POLITECNICO DI MILANO Scuola di Ingegneria Industriale e dell'Informazione Corso di Laurea in Ingegneria Meccanica



What is Modularization? A Literature-Grounded Ontology

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Appendix B – Attached documents

The attached file contains two documents:

- The literature collection, with some general information about every paper;
- The table containing the papers' keywords, divided into the different categories used to define the concept, its boundaries and its effects.

	Year on		Journal	Author #1		Author #3	Author #4	Author #5 Author #6 Author #7 Author #6	Keyword 1	Keyword 2 Keyword 3 Keyword 4 Keyword 5	Keyword 6 Keyword 7 Keyword 8 Keyword 9	Keyword 10 Keyword 11 Keyword 12 Keyword 13 Keyword 14	Keyword 15 Keyword 16 Keyword 17 Keyword 18	Кеуwo
Standardization, compatibility and innovation 19	1985 2100	0 http://www.jstor.org/stable/10.2307/2555589	RAND Journal of Economics	Farrell J	Saloner G									
Standardization and variety 194	1986 193	http://www.sciencedirect.com/science/article/pii/0165176586900844	Economics Letters (not available because polimi bought the review from 1995)	Farrell J										
Standardization, diversity, and learning: Strategies for the sequelution of technology and	2005 60	http://www.sciencedirect.com/science/article/pii/S0140988305000423	Energy Economics		Proult D	Thais F Wa	algenwitz G		Modularity S	Sequential invest Nuclear equipme Uncertainty Option value				
industrial capacity	1996 58	http://www.sciencedirect.com/science/article/pii/0167718795004750	International Journal of Industrial Organization		Rothwell S									
industries	1996 19		European Journal of Political Economy	David PA						Standardization Nuclear power plants				
	2010 15		Progress in Nuclear Energy		Garrone P	Locatelli G Ma	ancini M I	Mycoff C Trucco P Ricotti ME	Economies of scal S	Small-to-medium Modularity IRIS				
	1997 13		Nuclear engineering and design	Lapp CW	Golay MW									
· · ·	1995 1675	urrb://uprock/taa//oa/managing-in-au-age-oi-modularità/at/t_oi	Research Policy	Ulrich KT										
	1997 1594	ິກເຖິງໃນເບັ້ມເປັນເປັນເປັນເປັນເປັນເປັນເປັນເປັນເປັນເປັນ	cn	Baldwin CY							Product developn Technological change			
Modularity, flexibility, and knowledge management in product and organization design 19		3 Text=organization&searchText=knowledge&searchText=Modularity%2C&search nttpf//www.jstaf.org/stabTe//fno/2486/73r&Search=yes&searchrekit=productes	xsē	Sanchez R	Mahoney JT					nowledge manag modularity strategic flexibility				
Toward a General Modular Systems Theory and its Application to Interfirm Product	1995 834	Daraduct0/Decomposition0/DefromUcmoDeco0/Deruo0/Deco0/		Sanchez R					strategic flexibilit [,] ro	esource flexibilit coordination fleximanagerial innov technological inno	(dominant logic			
Modularity 200	2000 745		Academy of Management Review	Schilling MA		_								
stereo component industries	1992 705	http://www.sciencedirect.com/science/article/pii/0048733392900308	Research Policy		Robertson PL									
Modularity in technology and organization 200	2002 590	http://www.sciencedirect.com/science/article/pii/S0167268102000562	Journal of Economic Behavior and Organization	Langlois RN					Modularity P	Property rights Transaction costs Capabilities Standards				
Approaches to mass customization: configurations and empirical validation 20	2000 486	http://www.sciencedirect.com/science/article/pii/S0272696300000437	Journal of Operations Management	Duray R	Ward PT	Milligan GW Ber	erry WL		Mass customizati P	Process design Technology Marketing/operations interface				
The Use of Modular Organizational Forms: An Industry-Level Analysis 200	2001 486	http://www.jstor.org/stable/10.2307/3069394	Academy of Management Journal	Schilling MA	Steensma HK									
Reconfigurable manufacturing systems: Key to future manufacturing 20	2000 452	http://www.springerlink.com/content/q5634h3416xt2306/	Journal of Intelligent Manufacturing	Mehrabi MG	Ulsoy AG	Koren Y			Reconfigurable m n	nanufacturing sy system characteri system design machine design	ramp-up time reduction			
ARCHITECTURAL INNOVATION AND MODULAR CORPORATE FORMS 20	2001 442		hT Academy of Management Journal	Galunic DC	Eisenhardt KN	Λ			INTERNATIONAL Ł S	OCIOECONOMIC BUSINESS enterpr ORGANIZATIONAL TECHNOLOGICAL	STRATEGIC plann KNOWLEDGE tran ORGANIZATIONAL DECISION making	CREATIVE ability i PROFIT maximizal DIVERSIFICATION in industry Economic aspects		
Modularity and innovation in complex systems20	2004 371	http://mansci.journal.informs.org/content/50/2/159.short	Management Science	Ethiraj SK	Levinthal D				modularity c	complex systems nearly decomposable systems				
Technological and organizational designs for realizing economies of substitution 19	1995 364		ext Strategic Management Journal	Garud R	Kumaraswam	уА			technological innen	networks reuse modularity upgradability	standards			
Unpacking the black box of modularity: technologies, products and organizations 200	2001 361			Brusoni S	Prencipe A									
Managing product families: The case of the Sony Walkman 19	1995 335	http://www.sciencedirect.com/science/article/pii/004873339400797B	Research Policy	Sanderson S	Uzumeri M									
	2000 289	http://www.sciencedirect.com/science/article/pii/S0142694X99000034	Design Studies	Stone RB	Wood KL	Crawford RH			design methodolcp	product developn conceptual desigr functional modeling				
The Misalignment of Product Architecture and Organizational Structure in Complex Product Development	2004 289	http://mansci.journal.informs.org/content/50/12/1674.short	Management Science	Sosa ME	Eppinger SD	Rowles CM			product architect p	product developn technical commundesign structure r statistical networl	rk analysis			
	2001 268	http://www.sciencedirect.com/science/article/pii/S0142694X01000047	Design Studies	Dahmus JB	Gonzalez-Zug	asti Otto KN			design methodolcp	product developn conceptual desigr product platforms				
Design for variety: developing standardized and modularized product platform 200 architectures	2002 265	http://www.springerlink.com/content/gpu094u4la38xp3u/	Research in Engineering Design - Theory, Applications, and Concurrent Engineering	Martin MV	lshii K				Product platform A	Architecture Design Modularity Coupling				
	1998 249	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=650323&tag=1	IEEE Transactions on Systems, Man, and Cybernetics Part A:Systems and Humans.	Huang CC	Kusiak A				Costs D	Design engineerin Electrical product Manufacturing in Manufacturing pr	r Matrix decompos Partitioning algor Process design Product design	Production		
industry	2002 219		Strategic Management Journal	Worren N	Moore K	Cardona P			strategic flexibilit [,] n	nodularity global strategies				
Modularity, product variety, production volume, and component sourcing: Theorizing 200 beyond generic prescriptions	2002 213	http://www.scopus.com/record/display.url?eid=2-s2.0- 0036722566&origin=inward&txGid=wnqO3VcL3yLIDABo7HYUVJ0%3a28	Journal of Operations Management	Salvador F	Forza C	Rungtusanatham M			Case study resear N	Modularity Operational perfc Product variety Sourcing	Supply chain management			
	1999 207		Journal of Marketing	Sanchez R										
Product family design and platform-based product development: a state-of-the-art review 200	2007 205	http://www.springerlink.com/content/q86324686r0512mp/	Journal of Intelligent Manufacturing	Jiao J	Simpson TW	Siddique Z			Product family P	Product platform Product architect Customization Variety modularit	t Commonality Configuration			
Product modularization for life cycle engineering 19	1999 203	http://www.sciencedirect.com/science/article/pii/S0736584599000496	Robotics and Computer-Integrated Manufacturing	Gu P	Sosale S									
Evaluation of supply chain structures through modularization and postponement 20	2000 197	, http://www.scopus.com/record/display.url?eid=2-s2.0- 0033729541&origin=inward&txGid=wnqO3VcL3yLIDABo7HYUVJ0%3a30		Ernst R	Kamrad B				Assembly C	Cost effectivenes: Decision making Industrial econor Outsourcing	Product design Production contro Modularization Postponement	Supply chain strue Operations research		
	2003 183		Journal of Engineering Design	Gershenson JK		Zhang Y								
Inter-temporal economies of scope, organizational modularity, and the dynamics of 20	2004 179	http://onlinelibrary.wiley.com/doi/10.1002/smj.427/abstract	Strategic Management Journal	Helfat CE					economies of scold	liversification organization form modularity market entry				
diversification	1996 162	http://srl.gatech.edu/publications/1996/bb.dr.newcomb.confpro.96-DETC-DTM		Newcomb PJ						ife cycle Design for the life DFLC Product design				
	2006 161	1516.1996.pdf	Strategic Management Journal	Hoetker G						ouyer–supplier reknowledge-based transaction cost e management of ir	nnovation			
	1996 157		IEEE Transactions on Components Packaging and Manufacturin		Huang CC						Integrated circuit Manufacturing in Manufacturing pr Multichip module	Performance anal Space technology Thermal force		
	2002 148		Technology Part A CAD Computer Aided Design	Fujita K						Design optimizati Product family Modular archited Mathematical mo				
	2002 148		R and D Management	Mikkola JH										
	1999 126		Becoarch in Engineering Decign Theory Applications and	McAdams DA	Stopo PP	Wood K			Design by analog E	unctional analys Mass customizati Modular design				
Measuring modularity-based manufacturing practices and their impact on mass	2004 123		Concurrent Engineering Decision Sciences			MA Ragu-Nathan TS Rag	agu-Nathan B			Modularity-Based Process Choice/Di Product Planning Structural Equation				
customization capability: a customer-driven perspective	2004 123		International Journal of Automotive Technology and	Takeishi A										
production and supplier systems			Management			Zhang V				nodularisation product architect production syster supplier system				
The effect of product modularity on industry structure: The case of the world bicycle	2004 113		Journal of Engineering Design	Gershenson JK						design design theory design methods optimization				
industry	2001 109		Industry and innovation	Galvin P							INTERNATIONAL r Component parts efficiency			
	2005 109		Journal of Intelligent Manufacturing	Jose A	Tollenaere M					lexible manufact modular design product family de product platforms				
Modularity in organizational structure: the reconfiguration of internally developed and	2002 108		Interfaces	Benjaafar S	Heragu SS	Irani SA				Manufacturing: performance-productivity strategy				
acquired business units	2006 106	http://onlinelibrary.wiley.com/doi/10.1002/smj.547/abstract	Strategic Management Journal	Karim S		_					dynamic capabilit mergers and acquisitions			
	1996 105		CIRP Annals - Manufacturing Technology			Arnstrom A			Assembling N	Module Methodology				
	1997 100		CIRP Annals - Manufacturing Technology	Gu P	Hashemian M				design n	nodule methodology				
	1999 100		Journal of Integrated Design and Process Science			Allamneni S								
Modular Network Design: Using Information and Communication Technology to Allocate Production Tasks in a Virtual Organization	2007 99	http://onlinelibrary.wiley.com/doi/10.1111/j.1540-5915.1999.tb00919.x/abstrac				M Vervest PHM Wa	agenaar RW		Business Process In	nformation and (Networks Process Design				
The development of modular-based design in considering technology complexity 19	1999 99	http://www.sciencedirect.com/science/article/pii/S0377221798003506	European Journal of Operational Research	Tsai YT	Wang KS				Complexity N	Modular design Technology Concurrent engineering				
Impacts of supplier-buyer relationships on modularization in new product development		http://www.sciencedirect.com/science/article/pii/S096970129900026X	European Journal of Purchasing and Supply Management	Hsuan J					Modularization N	New product dev Supplier-buyer relationships				
Modular architectures, knowledge assets and organizational learning: new management processes for product creation 200	2000 97	http://inderscience.metapress.com/content/erkq61whkntuctna/ nttp://www.jstor.org/stable/20159262r&searcn=yes&searcn+ext=Dangers&sear	International Journal of Technology Management	Sanchez R					knowledge architek	nowledge managemodularity organisational leaprocess architectu	product architect product creation self-managing processes			
Modularity: implications for imitation, innovation, and sustained advantage 20	2006 96		Y% Academy of Management Review	Pil FK	Cohen SK									
Macro level product development using design for modularity 19	1999 86			Salhieh SM	Kamrani AK									
Supply chain implications of modularization 200	2003 82		ct International Journal of Operations & Production Management	t Doran D					Buyers C	Case studies Supplier relations Supply-chain management				
The impact of modular production on the dynamics of supply chains 19	1998 80	http://www.emeraldinsight.com/journals.htm?issn=0957- 4093&volume=9&issue=2&articleid=1527458&show=html	The International Journal of Logistics Management	Van Hoek RI	Weken HAM				Modular producti Ir	ntegration Automotive indus Electronics indust Volkswagen	Lear corporation Micro compact ca Supply-chain man Channel relationsh	nips		
Optimal return policy and modular design for build-to-order products 20	2005 80	http://www.sciencedirect.com/science/article/pii/S0272696304001226	Journal of Operations Management	Mukhopadhyay	y S Setoputro R				Reverse logistics N	Modular design Build-to-order Return policy				
Supply-chain integration: implications for mass customization, modularization and 200 costponement strategies	2004 78	http://www.tandfonline.com/doi/abs/10.1080/0953728042000238845	Production Planning and Control	Mikkola JH	Skjøtt-Larsen	Т			mass customization	oostponement modularization supply-chain management				
	2004 74	http://www.sciencedirect.com/science/article/pii/S0007850607600286	CIRP Annals - Manufacturing Technology	Gu P	Hashemian M	Nee AYC			Product Design A	Adaptable Design Life Cycle Design				
Competing—and learning—in modular markets 20	2001 74	http://www.sciencedirect.com/science/article/pii/S0024630101000991	Long Range Planning	Sanchez R	Collins RP									
ntegrated product and process design: A modularity perspective 200	2002 73	http://www.tandfonline.com/doi/abs/10.1080/09544820110108926	Journal of Engineering Design	Kusiak A					Product modulari C	Costs Life cycle Process engineeri Quality control	Reliability Product design			
oduct Modularization for Parts Reuse in Inverse Manufacturing 20	2001 64	http://www.sciencedirect.com/science/article/pii/S0007850607620782	CIRP Annals - Manufacturing Technology	Kimura F	Kato S	Hata T Ma	asuda T		Product design N	Module structure Product life cycle				
10deling tradeoffs in three-dimensional concurrent engineering: a goal programming 200 pproach	2004 64	http://www.sciencedirect.com/science/article/pii/S0272696304001123	Journal of Operations Management	Fine CH	Golany B	Naseraldin H			Goal-programmin S	Supply chain desi Concurrent engin Integrality Modularity	Tradeoffs modeling			
	1999 61	http://www.emeraldinsight.com/journals.htm?issn=0144- 3577&volume=19&issue=5&articleid=849183&show=html	International Journal of Operations & Production Management	t Muffatto M					Japan N	Motor industry Product developn Product planning				
	2005 57		International Journal of Computer Integrated Manufacturing	Molina A	Rodriguez CA	Ahuett H Cor	ortés JA I	Ramírez M Jiménez J Martinez S	Next-generation r R	Reconfigurable m Intelligent machir Machine design				
lext-generation manufacturing systems: key research issues in developing and integrating 200	2000 55	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=850644&tag=1	IEEE Transactions on Robotics and Automation	Irani SA					Assembly C	Character recogni Flow production Helium Holography	Production faciliti Pulp manufacturi Routing Systems engineer	Welding directed graphs industrial plants operations resear pattern clustering	facility layout layout module ne material-flow net material-flow pat	at multip
Next-generation manufacturing systems: key research issues in developing and integrating reconfigurable and intelligent machines			International Journal of Advanced Manufacturing Technology	Bi ZM	Zhang WJ					Modular design Modularity Modularity applic Taxonomy				
Next-generation manufacturing systems: key research issues in developing and integrating reconfigurable and intelligent machines20Custom design of facility layouts for multiproduct facilities using layout modules20	2001 50			Tseng HE		Li DJ				Green life-cycle e Grouping genetic Liaison intensity Green analysis				
Next-generation manufacturing systems: key research issues in developing and integrating reconfigurable and intelligent machines20Custom design of facility layouts for multiproduct facilities using layout modules20Modularity technology in manufacturing: Taxonomy and issues20	2001 50 2008 49	http://www.sciencedirect.com/science/article/pii/S0957417407001443	Expert Systems with Applications	-							Variety Modularity Layout design			
Next-generation manufacturing systems: key research issues in developing and integrating reconfigurable and intelligent machines201Custom design of facility layouts for multiproduct facilities using layout modules201Modularity technology in manufacturing: Taxonomy and issues201Modular design to support green life-cycle engineering201	2008 49				Reich Y				Common platforn P	Basic platform Product family Simulated anneal Standardization				
Next-generation manufacturing systems: key research issues in developing and integrating reconfigurable and intelligent machines201Custom design of facility layouts for multiproduct facilities using layout modules201Modularity technology in manufacturing: Taxonomy and issues201Modular design to support green life-cycle engineering201Progressive sharing of modules among product variants201	2008 49 2003 46	http://www.sciencedirect.com/science/article/pii/S0010448502001045	CAD Computer Aided Design	Dobrescu G						Basic platform Product family Simulated anneal Standardization				
Next-generation manufacturing systems: key research issues in developing and integrating reconfigurable and intelligent machines201Custom design of facility layouts for multiproduct facilities using layout modules201Modularity technology in manufacturing: Taxonomy and issues201Modular design to support green life-cycle engineering201Progressive sharing of modules among product variants201Modularization and the impact on supply relationships201	2008 49 2003 46 2007 44	http://www.sciencedirect.com/science/article/pii/S0010448502001045 http://www.emeraldinsight.com/journals.htm?articleid=1631175&show=abstrac	CAD Computer Aided Design act International Journal of Operations & Production Management	Dobrescu G t Howard M	Squire B	N				Product family Simulated anneal Standardization Product specificat Supplier relations				
Next-generation manufacturing systems: key research issues in developing and integrating reconfigurable and intelligent machines201Custom design of facility layouts for multiproduct facilities using layout modules201Modularity technology in manufacturing: Taxonomy and issues201Modular design to support green life-cycle engineering201Progressive sharing of modules among product variants201Modularization and the impact on supply relationships201Achieving product variety through optimal choice of module variations201	2008 49 2003 46 2007 44 2001 40	http://www.sciencedirect.com/science/article/pii/S0010448502001045 http://www.emeraldinsight.com/journals.htm?articleid=1631175&show=abstractionals http://www.springerlink.com/content/cc9kwqqj80xwlpml/	CAD Computer Aided Design act International Journal of Operations & Production Management IIE Transactions (Institute of Industrial Engineers)	Dobrescu G t Howard M Chakravarty AK	Squire B G Balakrishnan				Economic cooper: P	Product specificat Supplier relations				
Next-generation manufacturing systems: key research issues in developing and integrating reconfigurable and intelligent machines201Custom design of facility layouts for multiproduct facilities using layout modules201Modularity technology in manufacturing: Taxonomy and issues201Modular design to support green life-cycle engineering201Progressive sharing of modules among product variants201Modularization and the impact on supply relationships201Achieving product variety through optimal choice of module variations201	2008 49 2003 46 2007 44 2001 40 2008 38	http://www.sciencedirect.com/science/article/pii/S0010448502001045 http://www.emeraldinsight.com/journals.htm?articleid=1631175&show=abstraction http://www.springerlink.com/content/cc9kwqqj80xwlpml/ http://www.emeraldinsight.com/journals.htm?articleid=1728146&show=abstraction	CAD Computer Aided Design act International Journal of Operations & Production Management IIE Transactions (Institute of Industrial Engineers)	Dobrescu G Howard M Chakravarty AK Pekkarinen S	Squire B Balakrishnan Ulkuniemi P				Economic cooper: P Customer require C		Valiety Modulatity Layout design Image: State of the state of th		Image: Sector of the sector	

