	5.2	6.1	7.1, 7.2, 7.4	△	△	△1	△	X	X
M013	1.1	2.1	X	4.2	5.1	6.3	7.1, 7.2, 7.4, 7.5, 7.6	○	○	○	△	△	X
M014	1.1	2.1	X	4.2	5.1	6.1	7.1, 7.2, 7.4, 7.5	○	○	X			
M015	1.1	2.1	X	4.2	5.1	6.1	7.1, 7.2, 7.4, 7.5	○	○	X			
M016	1.1	2.1	X	4.2	5.1	6.1	7.1, 7.2, 7.3, 7.4	△	X	X			
M017	1.4	N/A	N/A	N/A	N/A	N/A	7.7	X	X	X			
1980s													
M018	1.1	2.1	X	4.2	5.6	6.1	7.1, 7.2, 7.4, 7.5, 7.6	△	△	X			
M019	1.1	2.1	X	4.2	5.1	6.1	7.1, 7.2, 7.4, 7.5, 7.6	△	△	○	△	△	X
M020	1.1	2.2	△	4.4	5.1	6.1	7.1, 7.2, 7.3, 7.5	○	△	△2	△	X	X
M021	1.4	2.7	X	4.6	5.6	6.6	7.2, 7.5, 7.6	X	X	X			
M022	1.2	2.7	X	4.6	5.3	6.2	7.4, 7.5, 7.6	△	○	○	△	△	△
M023	1.2	2.1	X	4.6	5.6	6.6	7.5	△	△	○	△	○	X
M024	1.1	2.3	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.5	△	△	X			
M025	1.4	2.7	X	4.6	5.1	6.1	7.1, 7.2, 7.5, 7.6	X	X	X			
M026	1.1	2.1	X	4.2	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	○	○	△	△	X
M027	1.1	2.5	X	4.4	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	○	○	△	△	X
M028	1.4	N/A	N/A	N/A	N/A	N/A	7.7	X	X	X			
M029	1.4	N/A	N/A	N/A	N/A	N/A	7.7	X	X	X			
M030	1.2	2.3	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	△	△2	○	X	X
M031	1.1	2.4	X	4.1	5.3	6.1	7.1, 7.2, 7.4, 7.5	X	X	X			
M032	1.4	2.7	X	4.6	5.6	6.6	7.4	X	X	○	△	△	X
M033	1.1	2.1	X	4.2	5.1	6.3	7.1, 7.2, 7.3, 7.4, 7.5	○	○	○	△	△	X
M034	1.1	2.4	X	4.6	5.3	6.3	7.1, 7.2, 7.4, 7.5	○	△	○	○	△	△
M035	1.2	2.1	X	4.6	5.1	6.2	7.5	△	○	○	△	○	X
M036	1.2	2.4	X	4.4	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	△	△2	○	X	X
M037	1.2	2.4	X	4.4	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	△	△2	○	X	X
M038	1.2	2.4	X	4.4	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	X	X			
M039	1.1	2.1	X	4.4	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	○	○	△	△	X
M040	1.2	2.3	X	4.2	5.2	6.1	7.1, 7.2, 7.4, 7.5, 7.6	X	X	X			
M041	1.1	2.7	X	4.2	5.1	6.1	7.1, 7.2, 7.3	○	X	△2	○	X	X
M042	1.1	2.7	X	4.6	5.2	6.1	7.1, 7.3, 7.4, 7.5, 7.6	△	△	○	○	△	X
M043	1.2	2.7	X	4.6	5.3	6.1	7.3, 7.5, 7.6	X	△	△2	○	X	X
M044	1.2	2.7	X	4.3	5.1	6.1	7.1, 7.2, 7.5	○	△	○	○	X	X
M045	1.2	2.7	X	4.2	5.1	6.1	7.1, 7.2, 7.5	○	△	○	○	X	X
M046	1.2	2.1	X	4.6	5.1	6.2	7.5	△	△	○	△	○	X
M047	1.1	2.1	X	4.2	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	△	X			
M048	1.1	2.1	X	4.2	5.1	6.1	7.1, 7.2, 7.4, 7.5	○	○	△2	△	△	X