Papers referenced in the research document	Year on Schola	nttp://www.scopus.com/record/display.urrreid=z-sz.u-	Journal American Society of Mechanical Engineers, Design Engineering	Author #1		Author #3	Author			Author #7 Author	#8 Keyword 1 Keyword 2 Keyword 3 Keyword 4 Keyword 5 Keyword 6 Keyword 7 Keyword 9 Keyword 10 Keyword 11 Keyword 12 Keyword 13 Keyword 14 Keyword 15 Keyword 16 Key	Keyword 17	Keyword 18
Product modularization for reuse and recycling Modular assembly in the car industry—an analysis of organizational forms' influence on	1997 38	0031361092&origin=resultslist&sort=plf- f8 cro-c8 ct1=Droduct modularization (for transmission) and transmission (for transmission)	Division (Publication)		Hashemian M						Design engineerin Design factors Modularization Detaching Clusters Algorithms Modular design Recycling		
performance	2002 31	http://www.sciencedirect.com/science/article/pii/S0969701202000187	European Journal of Purchasing and Supply Management	Fredriksson P							Modular assembl Performance Ownership Localization Locali		
Product modularity, information structures and the diffusion of innovation The effects of product modularity on competitive performance: Do integration strategies	1999 31	http://inderscience.metapress.com/content/pxlqju9eyy6qb5dr/ http://www.emeraldinsight.com/journals.htm?articleid=1623661&show=abstra	International Journal of Technology Management	Galvin P	Vickery SK						product modulari information struc innovation typolc innovation diffusi product interface product architect knowledge struct bicycle industry Automotive indus Competitive strat Integration Operations mana Product Design Regression analysis		
mediate the relationship?	1996 30	http://www.sciencedirect.com/science/article/pii/S0737678296000318	Journal of Product Innovation Management		Sundgren N	-							
	2008 29	http://www.sciencedirect.com/science/article/pii/S0007850608001911	CIRP Annals - Manufacturing Technology	Duflou JR	Seliger G	Kara S	Umeda Y	Ometto A	A Willems B		Disassembly Productivity End-of-life treatment		
Standardization and modularization driven by minimizing overall process effort	2006 28	http://www.sciencedirect.com/science/article/pii/S0010448505001910	CAD Computer Aided Design	Sered Y	Reich Y						Product family Design for variety Design process m Design structure r Reward Markov c Genetic algorithm		
Modularity in product design for manufacturability	1997 28	http://www.me.mtu.edu/~jkgershe/lel/research/IJAM'97.pdf	International Journal of Agile Manufacturing	Gershenson JK	Prasad GJ								
Evaluation of product customization strategies through modularization and postponement	2009 27	http://www.sciencedirect.com/science/article/pii/S0925527308003411	International Journal of Production Economics	Brun A	Zorzini M						Customization str Modularization Postponement		
	1999 27	http://www.sciencedirect.com/science/article/pii/S0925527398002266	International Journal of Production Economics	Weng ZK							Risk-pooling Manufacturing Supply chains Policies		
Integrated fuzzy-logic based for product modularization during concept development phase	2005 26	http://www.sciencedirect.com/science/article/pii/S0925527304001501	International Journal of Production Economics	Nepal B	Monplaisir L	Singh N					Modular architect Product modulari Fuzzy logic Optimization Concept development		
An integrated method for designing modular products	2004 25	http://www.emeraldinsight.com/journals.htm?articleid=1454579&show=abstra	ct Journal of Manufacturing Technology Management	Asan U	Polat S	Serdar S					Integration Product design systems		
Mechanism and rationales for the coordination of a modular assembly system	2006 22	http://www.emeraldinsight.com/journals.htm?issn=0144- 3577&volume=26&issue=4&articleid=1545256&show=html	International Journal of Operations & Production Management								Assembly lines Automotive indus Rationalization		
Supplying on a modular basis: an examination of strategic issues	2005 22		International Journal of Physical Distribution and Logistics Management	Doran D							Automotive indu: Car components Competitive strat Parts Supply chain management		
House of modular enhancement (home): a design tool for product modularization	2002 21	http://cer.sagepub.com/content/10/2/153.short	Concurrent Engineering Research and Applications	Sand JC	Gu P	Watson G					modular product: life cycle engineer design methodolc redesign product architect functionality		
Design process modularization: concept and algorithm	2007 18	http://cer.sagepub.com/content/15/2/175	Concurrent Engineering Research and Applications		Kim C	Lee C					product design pr modular synthesi module process modulari design structure r module finding algorithm		
Design of modular digital circuits for testability	1997 18	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=585144&tag=1	IEEE transactions on components, packaging and manufacturin technology. Part C. Manufacturing	^g Kusiak A	Huang CC						Controllability Digital circuits Integrated circuit Observability Modular product: Product modulari Test modules Integrated circuit layout		
Modularization as an Enabler for Cycle Economy	2008 16	http://www.sciencedirect.com/science/article/pii/S0007850608000590	CIRP Annals - Manufacturing Technology	Seliger G	Zettl M						Manufacturing Module Product		
Supporting 'Design for Re-use' with modular design	2007 15	http://cer.sagepub.com/content/15/2/141	Concurrent Engineering Research and Applications	Meehan JS	Duffy AHB	Whitfield RI					engineering desig multi viewpoints function working principle solution design structure matrix		
Evaluation of scenario-based modularization for lifecycle design	2009 8	http://www.sciencedirect.com/science/article/pii/S0007850609000365	CIRP Annals - Manufacturing Technology	Umeda Y	Fukushige S	Tonoike K					Lifecycle Modular design Evaluation		
Green product design through product modularization using atomic theory	2010 7	http://www.sciencedirect.com/science/article/pii/S0736584510000414	Robotics and Computer-Integrated Manufacturing	Smith S	Yen CC						Green product de Atomic theory Modular design Product lifecycle		
Suitable application situations of different postponement approaches: Standardization vs. modularization	2008 6	http://www.sciencedirect.com/science/article/pii/S0278612508000873	Journal of Manufacturing Systems	Huang CC	Li SJ								
Dynamic outsourcing through process modularization	2009 5	7154&volume=15&issue=2&articleid=1784444&show=html&PHPSESSID=i9u5km	q Business Process Management Journal	Wu L	Park D						Competences Continuous impro Outsourcing Process management		
Function and Postponement Strategy	2011 0	http://www.tandfonline.com/doi/full/10.1080/10919392.2011.541000	Journal of Organizational Computing and Electronic Commerce	Su CJ	Chuang HC						Customer Order E e-commerce mass customizatio product deployment strategy		
Current status and technical description of Chinese 2 × 250 MWth HTR-PM demonstration plant		http://www.sciencedirect.com/science/article/pii/S0029549309001332	Nuclear Engineering and Design	Zhang Z	Wu Z	Wang D	Xu Y	Sun Y	Li F	Dong Y			
PM project	2007 21	http://www.sciencedirect.com/science/article/pii/S002954930700283X	Nuclear Engineering and Design	Zhang Z	Sun Y								
From field to factory—Taking advantage of shop manufacturing for the pebble bed modular reactor	2006 11	http://www.sciencedirect.com/science/article/pii/S0029549306000367	Nuclear Engineering and Design	Wallace E	Matzie R	Heiderd R	Maddalena	na J					
	2010 9	http://www.sciencedirect.com/science/article/pii/S0255270110002035	Chemical Engineering and Processing: Process Intensification								Process intensific: Modularized man Future manufacturing		
Safety design approach for onshore modularized LNG liquefaction plant	2010 3	http://www.sciencedirect.com/science/article/pii/S0950423010000380	Journal of Loss Prevention in the Process Industries	Tanabe M	Miyake A						Deterministic app Risk based appro: Scenario based at ESSA LNG Module		
Small scale, modular and continuous: A new approach in plant design	2011 2	http://www.sciencedirect.com/science/article/pii/S0255270111002236	Chemical Engineering and Processing: Process Intensification	Seifert T	Sievers S	Bramsiepe C	Schembeck	cker G			Modularization Batch to continuc Multiproduct play Plant design		
Computer-aided web-based application to modular plant design	2010 2	http://www.sciencedirect.com/science/article/pii/S1570794610281154	Computer Aided Chemical Engineering	Hady L	Wozny G						computer-aided pmodular plant de modularization		
Efficient Engineering by Modularization into Package Units	2012 1	http://onlinelibrary.wiley.com/doi/10.1002/cite.201200029/abstract	Chemie Ingenieur Technik	Rottke J	Grote F	Fröhlich H	Köster D	Strube J			Downstream Proc Engineering Modularization Package Units Separation Technology		
	2010 1	http://chemistry-today.teknoscienze.com/pdf/kirschneckco1-10.pdf	Chimica Oggi	Kirschneck D							Manufacturing ef multi purpose flow chemistry continuous flow r microreactor process intensification		
Modularity And outsourcing: the nature of co-ovolution of product architecture and	2011 0	http://onlinelibrary.wiley.com/doi/10.1002/ceat.201000380/abstract	Chemical Engineering & Technology		Grünewald M						Modeling Plant design Plant optimizatio Process design Process engineering		
organization architecture in global automotive industry (Sako, M paper)	2004 173	odularity+And+outsourcing:+the+nature+of+co-		Sako M							modularity outsourcing automotive indus industry dynamic supply chain management		
Advanced Manufacturing Technology: Organizational Design and Strategic Flexibility The modular consortium in a new VW truck plant in Brazil: new forms of assembler and	1996 162	http://oss.sagepub.com/content/17/3/501.short	Organization Studies		Hitt MA	Goldhar JD					computer-integra computer-aided c modular organiza options economies of scoloose coupling		
supplier relationship Antecedents and Outcomes of Modular Production in the Brazilian Automobile Industry:		http://www.emeraldinsight.com/journals.htm?articleid=850733&show=abstract		Marx R	Zilbovicius M						Modular producti Motor industry		
A Grounded Theory Approach Modularisation and outsourcing: who drives whom? A study of generational sequences in the US automative cocknit inductor		http://www.jstor.org/stable/4540404?seq=1	Journal of International Business Studies International Journal of Automotive Technology and		Parente R						outsourcing modularization modular productitacit knowledge supply chain man global sourcing		
Modular production and technological up grading in the automotive inductory a case		http://inderscience.metapress.com/content/gx4jp34qx3t1y78g/	Management International Journal of Automotive Technology and		RoY	Liker JK					automotive supplfirm boundaries modularisation outsourcing product architect technological cha organisational chautomobile indus modular products modular architect vehicle cockpit modularity		
study	2005 9	http://inderscience.metapress.com/content/mmf9c15xw7hv0y3u/	Management International Journal of Automotive Technology and		Trujano G	Garcia-Garnica	a A				automobile indus Mexico modular producti technological up-jautomotive suppl technology Lear Corporation modular manufac intra-firm coordinintra-firm cooperation		
Knowledge transfer through the supply system: does modularity make it easier? Strategic modularisation and performance implications in the Brazilian automotive	2003 7	http://inderscience.metapress.com/content/veq7aaxrtxnd5519/	Management International Journal of Automotive Technology and		Zilbovicius M						modularity outsourcing modular producti supply chain automotive indus modular strategy knowledge transfer		
industry	2005 4	http://inderscience.metapress.com/content/726xa9e6deyvppja/	Management		Gu J	lavara 5		T Dritte ek evu		Ver Druggel II	Brazil automobile indus automotive codes conceptual frame empirical study organisational pe physical proximity communication strategic modular modular producti product modulari firm performance		
	1999 959	http://www.sciencedirect.com/science/article/pii/S0007850607632326	CIRP Annals - Manufacturing Technology	Koren Y	Heisel U	Jovane F	Moriwaki T	T Pritschow	v G Ulsoy G	Van Brussel H	Reconfiguration Manufacturing sy Machine tools		
Lifecycle oriented design of technical Product-Service Systems Integrating sustainable development in the supply chain: The case of life cycle assessment	2006 162 ^t 2007 98	http://www.sciencedirect.com/science/article/pii/S0959652606000795	Journal of Cleaner Production		Fuchs C	Wagenknecht (L				Life cycle enginee Process modulari; Integration of product and service c Investment goods industry		
in oil and gas and agricultural biotechnology	1997 95	http://www.sciencedirect.com/science/article/pii/S0272696307000150	Journal of Operations Management	Matos S Rogers GG							Life cycle assessm Sustainable devel Complexity theory		
Modular Production Systems: A New Manufacturing Paradigm Food purchases: impacts from the consumers' point of view investigated with a modular	2000 77	http://www.springerlink.com/content/q826j52674404764/ http://www.springerlink.com/content/m7105kx21kt50t6l/	Journal of Intelligent Manufacturing International Journal of Life Cycle Assessment		Tietje O	Scholz RW					New manufacturi modular manufac virtual manufacturing Consumers point consumption patidecision-making, eco-indicator 95 food, consumptio functional unit, fc marginal change meat modular, LCA LCA, modular LCA, simplified purchase vegetable		
LCA Reconfigurability Considerations in the Design of Components and Manufacturing	1997 70	http://www.springerlink.com/content/x68145n57116jw92/	International Journal of Advanced Manufacturing Technology		netje O						Consumers point consumption pat decision-making, eco-indicator 95 food, consumptio functional unit, fc marginal change meat modular, LCA undular LCA, simplified purchase vegetable Machine relocatic Manufacturing sy Reconfigurability		
Systems	2004 43	http://www.sciencedirect.com/science/article/pii/S0007850607607240	CIRP Annals - Manufacturing Technology		Massberg W						Life Cycle Manage Maintenance Service Engineering		
	2008 37	http://www.sciencedirect.com/science/article/pii/S0007850608000863	CIRP Annals - Manufacturing Technology		Fukushige S	Tonoike K	Kondoh S				Lifecycle Manage Maintenance Service Engineering Lifecycle Geometric model Modular design		
	2008 37	http://www.ingentaconnect.com/content/mcb/033/2001/00000021/00000001/a		Heilala J	Voho P	TOTIOIRE R	Kondon 3				Assembly Flexible Manufacturing Systems		
Applying collaborative design and modularized assembly for automotive ODM supply	2001 36	t00001 http://www.sciencedirect.com/science/article/pii/S0166361507001285	Computers in Industry	Trappey AJC							Assembly Flexible Manufacturing Systems Product lifecycle r Automotive indus Design collaboration		
chain integration Constructing a virtuous cycle of manufacturing agility: concurrent roles of modularity in	2008 31	http://www.sciencedirect.com/science/article/pii/S0166361507001285	Technovation	Watanabe C							Modularity Product platform Manufacturing ag Manufacturing lead time		
improving agility and reducing lead time	2003 19	http://www.sciencedirect.com/science/article/pii/S010043/202001189	CIRP Annals - Manufacturing Technology		Slevinsky M						Design Module Mechanical Bus Assembly Cost benefit analy Electronic equipr Life cycle Product developn Recycling Reusability Modular product Product life cycle Product design		
	2002 16	http://www.sciencedirect.com/science/article/pii/S0007850607614590	CIRP Annals - Manufacturing Technology	Westkämper E							Assembly Integration Life Cycle Management		
Managerial implications of the modular consortium model in a Brazilian automotive plant											Brazil Motor industry Outsourcing Supply-chain management		
	1997 121	http://www.sciencedirect.com/science/article/pii/S0263237397000303	European Management Journal		Bechler K	Pires S					Image: Problem in the state of the stat		
	2002 949	http://icc.oxfordjournals.org/content/11/3/451.short	Industrial and corporate change	Sturgeon TJ							competition (ecor corporate strateg economic develor electronics industrial development		
Industry Co-Evolution and the Rise of a Shared Supply-Base for Electronics Manufacturing		http://kms1.isn.ethz.ch/serviceengine/Files/ISN/29187/ipublicationdocument_s	in This paper was published as chapter two in: Global Taiwan:	Sturgeon TJ	Lee JR						Image: Second se		
	2007 356	gledocument/319ffb84-26c9-439a-a14a-d88f0cfab476/en/2001-003.pdf http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4141032&tag=1	Building Competitive Strengths in a New International Econom IEEE Robotics and Automation Magazine	Yim M	Wei-Min Shen	Salemi B	Rus D	Moll M	Lipson H	Klavins E Chirikjian G	S Modular self-reconfigurabl self-reconfiguring robot grand challenges		
	2007 57	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4154840	IEEE Transactions on Robotics	Zykov V		Desnoyer M					Evolutionary com modular robotics self-repair self-replication self-reproduction		
	2002 360	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1159221&tag=1	IEEE/ASME Transactions on Mechatronics	Murata S	Yoshida E	Kamimura A	Kurokawa	a H Tomita K	Kokaji S		Distributed auton metamorphic rob modular robot reconfiguration p self-reconfiguration.		
	2002 183	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=981854&tag=1	IEEE Spectrum	Yim M	Zhang Y	Duff D					Computer simula Constraint theory Data storage equi Embedded systen Infrared detector: Microcomputers Network protocol Redundancy Robot programmi Robotic arms Universal joints Controller area non Infrared sensors Reconfigurable ro Versatile robot Mode	dular robots	
Evaluating Efficiency of Self-Reconfiguration in a Class of Modular Robots	1996 153	http://onlinelibrary.wiley.com/doi/10.1002/%28SICI%291097- 4563%28199605%2913:5%3C317::AID-ROB5%3E3.0.CO;2-T/abstract	Journal of Robotic Systems	Chirikjian G	Pamecha A	Ebert-Uphoff I	I				Algorithms Efficiency Geometry Kinematics Motion planning Robotics Metamorphic syst Self reconfiguratic Modular robots		
Modularity and the Impact of Buyer–Supplier Relationships on the Survival of Suppliers	2007 63	http://mansci.journal.informs.org/content/53/2/178.short	Management Science	Hoetker G	Swaminathan <i>i</i>	A Mitchell W					modularity buyer-supplier relationship duration relationship duration		
A review of power electronics interfaces for distributed energy systems towards achieving ow-cost modular design	³ 2009 26	http://www.sciencedirect.com/science/article/pii/S1364032109000938	Renewable and Sustainable Energy Reviews	Chakraborty S	Kramer B	Kroposki B					Distributed energ Power electronics Modularity Integrated power electronics modules		
	2006 1	http://preview.powerelectronics.com/mag/605PET24.pdf	Power Electronics Technology	Mookken J	Haddad K								
Innovation, Modularity, and Vertical Deintegration: Evidence from the Early U.S. Auto Industry	2010 25	http://orgsci.highwire.org/content/21/4/842.short	Organization Science	Argyres N	Bigelow L						innovation modularity vertical integration		
	2008 274	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4358966&tag=1	IEEE Transactions on Knowledge and Data Engineering	Brandes U	Delling D	Gaertler M	Görke R	Hoefer M	I Nikoloski Z	Wagner D	Graph clustering graph partitioning modularity community struct greedy algorithm		
	2009 52	http://onlinelibrary.wiley.com/doi/10.1111/j.1540-5915.2009.00241.x/full	Decision Sciences	Voss CA	Hsuan J						Customization Modularity Service Design Service Science		
Managing modularity of product architectures: toward an integrated theory	2003 144	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1202983&tag=1	IEEE Transactions on Engineering Management	Mikkola JH	Gassmann O						Components degree of couplin interfaces modularity new product deve product architect substitutability		
	2006 68	http://onlinelibrary.wiley.com/doi/10.1111/j.1540-5885.2006.00188.x/full	Journal of Product Innovation Management	Mikkola JH									
Management of product architecture modularity for mass customization: Modeling and theoretical considerations	2007 40	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4077236&tag=1	IEEE Transactions on Engineering Management	Mikkola JH							mass customization fully product architecture modularity		
	1971 5	http://www.tandfonline.com/doi/abs/10.1080/05695557108974793	AllE Transactions (American Institute of Industrial Engineers)	Emmons H	Tedesco AR								
Introducing a platform strategy in product development	1999 134	http://www.sciencedirect.com/science/article/pii/S092552739800173X	International Journal of Production Economics	Muffatto M							Product planning Platforms Automobile indus Japan		
		http://www.ktulrich.com/uploads/6/1/7/1/6171812/platforms.cmr.pdf	MIT Sloan Management Review	Robertson D	Ulrich K								
Planning for Product Platforms	1998 647	http://www.ktulrich.com/uploads/6/1/7/1/6171812/platforms-smr.pdf											