1990s													
M049	1.4	2.3	X	4.2	5.3	6.6	7.7	X	X	X			
M050	1.2	2.4	X	4.6	5.3	6.1	7.1, 7.2, 7.3	X	X	X			
M051	1.1	2.4	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	○	X			
M052	1.1	2.3	X	4.4	5.3	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	○	○	△	X	X
M053	1.2	2.3	X	4.2	5.6	6.2	7.1, 7.2, 7.4, 7.5	△	△	○	○	△	X
M054	1.2	2.2	X	4.2	5.1	6.1	7.1, 7.2, 7.3	○	△	△2	○	X	X
M055	1.1	2.1	○	4.4	5.1	6.1	7.1, 7.2, 7.4, 7.5, 7.6	X	X	X			
M056	1.4	N/A	N/A	N/A	N/A	N/A	7.7	X	X	X			
M057	1.2	2.1	X	4.2	5.4	6.1	7.2, 7.4, 7.5	△	△	X			
M058	1.2	2.1	X	4.2	5.1	6.1	7.2	○	△	△2	△	△	X
M059	1.2	2.1	X	4.2	5.3	6.2	7.2, 7.5	○	○	○	△	○	X
M060	1.2	2.1	X	4.5	5.3	6.1	7.2, 7.5	○	△	○	△	○	X
M061	1.2	2.5	X	4.6	5.1	6.1	7.1, 7.2, 7.3	○	△	○	○	△	X
M062	1.2	2.1	X	4.6	5.1	6.3	7.2, 7.4, 7.5	○	○	○	△	○	X
M063	1.1	2.4	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	X	X	X			
M064	1.4	2.7	X	4.6	5.4	6.4	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	△	△	○	○	△	X
M065	1.1	2.1	X	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.5, 7.6	○	○	△2	△	X	X
M066	1.4	N/A	N/A	N/A	N/A	N/A	7.7	X	X	X			
M067	1.2	2.4	X	4.6	5.3	6.1	7.1, 7.2, 7.4, 7.5	X	△	△2	○	△	△

M068	1.1	2.4	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	○	○ + △2	○	△	△
M069	1.4	N/A	N/A	N/A	N/A	N/A	7.7	X	X	X			
M070	1.2	2.1	X	4.6	5.1	6.2	7.4, 7.5	△	○	○	△	○	X
M071	1.2	2.1	X	4.6	5.1	6.2	7.4, 7.5	△	○	○	△	○	X
M072	1.4	2.4	X	4.6	5.6	6.6	7.7	X	X	X			
M073	1.2	2.1	X	4.6	5.1	6.2	7,4, 7.5, 7.6	○	○	○	○	○	△
M074	1.2	2.4	○	4.6	5.3	6.1	7.1, 7.3, 7.5	X	X	X			
M075	1.2	2.4	X	4.4	5.1	6.1	7.1, 7.4, 7.5, 7.6	○	△	△2	○	X	X
M076	1.1	2.7	X	4.6	5.6	6.1	7.7	X	X	X			
M077	1.2	2.4	X	4.1	5.3	6.1	7.1, 7.3, 7.4	○	X	X			
M078	1.1	2.1	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	△	○ + △2	△	△	X
M079	1.1	2.4	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	○	△2	○	△	X
M080	1.1	2.4	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	○	△2	○	X	X
M081	1.1	2.4	△	4.4	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	○	○ + △2	○	△	△
M082	1.2	2.7	X	4.2	5.3	6.1	7.5, 7.6	X	X	X			
M083	1.4	2.7	X	4.6	5.6	6.6	7.7	X	X	X			
M084	1.4	2.7	△	4.6	5.1	6.3	7.7	X	△	○	△	△	X
M085	1.2	2.4	X	4.6	5.3	6.3	7.4, 7.5	△	△	○	○	○	△
M086	1.2	2.5	△	4.5	5.3	6.1	7.1, 7.2, 7.3, 7.5	△	△	○ + △2	△	△	X