ID	Papers referenced in the research document	Year on Scholar	Website	Journal	Author #1	Author #2	Author #3	Author #4	Author #5	Author #6	Author #7	Author #8	Keyword 1	word 1 Keyword 2 Keyword 3 Keyword 4 Keyword 4 Keyword 6 Keyword 6 Keyword 7 Keyword 8 Keyword 9 Keyword 10 Keyword 11 Keyword 11 Keyword 12 Keyword 13 Keyword 14 Keyword 15 Keyword 16 Keyword 17 Keyword 18 Keyword 18
155 Architectures for pr	oduct families	1997 227	http://www.sciencedirect.com/science/article/pii/S0166361597000225	Computers in Industry	Erens F	Verhulst K							Product architect	ct architect Product developn Modularity Integration Generic product structuring
156 Module design with	n substitute parts and multiple vendors	1989 9	http://www.sciencedirect.com/science/article/pii/0377221789902543	European Journal of Operational Research	Goldberg J	Zhu J							Design	manufacturing in nonlinear programming heuristics
157 Design of assembly	systems for modular products	1997 87	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=631226&tag=1	IEEE Transactions on Robotics and Automation	He DW	Kusiak A							Agileassembly	ssembly engineeringdesigr manufacturing modular products
158 Modular product de	esign and product support	1987 27	http://www.sciencedirect.com/science/article/pii/0377221787901950	European Journal of Operational Research	Karmarkar US	Kubat P							Design	product support logistics reliability
159 Defining Modules, N	Modularity and Modularization	1998 39	http://www.alvarestech.com/temp/PDP2011/CDAndrea/MODULARIDADE/MILLE %202005.pdf	R Proceedings of the ASME Design Engineering Technical Conference	Miller TD	Elgård P								
160 Modularity and Cor	mmonality Research: Past Developments and Future Opportunities	2007 74	http://cer.sagepub.com/content/15/2/85.short	Concurrent Engineering Research and Applications	Fixson SK								modularity	arity commonality innovation multidisciplinary research

ID	PAPER TITLE	Modularization definition related concepts		Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
3	Choice of nuclear power investments under price uncertainty: Valuing	modular project	competitive industry environment		technical uncertainties	discontinuity in workloads	market risk	sensitivity analysis	power generation		
		theoretical model			investments comparison		production costs reduction	real options theory			
		modular investment					economies of scale				
		multiple-module plant									
6	Economic features of integral, modular, small-to- medium size reactors	modular design strategies			capital costs		economies of scale	final modular assembly into customer sites	modular reactors		plant design
		modular investment			o&m costs		shorter construction schedules		power generation		
		shipping module									
		modularization like									
		modularity like									
		modularization									
7	Modular design and construction techniques for nuclear power plants	optimal modular design		minimizing inter- module interactions	module boundaries		quality	clustering methods	power generation		modular design
		modular design method		components prefabrication			cost reduction	modules alignement index			modular construction
		skid modules					capital costs	cost penalty method			assembly
		modular factory					construction				manufacturing
		modularization					resource efficiency				

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		measure of modularity									
		modules interface									
8	The role of product architecture in the manufacturing firm	modular architecture	flexible manufacturing	one-to-one mapping		inventory costs	cost reduction	individual component change	Automobile industry	suppliers	product development
		modular products	engineering skills	de-coupled interfaces		set-up costs	product variety	rapid innovation	Software industry	firms	management
		modular product designs	planning skills	modular labour division		tooling costs	product flexibility	technological change	Personal computer industry		
		localized modularization	division and coordination of labour	structuring product designs			system flexibility	testability	consumer electronics industry		
		modules relationships					standardized component interfaces	focused expertise	shelving systems industry		
							standardized interfaces	standardized parts	Freight trains		
							autonomous tasks	standardization			
							concurrent tasks	architectural innovation			
							flexible product designs				
9	Managing in an age of modularity	product modularity strategies		global financial markets	encapsulation	scarce and imperfect formal approaches to		handle increasingly complex	personal computer industry	managers	modular design
		degree of modularity			compatibility between technologies	problems emerge at the assembly	organizing complex products and	new niche markets and business	printers	designers	
		subsystems			customer needs		independent design groups	modular supply	automobile industry	producers	
		modularity in design			perfect fit modules		cost of product design	new design rules	Software industry	customers	

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		modular systems			dynamic markets		testing costs	alliance formation		suppliers	
		modular architecture			market change		market segmentation opportunities	joint development ventures		retailers	
		modules interface					cost reduction	subcontracting firms		engineers	
		standardized modules					reconfigurability	employment agreements		assemblers	
		modularity in use					stabilize the manufacturing process	financial arrangements			
		components' mix and match					product variety	decentralized industry structures			
		outsourcing						modularity technology			
		modular product markets									
		modular organization									
		modular products									
10	Modularity, flexibility, and knowledge management in product and organization	modular organization	advanced technological knowledge	increasingly dynamic product markets			coordination	learning	Aircraft industry	managerial authority	product creation
		coordinated self- organizing processes	loose coupling of component designs	autonomous tasks			product variety	easy-to-install components	Automobile industry	firms	during the entire commercial lifetime
		components' mix and match	high level of architectural knowledge	concurrent tasks			strategic flexibility	architectural innovation	consumer electronics industry	suppliers	modularity in product designs
		modular architecture	information structure	processes partitioned into tasks			manufacturing costs		Household appliance industry	component developers	modularity in organization designs
		literature review	loose coupling	flexible product designs			respond flexibly to environmental		Personal computer industry	customers	

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
				decomposing product designs			standardized component interfaces		Software industry		
				structuring product designs			standardized interfaces		Power tools industry		
				Modular components					earth-moving equipment industry		
				subsystems							
				loose coupling							
11	Strategic flexibility in product competition	modular products	loose coupling	hierarchies			product variety	information technology advances	Automobile industry	managerial authority	modularity in organization designs
		components' mix and match		standardized component interfaces			different cost characteristics	derived product models	Personal computer industry	managers	product creation
		modular organization		standardized parts			performance variety	subassemblies consolidation	Software industry	joint development ventures	modular product development
		literature review		technical improvements			switching costs	technological change	consumer electronics industry	suppliers	
				Modular components			switching time	economies of substitution	Household appliance industry	retailers	
				modular product designs			strategic flexibility		Test instruments		
				loose coupling			flexible product designs		Power tools industry		
				platform design			mix flexibility		quick-connect electronic interfaces		
							cost reduction		clothing industry		
							time reduction		new product lines development		

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
							modification flexibility				
							coordination				
							autonomous tasks				
							concurrent tasks				
							knowledge of market				
							preferences and				
12	Toward a General Modular Systems Theory and Its Application to Interfirm	modular products	inputs heterogeneity	disaggregation of organizational systems	changing environments	causal model	product variety	information technology advances	Personal computer industry	manufacturers	
		components' mix and match	demand heterogeneity	network externality	optimal configuration	information encapsulation	system flexibility	compatibility between technologies	Publishing industry	customers	
		modular product designs	hierarchies	separability	synergistic specificity	monoproduct markets	configuration options	individual component change	Household appliance industry	firms	
		interfirm product modularity	flexible manufacturing	autonomous tasks	competitive intensity	fixed and variable costs	pricing effects	economies of substitution	Bicycle industry	scholars	
		general modular system theory	lean manufacturing	standardized component interfaces	increased specialization	inventory costs	market segmentation opportunities	technological change	Software industry	project team	
		modular systems		loose coupling		components' bundling	no opportunity cost	recombination	Banking	vendors	
		modularization		loosely coupled production arrangements		resistance to change	components' reuse	new configurations with little loss of	Healthcare	third-party assemblers	
				loose coupling			economies in product design		mathematics		
							coordination		knowledge structures		
							production process decentralization		biological anatomy		

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
							switching costs slow the		social systems consumer		
							obsolescence		electronics industry		
							product costs		Automobile industry		
									shelving systems industry		
									Aircraft industry		
									organizational systems		
13	Networks and innovation in a modular system: Lessons from the microcomputer	modular systems	division and coordination of labour	compatible components	network externality		transaction costs reduction	economies of scale	Personal computer industry	customers	
		components' mix and match	availability of standards	unbundling				learning	consumer electronics industry	manufacturers	
		standardization		interchangeabilit y				rapid innovation	Software industry	firms	
		case study		interfirm networks						buyers	
				standardized parts							
				compatible components							
14	Modularity in technology and organization	components' mix and match	decomposability	standardized component interfaces	stock obsolescence	information encapsulation	cost reduction	learning	organizational design	component developers	
		modular systems	high level of architectural knowledge	standardized architecture	changing environments	problems emerge at the assembly	technical improvements	alliance formation	watchmakers industry	firms	
		remodularization		Modular components			product variety	recombination	Personal computer industry	subcontractors	