M087	1.2	2.4	○	4.6	5.3	6.2	7.4, 7.5	○	○	○	○	○	△
M088	1.1	2.4	○	4.6	5.3	6.4	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	○	○	○	○	△
M089	1.4	N/A	N/A	N/A	N/A	N/A	7.7	X	X	X			
M090	1.4	2.7	X	4.6	5.2	6.6	7.7	X	X	X			
M091	1.1	2.7	X	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	△	X	△2	○	X	X
M092	1.2	2.7	X	4.1	5.1	6.3	7.1, 7.2	△	△	○	△	△	X
M093	1.2	2.3	X	4.2	5.1	6.1	7.1	△	X	△2	○	X	X
M094	1.1	2.3	X	4.6	5.1	6.1	7.1, 7.3, 7.4, 7.5	○	△	△2	○	X	X
M095	1.2	2.4	△	4.2	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	X	△2	○	X	X
M096	1.2	2.4	X	4.6	5.1	6.2	7.1, 7.4	○	△	○	○	○	△
M097	1.1	2.4	X	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	○	○ + △2	○	△	△
M098	1.1	2.1	X	4.4	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	○	○ + △2	△	△	X
M099	1.1	2.4	△	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.5	△	△	X			
M100	1.1	2.4	△	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.5	△	△	X			
M101	1.1	2.3	△	4.4	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	△	X	X			
M102	1.2	2.1	○	4.4	5.3	6.1	7.2, 7.5, 7.6	X	X	X			
M103	1.2	2.4	X	4.1	5.1	6.1	7.1, 7.2, 7.4, 7.5, 7.6	△	△	X			
M104	1.1	2.7	X	4.6	5.1	6.1	7.3, 7.4, 7.5, 7.6	△	X	X			
M105	1.1	2.1	X	4.5	5.1	6.1	7.1, 7.2, 7.3, 7,4, 7.5, 7.6	△	X	X			
M106	1.2	2.7	X	4.6	5.3	6.2	7.2	○	△	△1	△	○	X
M107	1.4	2.7	△	4.3	5.3	6.1	7.1, 7.2, 7.5	○	△	X			
M108	1.3	N/A	N/A	N/A	N/A	N/A	7.1	X	X	△2	○	X	X
M109	1.2	2.5	X	4.5	5.1	6.1	7.5, 7.6	○	△	△2	○	X	X
2000s													
M110	1.4	2.7	X	4.6	5.1	6.1	7.1, 7.2, 7.5, 7.6	X	X	X			
M111	1.4	2.7	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	X	X	X			
M112	1.2	2.1	○	4.2	5.3	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	X	X	X			
M113	1.2	2.5	X	4.6	5.1	6.4	7.1, 7.2, 7.3, 7.4, 7.5	○	△	○	○	△	X
M114	1.4	2.7	△	4.1	5.3	6.6	7.1, 7.2, 7.5	○	X	X			
M115	1.1	2.5	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	△	X			
M116	1.1	2.5	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	△	△2	○	X	X
M117	1.2	2.1	X	4.6	5.3	6.3	7.5	△	○	○	△	○	X
M118	1.2	2.4	X	4.5	5.1	6.3	7.1, 7.2, 7.4, 7.5	○	△	△2	○	△	X
M119	1.2	2.1	X	4.6	5.3	6.1	7.5	△	○	○	△	○	X
M120	1.4	2.7	X	4.6	5.6	6.1	7.1, 7.2, 7.5	X	X	X			
M121	1.2	2.7	○	4.6	5.1	6.1	7.5, 7.6	X	X	○ + △2	○	X	X
M122	1.2	2.7	○	4.6	5.3	6.1	7.5, 7.6	X	X	○	△	X	X