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		modular innovation		network externality			product innovation	architectural innovation	consumer electronics industry	social communities	
		literature review		subsystems					Automobile industry		
		modular recombination		unbundling					toys industry		
		modularization									
15	Approaches to mass customization: configurations and	modular design		processes partitioned into tasks			economies of scale	manufacturing efficiency	flexible manufacturing systems (FMS)	manufacturers	manufacturing
		modular products		industry standards			economies of scope	component variety reduction	clothing industry		design
		standardization		standardized parts			product variety		consumer electronics industry		during the fabrication stage
		mass customization					time reduction				during the entire production lifetime
		case study					increase product features				
		modules relationships									
16	The Use of Modular Organizational Forms: An Industry-Level Analysis	modular organization	inputs heterogeneity	disaggregation of organizational systems	increased specialization		production process decentralization	alliance formation	Personal computer industry	modular firms	shorter product life cycles
		case study	demand heterogeneity	interfirm networks	synergistic specificity		scope flexibility	contract manufacturing	Software industry	contract agency workers	
		modular systems	availability of standards	industry standards	competitive intensity			technological change	clothing industry	temporary agency workers	
			loose coupling	autonomous tasks	changing environments			recombination	electronics industry	vendors	
				standardized component interfaces	outsourcing				pharmaceutical and biotech industries	managerial authority	

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
				loose coupling	technological change				telecommunicati ons		
				loose coupling					cigar industry		
									consumer electronics industry		
									construction		
									food service		
17	Reconfigurable manufacturing systems: Key to future	modular processes		production process decentralization			reconfigurability	autonomy	reconfigurable manufacturing systems		
		modular systems		team-based approach			components' reuse		Software industry		
		literature review									
18	ARCHITECTURAL INNOVATION AND MODULAR CORPORATE	modular processes	decomposability	loose coupling			dynamism	adaptive potential	Personal computer industry	corporate	modularity in organization designs
		modular organization		subsystems			modular innovation	new productive assets	IT	multibusiness firm	
		modular structures		standardization			adaptation	recombination		firms	
		dynamic capabilities					increased specialization	architectural innovation		scholars	
		case study						rewards			
19	Modularity and innovation in complex systems	components' mix and match	decomposability	adaptation	rapid innovation	information encapsulation	flexible product designs	alliance formation	Personal computer industry	managerial authority	modularity in product designs
		modular innovation		design structure	outsourcing		parallelism	contract manufacturing	Software industry	subcontractors	early stages of design evolution

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		theoretical model		subsystems			coordination	recombination		designers	product development
		module as a design parameter					time reduction				modularity in organization designs
		module performance					product innovation				
		modularization					product variety				
							module variety				
20	Technological and organizational designs for realizing economies of	components' mix and match		standardized interfaces	customer needs	initial design costs	product development time reduction	economies of substitution	Software industry	designers	
		modular platforms		compatible components		testing costs	leverage investments	easy-to-install components	telecommunicati ons	firms	
		literature review		flexible specialization		economies of substitution: search costs	provide customers with continuity	product upgradability	Personal computer industry	manufacturers	
				standardized parts			components' reuse	competency- enhancing knowledge	Automobile industry	customers	
							risk reduction	rapid innovation	organizational systems		
							incorporation costs reduction	modular upgradability			
							interfirm coordination	rewards			
							transaction costs reduction				
							economies of scope				
							economies of scale				

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
21	Unpacking the black box of modularity: technologies, products and organizations	modular product designs	advanced technological knowledge	standardized component interfaces		modular labour division	increased specialization	architectural innovation	chemical plants	component developers	modularity in product designs
		modular products	loose coupling of component designs	interfirm networks		division and coordination of labour	product variety	off-site module construction	Aircraft industry Personal	suppliers	modularity in organization designs
		modular organization		product decomposition			product flexibility		computer industry	engineers	
		knowledge modularity		technological maturity			product upgradability			managers	
		modular product architecture		standardized parts			cost reduction				
		components' mix and match		Modular components			time reduction				
		equipment modularity					risk reduction				
		case study					switching costs construction de-				
		modularization					coupling safe				
							construction interfirm				
							coordination				
22	Managing product families: The case of the Sony Walkman	modular design		flexible manufacturing				rapid innovation		project team	
		case study		platform design				derived product models		retailers	
								incremental innovation			
23	A heuristic method for identifying modules for product architectures	modular product architecture		one-to-one mapping	customer needs		cost reduction	product development time reduction	Power tools industry		design afterthought

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		modular products modules relationships method of module heuristics case study		subsystems			product variety	product development cost reduction	power generation Household appliance industry		
24	The Misalignment of Product Architecture and Organizational Structure in	modular systems					design interfaces	design structure matrix modular innovation		designers managers	
25	Modular product architecture	modular product architecture modular innovation modular products modular architecture modular product designs case study		platform design interfirm networks shared modules Modular components separability			product variety cost reduction market segmentation opportunities pricing effects	portfolio architecture family function structure technological change	Automobile industry consumer electronics industry	system engineer	updates on regular time- cycles modularity in product designs

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		components' mix and match									
		modularity matrix									
26	Design for variety: developing standardized and modularized product	standardized architecture		standardized parts	coupling index		cost reduction	component variety reduction	telecommunicati ons	project team	
		standardization						product platform architecture	consumer electronics industry	customers	
		modular building blocks							,		
		modularization									
		case study									
		modular architecture									
27	Modularity in design of products and systems	Production modules	decomposability	product decomposition			economies of scale	testability	Software industry		modularity in product designs
		Function modules	product family	subsystems			product variety		Personal computer industry		manufacturing
		modules relationships	Independent module design				switching costs		Automobile industry		management
		modular product designs					time reduction				product creation
		modular product architecture					risk reduction				early stages of design evolution
		modular products					easy product diagnosis, maintenance,				
		case study					cost reduction				

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		modularity matrix					strategic flexibility				
28	Modularity, strategic flexibility, and firm performance: a study of	modular products	advanced technological knowledge	standardized component interfaces	increasingly dynamic product markets	continuous platform renewal	components' reuse	learning	Household appliance industry	local development centers	product development
		modular architecture		outsourcing	industry standards	coordination costs	switching time	technological change	Software industry	firms	modularity in product designs
		modular product architecture		modular platforms	economies of scale	organizational flexibility	product variety	module database	Personal computer industry	customers	
		modular process architecture		organizational flexibility	quality		strategic flexibility	incremental innovation	Automobile industry	suppliers	
		strategic modularity		reconfigurable building blocks	cost reduction		economies of scale		consumer electronics industry		
		modular organization		standardization	easy imitation risks		customer needs				
		modular innovation		reengineering of work			cost reduction				
		case study		codification			product innovation				
		components' mix and match		product decomposition			process innovation				
		conceptual model		Modular components			new markets				
		modularization									
		modular systems		platform design			knowledge transfer				
29	Modularity, product variety, production volume, and component sourcing:	combinatorial modularity		standardized parts	performance variety		product variety	postponement	product interfaces	customers	modularity in product designs
		modular product architecture		product family	types of modularity		easier management	inventory risk	Personal computer industry	suppliers	manufacturing

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		components' mix and match		components' commonality	customer needs		economies of scope	component variety reduction	Automobile industry	firms	
		modular products		loosely coupled production arrangements			economies of scale		consumer electronics industry	assemblers	
		modular product designs		standardized interfaces			time reduction		Household appliance industry	managers	
		case study		one-to-one mapping					telecommunicati ons		
		modularization		outsourcing							
				interface simplification							
30	Modular architectures in the marketing process	modular product architecture	changing environments	standardized interfaces	market risk		product variety	process innovation	modular product markets	managers	product creation
		modular products	global information systems	loose coupling	tight coupling		cost reduction	rapid innovation	Personal computer industry	subcontractors	
		modular process architecture		decoupling			organizational flexibility	competitive strategies	Software industry	firms	
		knowledge modularity		architecture complexity reduction			time reduction	market change	quick-connect electronic interfaces	consumers	
		modular architecture		components' commonality			economies of substitution	knowledge of market preferences and	consumer electronics industry	designers	
		modular product, process, and knowledge		platform design			adaptation	derived product models	telecommunicati ons	engineers	
		components' mix and match		industry standards			market segmentation opportunities	interchangeabilit y	Bicycle industry		
		modular design		Modular components			components' reuse	technical uncertainties	automation systems		
		mass customization		component decoupling			component reliability	interfirm product modularity	Power tools industry		

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		case study					initial investment reduction	network externality	Automobile industry		
							product costs	learning	Aircraft industry		
							infrastructures cost reduction	greater speed to market	clothing industry		
							made to order products	new components development	organizational systems		
								technological change			
31	Product family design and platform-based product development: a state-of-	modular process design	standards and design rules	types of modularity	distinctiveness	architectural innovation	product variety	design structure matrix	Automobile industry	suppliers	early stages of product architecture
		product platform architecture	geographical spread	reconfigurable building blocks	product decomposition	quality	economies of substitution	collaborative arrangements	flexible manufacturing systems (FMS)	multiproduct enterprises	manufacturing
		modular architecture	decomposability	platform design	degree of modularity		interchangeabilit y	postponement	telecommunicati ons	customers	module creation
		modular platforms		standardized interfaces	fixed and variable costs		design reuse	real options theory			
		modular product architecture		outsourcing	customer knowledge		reconfigurability				
		modular products		decoupling							
		literature review		standardized parts							
		modularization		modular supply chains							
				subsystems							
32	Product modularization for life cycle engineering	modular products	adaptive design	quality function deployment	fixed and variable costs		product variety	easy product diagnosis, maintenance,	Automobile industry	customers	product life cycle

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		modular design	decomposability	standardized interfaces	interaction analysis		components' reuse	individual component change	Bicycle industry	manufacturers	design
		modular product architecture		reduce interactions			concurrent tasks	mass customization	Personal computer industry		assembly
		case study		modules independence			cost reduction		Household appliance industry		service
		module merging		standardization			quality				recycle
		common modules		hierarchies			production efficiency				product design
		modularization					reconfigurability				maintenance
		life cycle oriented modularization									reuse
33	Evaluation of supply chain structures through modularization and	modular design	advanced technological knowledge	standardization		technological restrictions	system flexibility	postponement	Automobile industry	manufacturers	manufacturing
		modular process design		industry standards		organizational systems	economies of scope	manufacturabilit y	Personal computer industry	firms	
		modularized contracting		interfirm networks			economies of scale		clothing industry	suppliers	
		case study		independent components			outsourcing	product development time reduction		subcontractors	
		modular product architecture		standardized parts			economy in resources	easy-to-install components		customers	
		conceptual framework					time reduction				
		modularization					component variety reduction				
							production costs reduction				

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
							contract manufacturing				
							fixed and variable costs				
34	Product modularity: Definitions and benefits	modular products	attribute independence	product platform architecture	competitive intensity	no model to validate modularity	product variety	interchangeabilit y	Software industry	design engineers	product development
		modular design		standardized parts	components' reuse	ill-defined modules	mass customization	individual component change	Automobile industry	product development managers	product life cycle
		modular product designs		standardization	customer needs		strategic flexibility	rapid innovation		customers	product retirement
		modular building blocks		modules independence	functional requirements		economies of scale	concurrent tasks		designers	modularity for product recycling
		modules relationships		functional independence			component variety reduction	testability		engineers	
		components' mix and match					time reduction	learning			
		modular architecture					flexibility	assembly time reduction			
		literature review					product development cost reduction	easy product diagnosis, maintenance,			
		common modules					modification flexibility	easy-to-install components			
							product flexibility	technological change			
							risk reduction	life cycle modularity			
							infomation flow				
							materials flow				

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
							inventory costs				
							labour cost reduction				
							quality				
							life cycle costs reduction				
35	Inter-temporal economies of scope, organizational modularity, and the	modular organization	decentralized structure		market change		economies of scope	recombination	dynamic markets	top management	mature, declining, or defunct
		M-form			resources sharing		centralized coordination and control	rewards	consumer electronics industry	managers	
		modular business units			governance economies		technological change		personal computer industry		
		case study					market segmentation opportunities		electronics industry		
		modular structures							organizational systems		
		modular recombination									
36	Implications of modularity on product design for the life-cycle	life cycle modularity		product decomposition	design interfaces	redundant architecture costs	reduced number of people involvment	simplified assembly	automobile industry	designers	recycle
		one-to-one mapping		subsystems	life cycle requirements on a product's	excessive capability	independent design groups	ease of disassembly	photocopiers	manufacturers	design
		product architecture strategy		easily separable components	rethink post-life intent	similarity	assembly costs reduction	improved serviceability		recyclers	manufacturing
		logical units		modules independence		static product architectures	disassembly costs reduction	easier maintenance			assembly
		clumping components into modules					service costs reduction	design structure matrix			reuse

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		standardized parts					components' reuse	product architecture decomposition			service
		common modules					different materials reduction				product retirement
		case study					compatible materials				materials recycling
37	Do modular products lead to modular organizations?	modular organization	loose coupling		empirical investigations	costs of design modular organization	individual component change	modular innovation	consumer electronics industry	network of organizational actors	product design
		outsourcing	reconfigurability		transaction costs reduction	maintain modular	less opportunism	less management over the design	personal computer industry	suppliers	product development
		modular products	autonomy		managers	reduced technical capabilities	easier suppliers replacement	loose coupling	automobile industry	other components makers	manufacturing
		degree of modularity			relationship with suppliers	highly interactive organizational	easier supply chain reconfiguration	use technical criteria when choosing		manufacturers	
		modular product architecture			less communication necessary	knowledge loss	independent components			governance	
		communication challenges			one-to-one mapping	hierarchies	competitivity			buyers	
		governance challenges			specifications negotiation		no hard-to- manage supplier cost				
		causal model			advanced technological knowledge		ease to reconfigure organizational				
		case study			suppliers' switching		more flexible supply chain				
							broader the range of suppliers				
							knowledge transfer				
38	Development of modular products	function-oriented modularity representation	high degree of functional interaction	Modular components	functional requirements		respond flexibly to environmental		electronics industry		manufacturing

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		module performance		modular functional space	design parameters						design
		modular product designs		subsystems	module cost						conceptual design
		schematic graphs		design process: early modules formation							conceptual design
		interaction graph		reconfigurable building blocks							
		modules relationships									
		fuzzy logic approach									
39	Product variety optimization under modular architecture	modular architecture	quality function deployment	common modules	functional requirements	over- specification cost	economies of scale	design optimization	aircraft industry		conceptual design
		standard configuration	similarity	modules independence	product variety	fixed and variable costs	performance variety		Automobile industry		manufacturing
		design for assembly		functional independence	optimal module combination		product variety		consumer electronics industry		
		modular design			cost structure						
		Independent module design									
		similar module design									
		common module design									
		successive quadratic programming (SQP)									
		case study									

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors		Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
40	Modularity, component outsourcing, and inter-firm learning	modular design strategies	product architecture strategy	delegating	multiple models quick introduction	supplier/buyer interdependence	product variety	partnerships	Automobile industry	manufacturers	product development
		product modularity strategies	loose coupling	standardized interfaces	outsourcing		cost reduction	alliances	consumer electronics industry	suppliers	new product development
		product architecture designs	loosely coupled interfaces	component specification	demand variability		component variations	performance variety	photocopiers	competitors differentiation	
		manageable parts		component standardization	customization		flexibility gain	different cost characteristics	elevator manufacturing industries	customers	
		components' mix and match		complex systems decomposition	supplier selection		cost reduction	specialization	Software industry	competitors	
		product family		independent elements management	knowledge sharing		suppliers compatibility	economies of scale		managers	
		product architecture		substitutability	technical complexity		firm's specialization	interchangeabilit y		buyers	
		degree of modularity			perfect fit modules		complex systems management	learning			
		case study			cost and benefit compromises		specialization of knowledge	technical problems solving through			
		modularization					economies of substitution				
							transaction costs reduction				
41	Functional independence and product similarity based on customer needs	module as a design parameter			exact module incorporation		economies of scale	mass customization	household appliance industry	customers	manufacturing
		product architecture			customer needs			modules relationships		designers	conceptual design
		modular architecture						sensitivity analysis			product design
		case study									assembly

		Modularization						Advancement /	Application		
ID	PAPER TITLE	definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Innovational aspects	fields	Actors involved	Timeline
42	Measuring modularity- based manufacturing practices and their impact	Modularity-based manufacturing	tight coupling	standardization	customer needs		product variety	mass customization	Software industry	customers	modularity in product designs
		modular production		technological change	demand variability		service variety	new form of supplier–custom er relationship	Automobile industry	manufacturers	modularity in production process design
		modular components		standardized modules	increasing technical complexity		uncertainty reduction	integration with upstream suppliers and	bicycle industry	suppliers	modularity in organization designs
		Modularity-based manufacturing practices (MBMP)		component standardization	lower prices		complexity reduction	combine the advantages of standardization	human resource management in manufacturing	project team	modular organization of the
		theoretical model		general modular system theory	complex technology- intensive		product development time reduction	organizing complex products and	contract manufacturing	corporate divisions	designing modular products
		modular products		components that can be assembled in	higher production costs		cost reduction	new configurations with little loss of	alternative work arrangements	designers	organizational process design
		Process Modularity		reconfigurable standard interfaces	Close and continuous customer		impacts on a firm's supply chain and its	reengineering entire supply chains	alliances	producers	
		modularity as a manufacturing strategy			customer knowledge		managerial cost reduction	final modular assembly into distribution			
		modular architecture			tight coupling		new product entrance barrier elimination	final modular assembly into customer sites			
		dynamic modules					more responsive supply chain	new niche markets and business			
		industry level					reorganize manufacturing teams quickly	handle increasingly complex			
		modular product architecture					more flexibility in the manufacturing	economies of scope			
		process modularity					strategic flexibility	greater organizational innovation			
		team modularity					lower costs for design, production,				
		modular manufacturing architecture					products are easier to				

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		case study					flexibility				
		modularization					minimize the cost of customization				
43	Modularization in the auto industry: interlinked multiple hierarchies of	modularization in product architecture	multiple, interlinked hierarchies	outsourcing	architectural changes	no case of adopting the same modules	decreased interdependence between	design	Automobile industry	designers	product function designing
		modularization in production	subsystems	interface simplification	division of labour		easier material handling management	subsystems' functional independence	electronics industry	outside suppliers	product structure designing
		modularization in interfirm system	hierarchies	interface standardization	make-or-buy decisions		easier quality control management	subsystems' structural cohesiveness	Personal computer industry	Product engineers	production process designing
		structurally cohesive modules	and skills training	modular supplier system	module dimensions		modules quality control	expansion of the subassembly scope	bicycle industry	process engineers	production
		Product Process hierarchy	independent components' function	component standardization	shift to integral architecture		testable set of components	lean manufacturing	consumer electronics industry	purchasing managers	development
		outsourcing of product designing		functional independence	individual parts complex functions		division of labour with outside suppliers	different product lines and market	software industry	automakers	purchasing
		modular product architecture		component sharing	components' redesign		greater value for consumers	design structure matrix		customers	modular design
		modularity in use			hierarchies redefinition					workers	
		modularity in production									
		modularization									
		conceptual framework									
44	Product modularity: Measures and design methods	components relationships constitutive matrix	and process graphs	maximizing intra- module interactions	set-up costs		increase diversity	design structure matrix		designers	modular design
		modular product information representation	analysis of interfaces	minimizing inter- module interactions	modularity- impacting decisions		products' lower cost	Process graphs			life cycle representation

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		product architecture	design for assembly	clustering components into modules			reusability	measure of modularity			modular product development
		modules relationships		modular design method	Different modularization scenarios		ease of disassembly	cost model			recycle
		modular architecture			design time reduction			Holonic Product Design (HPD) method			redesign
		degree of modularity			cost reduction			clustering methods			reuse
		literature review			optimal configuration						modular products creation
		modularization									feasibility
											module creation
45	The effect of product modularity on industry structure: The case of the	modular products	defined component interfaces	standardized interfaces	government regulation	single firm market domination	components' improvement	more regular incremental and modular	bicycle industry	manufacturing firms	development
		product family	internationally accepted standards	standardizing attachment and spatial interfaces		price-based competition	constant interface	constantly upgraded elements	Power tools industry	manufacturers	
		modular product architecture	tight coupling	loose coupling		product architecture unlikely to	organizational flexibility	coping with rapidly changing markets	consumer electronics industry	assemblers	
		relatively constant component interfaces	decentralized structure			hard to alter component interfaces	strategic flexibility	embedded coordination	software industry	subcontracting firms	
		case study				specialization: fragmented industry	independent components	reduced need for management coordination	personal computer industry	competitors	
						reduced communication and cooperation high levels of	cheap components' upgrading easy	Decentralized industry structures respond flexibly	aircraft industry	component manufacturers	
						price-based competition	components' upgrading	to environmental			
							economies of scale	cost reduction			

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								specialized capabilities			
								incremental innovation			
46	Modular and platform methods for product family design: literature analysis	the use of more different modules	с	one-to-one mappin	coordination	over-equipment of components	product variety	relative cost measurement	Automobile industry	development groups	design
		modular organization		function sharing	assembly precision		module task specialization	incremental improvements such as upgrade,			optimization
		modular product architecture		technological similarity	localization of change		economies of scale	System reliability	household appliance industry		modular product development processes:
		modules relationships		portability interfaces	complexity of interface characteristics		costs savings in inventory and logistics	Faster assembly and less production time Parallel			product development
		types of modules					life cycle costs reduction	manufacture of module Fast			platform development
		modular hierarchy					easier maintenance	development of products			
		modular architectures: successful					shorter product life cycles	standardization			
		modularization									
		group technology					flexibility in component reuse	matematical programming methods			
		literature review					outsourcing	genetics algorithms			
47	Next Generation Factory Layouts: Research Challenges and Recent	modular layouts		design procedures			activities quick scaling up/down	connected supplier production lines	automobile industry		
		literature review		machines aggregation into cell modules			minimize machine- duplication costs	modular layouts	telecommunicati ons		
48	Modularity in organizational structure: the reconfiguration of	modular business unit change	organizational structure		reconfiguration costs		knowledge transfer	modular structural change			

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		modular recombination						recombination			
		case study									
		modular systems									
49	Modularity: The Basis for Product and Factory Reengineering	factories in the factory		quality function deployment				module drivers			product reengineering
		modular reorganization						modular function deployment			factory reengineering
		case study						module indication matrix			
50	An integrated modular design methodology for life- cycle engineering	Modular design							household appliance industry		
		case study									
		modularization									
		modular design method									
51	Modular product design: a life-cycle view	life cycle modularity	Attribute Independence	modules independence				measure of modularity			
		modular design method	Process Independence					Process graphs			
		case study	Process Similarity								
52	Modular Network Design: Using Information and Communication	modular network design							air cargo industry		production
		process modularization							it		service

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		case study									organizational process design
		virtual organization									
53	The development of modular-based design in considering technology	modular design							AGV systems		assembly
		conceptual model									
		function modules									
54	Impacts of supplier–buyer relationships on modularization in new	components' mix and match	product process hierarchy	disaggregation of organizational systems	interface compatibility effects	interface constraints	module variety	modular innovation	automobile industry	suppliers	
		modular product designs			social systems		component customization	modularization characteristic curve	telecommunicati ons	buyers	
		modularization			supplier-buyer relationships		value inputs	architectural innovation	software industry		
		modular systems									
		modular components									
		modular product architecture									
		remodularization									
		levels of modularization									
		modular hierarchy									
		modularity in use									

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		case study									
55	Modular architectures, knowledge assets and organizational learning:	modular product, process, and knowledge	information structure	loosely coupled processes	knowledge structures		flexible product architecture	modular products creation	consumer electronics industry	architects	design
		modular architecture	organizational knowledge	cycles of synthesis and decomposition			greater speed to market	modular product creation process		managers	testing stage
		modular product architecture		new design rules			technologically upgraded products quick	learning			
		standardized component interfaces		component specification			product variety	learning-by- leveraging			
		components' mix and match		standardized interfaces			lower costs for design, production,	learning-by- planning			
		literature review		concurrent and self-managing development			strategic flexibility	rewards			
		loose coupling		codification			managing interface specifications	long-term technology and market			
56	Modularity: implications for imitation, innovation, and sustained advantage	modular capability		hierarchical decoupling	easy imitation risks	high architectural costs	product heterogeneity and associated	modular innovation	automobile industry	customers	modular design
		modular product designs		component decoupling	reverse engineering		reuse	component radical innovation	consumer electronics industry	competitors	
		conceptual framework		modules independence			durability of performance	incremental innovation	intellectual property	firms	
								recombination		scholars	
								architectural innovation			
57	Macro level product development using design for modularity	modular products	independent components	component standardization	functional requirements				production systems		modular design
		basic core unit		modules independence					personal computer industry		

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		problems decomposition modular production system clumping components into modules modular design method case study							automobile industry		
58	Supply chain implications of modularization	modular supply chains modular supply modularization			value shifting outsourcing			supplier-buyer relationships	automobile industry	first-tier suppliers module supplier oem	assembly
		case study								VAST suppliers buyers	
59	The impact of modular production on the dynamics of supply chains	modular production case study	product platform architecture	interchangeabilit y components' commonality	commonality index redesign		module variety logistics costs	simplified assembly	automobile industry household appliance	suppliers oem	
		components' mix and match standard products			integration with upstream suppliers and		inventory costs		industry modular truck building consumer electronics industry	module supplier assemblers	
		Levels of Modular Production							software industry	manufacturers	