M123	1.2	2.3	X	4.1	5.1	6.1	7.1	△	X	X			
M124	1.2	2.5	○	4.5	5.4	6.1	7.1, 7.2, 7.3, 7.5	○	△	△2	○	X	X
M125	1.2	2.4	X	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	△	△	△2	○	X	X
M126	1.2	2.5	X	4.5	5.6	6.6	7.1, 7.3, 7.4, 7.5	△	X	X			
M127	1.2	2.7	X	4.6	5.1	6.2	7.4	○	△	○ + △2	○	△	X
M128	1.1	2.7	X	4.6	5.4	6.1	7.7	X	X	X			
M129	1.4	N/A	N/A	N/A	N/A	N/A	7.7	X	X	X			
M130	1.2	2.4	X	4.5	5.3	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	△	X	△2	△	X	X
M131	1.4	2.7	X	4.6	5.2	6.2	7.3, 7.4	X	△	△1	△	○	X
M132	1.2	2.5	△	4.6	5.1	6.1	7.1, 7.2, 7.5	△	△	△2	○	X	X
M133	1.2	2.7	X	4.6	5.3	6.4	7.2, 7.5	○	X	○	○	○	△
M134	1.2	2.5	○	4.5	5.2	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	△	△2	○	X	X
M135	1.2	2.7	X	4.5	5.1	6.1	7.1, 7.3, 7.4	X	△	○	△	△	X
M136	1.2	2.5	○	4.3	5.3	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	X	X			
M137	1.2	2.5	△	4.6	5.2	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	△	△2	○	X	X
M138	1.2	2.7	△	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	X	X			
M139	1.2	2.4	△	4.5	5.1	6.1	7.1, 7.2, 7.4	△	△	X			
M140	1.2	2.7	△	4.5	5.3	6.1	7.1, 7.2, 7.5, 7.6	○	△	X			

M141	1.1	2.4	○	4.6	5.3	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	X	X			
M142	1.4	2.7	X	4.6	5.2	6.6	7.7	X	X	X			
M143	1.2	2.4	X	4.5	5.1	6.1	7.1, 7.2	△	X	△2	○	X	X
M144	1.4	2.7	X	4.6	5.4	6.1	7.7	X	△	△2	△	○	X
M145	1.2	2.4	○	4.5	5.2	6.4	7.1, 7.3	△	X	△2	○	△	△
M146	1.2	2.5	○	4.1	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	△	X	△2	○	X	X
M147	1.2	2.5	X	4.5	5.1	6.1	7.1, 7.2, 7.3	△	X	X			
M148	1.2	2.2	X	4.6	5.1	6.1	7.2, 7.3, 7.5	X	X	X			
M149	1.1	2.5	△	4.5	5.3	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	△	△2	○	X	X
M150	1.4	2.7	X	4.6	5.6	6.6	7.7	X	△	○	△	○	X
M151	1.4	2.7	X	4.6	5.6	6.1	7.7	X	X	X			
M152	1.2	2.1	X	4.6	5.1	6.2	7.4, 7.5	△	○	○	○	○	△
M153	1.2	2.5	X	4.6	5.3	6.1	7.1, 7.3, 7.4, 7.5	○	X	X			
M154	1.2	2.4	X	4.6	5.1	6.1	7.1, 7.3, 7.4	△	△	○	○	○	△
M155	1.2	2.1	X	4.2	5.3	6.3	7.1, 7.2	○	△	○	△	○	X
M156	1.2	2.7	X	4.3	5.1	6.6	7.1, 7.2	△	△	X			
M157	1.4	2.7	△	4.5	5.3	6.1	7.7	X	X	X			
M158	1.2	2.7	X	4.6	5.1	6.1	7.2, 7.3, 7.5	X	X	X			
M159	1.4	2.7	X	4.6	5.6	6.6	7.7	X	X	X			
M160	1.1	2.4	△	4.5	5.1	6.1	7.1, 7.2, 7.3, 7,4, 7.5	○	○	△2	△	X	X