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		modular consortium							automation systems	distributors	
		modularization									
60	Optimal return policy and modular design for build-to- order products	modularity index			value shifting	cost of returned merchandise	sales increase	theoretical model	made to order products	module supplier	product design
		modularity in product designs				cost of product design		sensitivity analysis		retailers	
		theoretical model									
61	Supply-chain integration: implications for mass customization,	mass customization		modular interface redesign	opportunity for modularization	higher production costs	inventory costs	modular supply chains	automobile industry	suppliers	product design
		modular components		component decoupling	interface compatibility effects		inventory risk	standardized finished products	telecommunicati ons	buyers	assembly
		postponement			component customization		outsourcing	supplier-buyer relationships	personal computer industry		manufacturing
		modularization			value inputs		economies of scale		consumer electronics industry		
		components' mix and match			supplier/buyer interdependence		economies of scope		elevator manufacturing industries		
		modularization characteristic curve			interface constraints						
		modular product architecture									
		product platform architecture									
62	Adaptable Design	modules relationships		standardized interfaces	components' common lifespan inside a		adaptation	modular platforms	bicycle industry		modular design
		modular architecture		minimizing inter- module interactions			component variations	reusability			platform development

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		adaptive design		functional independence			parallel development				
		modular product designs					maintenance				
		modularization					materials recycling				
							module variety				
63	Competing—and learning—in modular markets	modular product, process, and knowledge		components' mix and match	highlight capability bottlenecks		product variety	knowledge management	automation systems	designers	product creation
		modular product architecture		standardized interfaces	technological change		less management over the design	strategic learning	personal computer industry	managers	modular development process
		modular architecture					managing interface specifications	compatible components	banking		
		modular process architecture						new components development	consumer electronics industry		
		learning organizations						modular platforms	automobile industry		
		modular building blocks							modular product markets		
		modular organization									
64	Integrated product and process design: A modularity perspective	modular product architecture			design process: early modules formation	redundant architecture costs	economies of scale	modularity algorithm	aircraft industry	designers	module creation
		components' mix and match				excessive capability	individual component change	modularity matrix	consumer electronics industry		modular product development
		modular components				static product architectures	product variety		automobile industry		
						similarity	reduced lead time				

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
						scarce and imperfect formal approaches to	risk reduction easy product diagnosis, maintenance,				
65	Product Modularization for Parts Reuse in Inverse Manufacturing	modularization in product architecture standardization		functional independence components' commonality	module cost module characteristics		easier maintenance easier manufacturing		automobile industry		reuse product life cycle
		modularization subsystems' functional independence life cycle oriented modularization modules relationships									
66	Modeling tradeoffs in three- dimensional concurrent engineering: a goal			intellectual property	assembly costs reduction fidelity tradeoffs between integrality and			weighted goal programming	three- dimensional concurrent automobile industry		supply chain design product design modular design modular product designs

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
67	Platform strategies in international new product development	product architecture	product platform architecture				simplified assembly				product development
											platform development
68	Next-generation manufacturing systems: key research issues in	reconfigurable manufacturing systems							open modular architecture controllers		
									mechatronics industry		
69	Custom design of facility layouts for multiproduct facilities using layout	modular layouts heuristic procedure for design of modular layouts case study			materials flow			modular layouts			modular design
		module merging									
70	Modularity technology in manufacturing: Taxonomy and issues	modular architecture optimal modular system configuration modularity technology modular components modular design method modular systems		module drivers	functional requirements				automation systems		modular design modular product designs
71	Modular design to support green life-cycle engineering	green life cycle engineering						genetics algorithms			modular product designs

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		modular products						clustering methods			modular design
		case study									
72	Progressive sharing of modules among product variants	standardization		modular common platform	product variety		module variety				designers
		product family			optimal configuration						
		product family architecture									
		modular components									
		optimization									
		module merging									
73	Modularization and the impact on supply relationships	supplier-buyer relationships	loose coupling	partnerships	customer needs	uppliers' switchin	greater collaboration	autonomy		buyers	supply chain design
		product architecture		outsourcing			information sharing			suppliers	
		cross-sectional research									
		modularization									
74	Achieving product variety through optimal choice of module variations	module supplier			manufacturing costs			sensitivity analysis	automobile industry	oem	product design
		optimization			development costs					suppliers	modular product designs
		module options			product variety						

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		case study			module commonality						
75	Modularity in developing business services by platform approach	modular service platform	competitive industry environment	modularity in organization designs	customer needs		standard configuration	flexibility gain	business services	logistics service providers	product development
		empirically grounded model	availability of standards		customer knowledge		flexibility of differentiation	production costs reduction	service industries		manufacturing
		modular platforms	technological change						it		modular design
		modularized logistics services							personal computer industry		
		strategic modularity									
		modularity dimensions									
		modularity in production									
		case study									
76	Activity-based costing as a method for assessing the economics of	activity-based costing		module commonality	modularity costing		economies of scale			customers	product design
		modular products			over- specification cost						product development
		case study			inventory costs						
		modular structures			support activities cost						
		modularization			R&D costs						
					development costs						

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
77	Optimizing modular product design for reconfigurable	modular products			quality	quality loss due to modularization			manufacturing	customers	product design
		reconfigurable manufacturing systems			reconfiguration costs						modular design
		modular products			customer needs						assembly
		optimization									modular product designs
		integer programming									
79	Modular assembly in the car industry—an analysis of organizational forms'	module assembly units			"inside" pre- assembly			autonomy	automobile industry	suppliers	assembly
		modular assembly			outsourcing				organizational systems	manufacturers	
		temporary organizational forms			module dimensions					customers	
		case study									
80	Product modularity, information structures and the diffusion of innovation	modular products		standardized component interfaces	innovation typology			innovation diffusion	bicycle industry		
		information structure			information encapsulation			modular innovation	personal computer industry		
		product interfaces						architectural innovation			
		product architecture									
81	The effects of product modularity on competitive performance: Do	regression analysis			competitive performance		low inventory	quality	automotive industry	managers	product design
		modular products			cost reduction		economies of scale	cycle time			design

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		integration strategies			intellectual property		inventory risk				manufacturing
		standardization					reduced set-ups				modular design
		modular product architecture									
		supply management									
		group technology									
		case study									
82	Remodularization of a product line: Adding complexity to project	remodularization	functional management		project autonomy	product costs	meet challenging time and cost objectives	modular innovation	manufacturing	design engineers	task specification phase
		product architecture			task specification	organizational boundaries		incremental innovation	product line management	managers	design
		case study			task ownership					project team	
		compatible modules			production simplification						
		subsystems			new technologies						
		innovation typology			integrated components						
		product line parts			information sharing						
		modules interface									
		modular design strategies									

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		modular architecture									
83	Efficiency and Feasibility of Product Disassembly: A Case-Based Study	modular disassembly toolkit					value recovery	recyclability	single use cameras		reuse
		case study					module cost	sensitivity analysis			modular design
		modular products									
84	Standardization and modularization driven by minimizing overall process	architecture						standardization and modularization			design
		component modularization						sensitivity analysis			
		standardization									
		modularization									
		case study									
85	Modularity in product design for manufacturability	modular products	independent components	functional independence	customer needs	redesign	manufacturing costs	interchangeabilit Y	product life cycle		manufacturing modularity
		product family	process independence				reduced lead time	greater value for consumers	household appliance industry		product development
		group technology					life cycle costs reduction	design for manufacturabilit y			modular design
		degree of modularity						flexible product designs			
		attribute independence									
		process similarity									

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		similarity									
86	Evaluation of product customization strategies through modularization	customization	low customization		customer needs			combinatorial modularity		manufacturers	modular design
		modularization characteristic curve	high complexity								
		components' mix and match									
		modularization									
		modular supply chains									
		case study									
87	Risk-pooling over demand uncertainty in the presence of product modularity	modular products			risk reduction			cost reduction	disposable hospital supplies manufacturer	retailers	modular product designs
					inventory costs					manufacturers	
88	Integrated fuzzy-logic based for product modularization during	modular architecture			module cost		product development time reduction	optimization			modular design
		modular products					compatible components	cost reduction			conceptual design
		standardization					components' reuse	fuzzy logic approach			
		case study					reusability				
		modularization									
89	An integrated method for designing modular products	modular architecture		modules independence	customer needs			optimization			modular design

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		modularization modularization in product architecture degree of modularity product modularity strategies modularization process appropriateness to modularity case study						real options theory			
90		standardization organizational modules mass customization modularity in production modular products modular processes case study			modules interface		economies of scale resources sharing modules quality control	coordination assembly activities synchronization activities and resources development	automobile industry	suppliers customers	modular assembly
91	Supplying on a modular basis: an examination of strategic issues	modular supply chains			value inputs				automotive industry	suppliers	modular design

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		case study			supplier-buyer relationships					oem	assembly
										first-tier suppliers	
										customers	
92	House of modular enhancement (home): a design tool for product	modular products			redesign			materials recycling		designers	modular design method
		case study			functional requirements						modular design
		HOME method (house of modular enhancement)									assembly
		life cycle oriented modularization									
		interaction analysis									reuse
		modularization									module creation
93	Design process modularization: concept and algorithm	process modularization			modules relationships	modules independence		design structure matrix		managers	modular design
		modularization									product design
94	Design of modular digital circuits for testability	modular products		reconfigurable building blocks	decomposability		reusability	modular design method			design for testability
		test modules			testability			modularity matrix			testing stage
		modules relationships									integrated design approach
		test modularity									

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95	Modularization as an Enabler for Cycle Economy	modular product architecture		module drivers	value inputs	development costs		software tool	telecommunicati ons		product life cycle
		case study			customer needs						modular product development
		modular products			recyclability						modular production
		modularization			easy imitation risks						
		life cycle oriented modularization									
96	Supporting 'Design for Re- use' with modular design	product family		clustering components into modules	market requirements		complexity reduction	modular design method		designers	modular design
		knowledge modularity					module variety	design structure matrix			design reuse
		modular structures						genetics algorithms			modular product development
		modular products									
97	Evaluation of scenario- based modularization for lifecycle design	modular products			modular upgradability				photocopiers	designers	modular design
		case study			resource efficiency						life cycle design
		modularization									reuse
		modular products									maintenance
											recycle
98	Green product design through product modularization using	case study			compatible materials			design structure matrix		engineers	modular design

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		modularization			recyclability			genetics algorithms		designers	product design
		modular products			ease of disassembly			atomic theory			product life cycle
		module merging									green design
											life cycle design
99	Suitable application situations of different postponement approaches:	postponement						mathematical model			
		modularization									
		case study									
100	Dynamic outsourcing through process modularization	organizational modularization	organizational structure	analytical hierarchy process					procurement and marketing module	customers	operational level
		outsourcing							manufacturing module	scholars	
		modular systems							shipping module		
		modularization									
		modular organization									
101	Toward Mass Customized Product Deployment in E- Commerce: The	customization		modular components				modularization function	bicycle industry		
		postponement									
		degree of modularity									

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		modular product architecture									
		mass customization									
102	Current status and technical description of Chinese 2 × 250 MWth HTR-	standardization					shorter construction schedules	economic competitiveness	high- temperature gas- cooled test		design
		modularization					reduced financial costs	common auxiliary systems			engineering
		modular reactors					simple systems				
		multiple-module plant					production efficiency				
							life cycle costs reduction				
103	Economic potential of modular reactor nuclear power plants based on the	modular reactors			specific costs		cost reduction	cost model	high- temperature gas- cooled test		design
		modularization			technical uncertainties		mass production	economies of experience			engineering
							economies of scale	down scaling cost reduction			modular design
							risk reduction				
104	From field to factory—Taking advantage of shop manufacturing for	modular reactors		internationally accepted standards			learning	cost model	high- temperature gas- cooled test		construction
		modular factory					shorter construction schedules	safe design			manufacturing
		multiple-module plant					reuse	factory assembly modularization			design
		modularization					modular factory pre-assembly	series build program			module building