M161	1.1	2.1	X	4.5	5.1	6.1	7.1, 7.3, 7.4, 7.5	△	X	X			
M162	1.1	2.2	X	4.6	5.2	6.1	7.2, 7.5	△	X	X			
M163	1.4	2.7	X	4.6	5.6	6.1	7.7	X	△	△2	○	X	X
M164	1.4	2.7	X	4.6	5.6	6.6	7.7	X	△	○	○	△	X
M165	1.2	2.7	X	4.3	5.1	6.1	7.2, 7.5	△	△	X			
M166	1.2	2.7	X	4.1	5.3	6.1	7.5, 7.6	△	X	X			
M167	1.2	2.4	X	4.5	5.3	6.1	7.1, 7.2, 7.3, 7.4, 7.5	△	X	X			
M168	1.2	2.7	X	4.6	5.1	6.1	7.1, 7.2, 7.5	○	△	△2	○	X	X
M169	1.4	2.7	X	4.5	5.6	6.6	7.7	X	X	X			
M170	1.2	2.7	X	4.5	5.1	6.1	7.1, 7.3	△	△	△1	○	X	X
M171	1.2	2.7	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	X	X			
M172	1.4	2.7	○	4.6	5.3	6.1	7.7	X	X	X			
M173	1.2	2.1	X	4.6	5.1	6.1	7.1, 7.2, 7.5	△	X	△2	○	X	X
M174	1.1	2.5	△	4.5	5.4	6.1	7.1, 7.2, 7.3, 7,4, 7.5, 7.6	○	○	○ + △2	○	X	X
M175	1.1	2.5	△	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	○	○ + △2	○	△	△
M176	1.1	2.5	○	4.5	5.3	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	○	△2	○	X	X
M177	1.1	2.7	△	4.6	5.3	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	△	X	X			
M178	1.2	2.5	○	4.6	5.3	6.1	7.1, 7.3, 7.4, 7.5	○	○	○	○	○	△
M179	1.2	2.4	X	4.6	5.1	6.3	7.1, 7.4, 7.5	○	△	○	○	○	△
M180	1.2	2.4	△	4.5	5.3	6.1	7.1, 7.2	X	X	△2	○	X	X
M181	1.2	2.4	X	4.6	5.6	6.6	7.1, 7.2, 7.3, 7.4	○	X	X			
M182	1.1	2.5	△	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	△	△	△2	○	X	X
M183	1.4	2.7	X	4.6	5.6	6.6	7.7	X	△	○	△	△	X
M184	1.2	2.4	X	4.5	5.6	6.6	7.1, 7.2, 7.3, 7.4, 7.5	○	X	X			
M185	1.2	2.4	X	4.6	5.6	6.6	7.1, 7.2, 7.4, 7.5	X	X	X			
M186	1.2	2.7	X	4.6	5.6	6.6	7.7	X	X	X			
M187	1.2	2.7	X	4.6	5.6	6.1	7.1, 7.2, 7.3, 7,4, 7.5	X	X	△1	○	X	X
M188	1.2	2.5	X	4.5	5.4	6.1	7.1, 7.2, 7.3, 7,4, 7.5, 7.6	○	○	△2	○	X	X
M189	1.2	2.5	△	4.6	5.3	6.1	7.5, 7.6	X	X	X			
M190	1.1	2.5	○	4.6	5.3	6.3	7.1, 7.2, 7.3, 7.4, 7.5	△	△	○ + △2	○	△	△
M191	1.1	2.4	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	X	○ + △2	○	X	X
M192	1.4	2.7	X	4.6	5.2	6.1	7.7	X	X	△2	△	△	X
M193	1.4	2.7	X	4.6	5.4	6.6	7.7	X	X	X			
M194	1.4	2.7	X	4.6	5.2	6.6	7.7	X	X	X			
M195	1.2	2.1	X	4.6	5.1	6.3	7.2	○	△	○	△	○	X
M196	1.2	2.1	X	4.6	5.1	6.1	7.2	○	△	X			
M197	1.2	2.1	X	4.6	5.2	6.6	7.2	○	△	X			
M 198	1.2	2.4	X	4.5	5.3	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	△	X	X			
2010s													
M199	1.1	2.7	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	△	△2	○	X	X
M200	1.1	2.2	△	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.5	○	○	△2	△	X	X
M201	1.1	2.2	○	4.5	5.4	6.1	7.1, 7.2, 7.3, 7.5	○	○	○ + △2	△	X	X
M202	1.2	2.4	△	4.5	5.3	6.1	7.1, 7.3	○	△	○	○	△	△
M203	1.2	2.4	X	4.6	5.1	6.1	7.1, 7.3, 7.4, 7.5	○	△	△2	○	X	X
M204	1.4	2.7	X	4.6	5.6	6.6	7.7	X	○	○ + △2	○	X	X
M205	1.1	2.5	X	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	○	○ + △2	○	X	X
M206	1.4	2.7	X	4.5	5.1	6.1	7.7	X	○	○ + △2	○	X	X
M207	1.1	2.5	X	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	○	○ + △2	○	X	X
M208	1.1	2.5	○	4.6	5.3	6.1	7.1, 7.2, 7.3, 7,4, 7.5	△	X	X			
M209	1.1	2.5	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7,4, 7.5	△	X	X			
M210	1.1	2.5	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	X	X			
M211	1.2	2.5	X	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	△	△	△2	○	X	X

M212	1.2	2.7	X	4.6	5.1	6.1	7.1, 7.3	X	○	○	△	△	X
M213	1.2	2.4	X	4.6	5.6	6.6	7.1, 7,2, 7.3, 7.4, 7.5	X	X	X			
M214	1.2	2.5	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	△	△	△2	△	X	X
M215	1.1	2.5	○	4.5	5.3	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	△	△2	○	X	X
M216	1.2	2.5	X	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	△	△2	○	X	X
M217	1.2	2.7	X	4.6	5.3	6.1	7.4, 7.5	△	X	○	○	○	△
M218	1.2	2.1	X	4.6	5.1	6.6	7.2, 7.4	○	○	○	△	○	X
M219	1.2	2.1	X	4.6	5.3	6.6	7.2, 7.4	○	○	X			
M220	1.2	2.1	X	4.6	5.6	6.6	7.2, 7.4	○	○	X			
M221	1.2	2.1	X	4.6	5.1	6.1	7.1, 7.2, 7.4	○	○	○	△	○	X
M222	1.2	2.1	X	4.6	5.1	6.1	7.1, 7.2, 7.5	○	○	△2	△	△	X
M223	1.2	2.1	X	4.6	5.1	6.1	7.1, 7.2, 7.4, 7.5	○	○	△2	△	△	X
M224	1.2	2.5	△	4.1	5.1	6.1	7.1, 7.2, 7.3, 7.5, 7.6	△	X	X			
M225	1.2	2.4	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4	X	X	X			
M226	1.2	2.4	X	4.6	5.6	6.6	7.1, 7.2, 7.3, 7.4, 7.5	X	X	X			
M227	1.2	2.5	X	4.2	5.6	6.1	7.2, 7.3, 7.5	X	X	X			
M228	1.2	2.5	X	4.3	5.1	6.1	7.2, 7.5	△	X	X			
M229	1.2	2.5	○	4.6	5.1	6.1	7.1, 7.2, 7.5	○	○	△2	○	△	△
M230	1.2	2.5	X	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	○	△2	○	X	X
M231	1.2	2.4	X	4.3	5.3	6.1	7.2, 7.3, 7.5	X	X	X			
M232	1.3	2.7	X	4.6	5.6	6.6	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	△	△	△2	○	X	X
M233	1.1	2.5	X	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	△	△2	○	X	X
M234	1.2	2.5	X	4.6	5.1	6.1	7.1, 7.2	X	X	X			
M235	1.2	2.5	○	4.1	5.1	6.1	7.1, 7.2	△	X	X			
M236	1.2	2.7	X	4.1	5.6	6.1	7.1, 7.2, 7.4, 7.5	△	X	X			
M237	1.2	2.5	X	4.5	5.6	6.6	7.1, 7.2, 7.4, 7.5	△	X	△2	○	X	X
M238	1.1	2.5	△	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	△	△	△2	○	X	X
M239	1.1	2.5	X	4.1	5.1	6.1	7.1, 7.2, 7.4, 7.5	△	X	△2	○	X	X
M240	1.2	2.5	X	4.3	5.6	6.6	7.1, 7.2, 7.5	△	△	△2	○	X	△
M241	1.2	2.5	X	4.5	5.1	6.1	7.1, 7.3, 7.4	△	○	○	○	○	△
M242	1.2	2.7	X	4.6	5.6	6.6	7.7	X	X	X			
M243	1.2	2.7	X	4.4	5.6	6.6	7.2, 7.3, 7.5	X	X	X			
M244	1.2	2.5	X	4.5	5.6	6.6	7.1, 7.2, 7.5	X	X	X			
M245	1.2	2.5	X	4.4	5.6	6.6	7.1, 7.2, 7.3, 7.5	X	X	X			
M246	1.1	2.5	X	4.5	5.3	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	△	X	X			
M247	1.2	N/A	N/A	N/A	N/A	N/A	7.7	X	X	X			
M248	1.2	N/A	N/A	N/A	N/A	N/A	7.7	X	X	X			
M249	1.1	2.4	△	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5, 7.6	○	○	○ + △2	△	△	X
M250	1.2	2.5	X	4.4	5.6	6.6	7.1, 7.3	X	X	X			
M251	1.3	N/A	N/A	N/A	N/A	N/A	7.1, 7.2, 7.3, 7.4, 7.5	○	X	△2	○	X	X
M252	1.2	2.5	△	4.5	5.1	6.1	7.1, 7.2, 7.3, 7.4, 7.5	○	△	△2	○	X	X
M253	1.1	2.4	△	4.6	5.1	6.1	7.1, 7.2, 7.3, 7.5, 7.6	○	△	△2	○	X	X
M254	1.2	2.5	△	4.3	5.2	6.6	7.1, 7.2, 7.5	X	X	X			
M255	1.3	N/A	N/A	N/A	N/A	N/A	7.2	X	X	X			
M256	1.2	2.2	△	4.2	5.1	6.1	7.1, 7.2, 7.3	○	X	X			
M257	1.2	2.7	X	4.5	5.6	6.6	7.7	X	X	X			
M258	1.2	2.5	○	4.5	5.4	6.1	7.1, 7.2, 7.5, 7.6	△	X	△2	○	X	X
M259	1.2	2.7	X	4.6	5.6	6.6	7.2, 7.5	X	○	○ + △2	○	△	△
M260	1.2	2.1	X	4.1	5.1	6.1	7.2, 7.5	△	X	△2	△	X	X
M261	1.2	2.5	△	4.5	5.4	6.6	7.1, 7.2, 7.5, 7.6	○	X	△2	○	X	X
M262	1.2	2.4	△	4.6	5.6	6.1	7.2, 7.3, 7.5, 7.6	X	X	△2	○	X	X
M263	1.2	2.7	X	4.4	5.1	6.1	7.7	X	X	X			
M264	1.3	N/A	N/A	N/A	N/A	N/A	7.7	X	X	X			
M265	1.3	N/A	N/A	N/A	N/A	N/A	7,2. 7.5, 7.6	X	X	△2	○	X	X
M266	1.3	N/A	N/A	N/A	N/A	N/A	7.7	X	X	X			

3) A List of 266 Fuzzy Front End Studies

– Park, D, and Childs, PRN, Dyson School of Design Engineering, Imperial College London, UK

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In the table above, some papers which have similar features and affect other models; these are not arranged in chronological order. Instead, they are grouped. However, when the historical trend analysis was conducted with SPSS, those models were arranged in chronological order.