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
											maintenance
105	Future manufacturing approaches in the chemical and pharmaceutical	modularization			economies of scale			modularized continuous plant	pharmaceutical and biotech industries	engineers	modular process design
		modular plant									development
		modular platforms									
		standardization									
106	Safety design approach for onshore modularized LNG liquefaction plant	modular structures							liquefaction plant		modular design
		modularization									
		case study									
107	Small scale, modular and continuous: A new approach in plant design	standardized modules			module selection		greater speed to market	reuse	pharmaceutical and biotech industries		modular design
		modular plant			optimal module combination		cost reduction	modular factory pre-assembly			
		modular processes			fixed and variable costs		initial investment reduction	module database			
		compatible modules					flexibility	modularized continuous plant			
		equipment modularity									
		modular design space									
		modularization									

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		case study									
108	Computer-aided web-based application to modular plant design	modular plant		modularity technology	levels of modularization			reuse		engineers	modular design
		modularization			standards and design rules			computer-aided plant design			conceptual design
		standardization						module database			construction
109	Efficient Engineering by Modularization into Package Units	modularization					project execution time reduction	process simulation tool	high pressure liquid chromatography	customers	modular design
		standardization						software tool			
		modular plant									
		standardized modules									
		modularized planning									
		skid modules									
110	Manufacturing efficiency by modular multipurpose plants	modular plant					flexibility	modularized continuous plant			
111	Net present value analysis of modular chemical production plants	modular plant			flexibility	material and space invested for building	learning	flexibility	chemical plants		development
		manageable parts			economies of scale		initial investment reduction	design reuse			construction
		case study			modules independence		greater speed to market	scalable production capacity			operation phase
							exchangeability				

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
							modules built and operated separately investment				
							spread over time energy efficient operating point				
112	Modularity And outsourcing: the nature of co-evolution of product	outsourcing		module boundaries	knowledge management	initial design costs	modules reconfigurable standard interfaces	testability	automotive industry	oem	modular design
		product architecture		decreased interdependence between	slow the obsolescence	initial engineering costs	strategic drivers	architectural innovation	automobile industry	suppliers	
		organization architecture		de-coupled interfaces	set-up costs				personal computer industry	module supplier	
		modularity in use			tradeoffs between integrality and					first-tier suppliers	
		modularity in production			module boundaries						
		degree of modularity			hierarchies						
		modular product architecture									
		modularity in organization designs									
		postponement									
		customization									
		components' mix and match									
		standardization									

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		one-to-one mapping									
		modular organization									
114	The modular consortium in a new VW truck plant in Brazil: new forms of	modular consortium	new "greenfield" plant	partnerships	economic risk		organizing complex products and		automotive industry	subcontracting firms	assembly
		outsourcing	product platform architecture		technological risk					engineers	
		case study	advanced technological knowledge		managing interface specifications					suppliers	
										assemblers	
115	Antecedents and Outcomes of Modular Production in the Brazilian Automobile	theoretical model	technological change		knowledge management	information encapsulation	supplier-buyer relationships	product variety	automobile industry	suppliers	modular production
		strategic modularization	efficient communication mechanism		competitivity	supply chain coordination	flexibility gain	components' reuse	modular firms	module supplier	assembly
		modular consortium	physical proximity		blurry firm's boundaries	risk of losing the core business capabilities	product development cost reduction	flexibility	new "greenfield" plant	managers	modular development process
		case study			market change		production costs reduction	collaborative arrangements		assemblers	
		strategic flexibility			customer needs		cycle time	modules production decentralization		buyers	
		competitive strategies			demand heterogeneity		components' mix and match				
		module boundaries			resource chains		manufacturing plant adopting strategic				
		production process decentralization					less employees necessary				
		modularization					cost structure				

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							greater speed to market				
							job turnaround times reduction				
							waste reduction				
							knowledge transfer				
116	Modularisation and outsourcing: who drives whom? A study of	product architecture							personal computer industry	oem	conceptual design
		case study							automotive industry		product development
		modularization									
		outsourcing									
117	Modular production and technological up-grading in the automotive industry: a	case study			multiple, interlinked hierarchies		cost reduction	task structure matrix	automobile industry	customers	modular production
							constantly upgraded elements			suppliers	modular design
							greater productivity				
119	Strategic modularisation and performance implications in the Brazilian	modular production			dynamic capabilities		cycle time	modular supply chains	automotive industry	managers	new product development
		conceptual framework			market change		job turnaround times reduction			suppliers	
		strategic modularization			supplier-buyer relationships		waste reduction			module supplier	
		degree of modularity					relationship with suppliers			assemblers	

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		knowledge sharing					slow the obsolescence			buyers	
		conceptual model									
		modular product, process, and knowledge									
		components' mix and match									
		case study									
		modular supply									
120	Reconfigurable Manufacturing Systems	modular components		standardization	manufacturing responsiveness		reduced lead time	increased specialization	reconfigurable manufacturing systems		design
		modular architecture					reconfiguration time	configuration options			modular assembly
		modular machine						module variety			modular construction
		modules interface						design for reconfigurability			
		case study									
		modules library									
		modular design method									
121	Lifecycle oriented design of technical Product-Service Systems	process modularization		standardized interfaces				life cycle oriented process design			product design
		case study									reuse

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		life cycle oriented modularization									design
122	Integrating sustainable development in the supply chain: The case of life cycle	complex systems decomposition supply management case study life cycle assessment		design structure matrix	design parameters						design
123	Modular Production Systems: A New Manufacturing Paradigm	modular production system		standardized modules			slow the obsolescence	flexible production	automation systems	suppliers	reuse
		modular manufacturing architecture					cost reduction		production systems		modular design
							easier maintenance		electronics industry		redesign
							reconfiguration costs				
							reconfiguration time				
							knowledge transfer				
124	life cycle assessment	modular life cycle assessment									
	Poconfigurability	case study									
125	Reconfigurability Considerations in the Design of Components and	reconfigurability									design for reconfigurability
											modular design

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
126	Life Cycle-Based Service Design for Innovative Business Models	product family		standardized parts	quality			unique service modules	modularized contracting	customers	
		service module			cost structure					suppliers	
		service modularization			resource efficiency						
127	Product modularity for life cycle design	modular structures			product life cycle		recyclability	modular design method	printers		modular design
		geometric feasibility of modules			cost structure		ease of disassembly				life cycle design
		case study			environmental loads		easy product diagnosis, maintenance,				
		modularization					modular upgradability				
128	Modular reconfigurable flexible final assembly systems	reconfigurability modular assembly systems modular building blocks		standardized interfaces				modular semi- automatic approach	flexible manufacturing systems (fms)	vendors	modular assembly
129	Applying collaborative design and modularized assembly for automotive	modular products designing modular products design modularization case study						modularized collaborative design on-line configuration of modularized	automotive industry		design for assembly
130	Constructing a virtuous cycle of manufacturing agility: concurrent roles of	modular platforms					agility of manufacturing	combinatorial modularity	automotive industry		manufacturing

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		product architecture					manufacturing lead time reduction	learning			design
		modular architecture					flexibility	mathematical model			
		product platform architecture					product upgradability				
		modular product architecture									
131	Mechanical Bus for Modular Product Design	modular products		design interfaces	modules interface		manufacturing efficiency	parallel manufacture of module	personal computer industry		modular design
		modules connections					customization	parallel assembly	gardening power tools		assembly
		modular platforms					product upgradability				platform design
		modular product architecture					more efficient design process				
		case study					simplified assembly				
							improved serviceability				
							easy components' upgrading				
							ease of disassembly				
132	Platform for the Integration of Assembly, Disassembly and Life Cycle Management	modular products		standardized interfaces						manufacturers	product life cycle
		modular structures									modular construction
		modular components									assembly

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
133	Managerial implications of the modular consortium model in a Brazilian	modular consortium			cost reduction		new niche markets and business	connected supplier production lines	automobile industry	module supplier	production
		outsourcing			supply chain coordination		cross- organisational teamwork	new form of supplier–custom er relationship	automotive industry	suppliers	design
		modularization			market share			supplier's responsibility		first-tier suppliers	manufacturing
					competitive intensity			conceptual model		manufacturers	assembly
					materials flow						
134	Outsourcing in the automotive industry: From JIT to Modular Consortia	modular consortium				difficult to adapt existing or "brownfield"	supplier-buyer relationships	partnerships	automotive industry	suppliers	manufacturing
		outsourcing					interfirm learning			manufacturers	assembly
		governance challenges								first-tier suppliers	design
		modular supply								VAST suppliers	
										module supplier	
										buyers	
135	Modular production networks: a new American model of industrial	modular production network		internationally accepted standards	make-or-buy decisions		economies of scale	partnerships	contract manufacturing	turn-key suppliers	production
		modular product designs			limit high levels of mutual dependence		risk reduction		electronics industry	suppliers	new product development
		product innovation					cost reduction		personal computer industry		
		modular product markets							telecommunicati ons		

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		case study									
		modular network									
		value chain modularity									
136	Industry Co-Evolution and the Rise of a Shared Supply- Base for Electronics	I INI AFIIFM			customer needs		interfirm specialization	organizational flexibility	contract manufacturing	suppliers	modular design
		modular supply						shared supply base			
		outsourcing									
		modular production network									
		case study									
		value chain modularity									
137	Modular Self- Reconfigurable Robot Systems [Grand Challenges	modular building blocks		uniform docking interfaces	reconfigurability		versatility		modular self- reconfigurable robotic systems		
		product architecture					robustness		space exploration		
							low cost		bucket of stuff		
138	Evolved and Designed Self- Reproducing Modular Robotics								modular robotics		conceptual design
									self-reproducing machines		design
139	M-TRAN : Self- Reconfigurable Modular	modules connections					efficiency		modular transformer		module design

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140	Modular robots	modular systems					versatility		modular self- reconfigurable robotic systems		
							robustness				
							low cost				
141	Evaluating Efficiency of Self- Reconfiguration in a Class of Modular Robots	homogenous modules						mathematical model	mechatronics industry modular self- reconfigurable robotic systems		
142	Modularity and the Impact of Buyer–Supplier Relationships on the	modularity in product designs			customer's autonomy		more flexible supply chain	supplier-buyer relationships	automobile industry	customers	product design
		modular components			autonomy		modules quality control	modularity's effects on buyers		buyers	
		interfirm modularity			relationship duration		flexibility	failure rate model			
		high/low- modularity			customer needs						
		case study			suppliers' switching						
143	A review of power electronics interfaces for distributed energy systems	standardized interfaces	hierarchies	functional building blocks standardization	intellectual property		maintenance	final modular assembly into customer sites	modular power electronics		design for testability
		standardized controls		of communication	scalability		high volume production	integrated power electronics			
		hierarchical control structure			modules connections		reduced engineering effort				
		interfaces' commonality					low cost				
		standardization					system reliability				

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							durability of performance				
144	Modular Approach Simplifies Power-System Design	optimization					greater speed to market	highly integrated and intelligent power modules			design simplification
		standardization									
146	On Modularity Clustering	clustering methods						integer programming			
		complex systems management						mathematical model			
		measure of modularity						modularity algorithm			
		optimization									
147	Service Architecture and Modularity	service architecture		product architecture decomposition	customer needs	strenghs of integral architecture	strenghs of integral architecture	service modularity function	banking	designers	new product development
		degree of modularity			dynamic architectures		replication ability	mathematical model	service industries		
		modular architecture			defined component interfaces		customization	modular service platform	modular supply chains		
		product architecture					service customization	mass replication	service		
		modular systems					specialized modules	sensitivity analysis	service bundle		
		modularity dimensions					replicability	unique service modules	logistics service providers		
		modular product architecture					product variety		sea cruise service		
		components' mix and match									

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		mass customization									
		division of labour									
		outsourcing									
		modularization strategies									
		coupling index									
		combinatorial modularity									
		modules interface									
		product interfaces									
		interfaces in services									
		case study									
		modular service architecture									
148	Managing modularity of product architectures: toward an integrated	modular product architecture		standardized interfaces	tradeoffs between integrality and	information encapsulation	substitutability	mathematical model	elevator manufacturing industries	firms	new product development
		defined component interfaces			technological risk	easy imitation risks	economies of scale	modularization function			modular design
		degree of modularity			product novelty		cost reduction	specialized capabilities			reuse
		product architecture			superior performance		firm's specialization	modular upgradability			independent components development

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		coupling index			synergistic specificity		limited imitation	critical components identification			
		standardization					economies of substitution	modular innovation			
		component sharing					product variety	platform flexibility			
		outsourcing					module task specialization	incremental improvements such as upgrade,			
		case study					inventory costs				
		modularization					logistics costs				
							life cycle costs reduction				
							shorter product life cycles				
							system reliability				
149	Capturing the degree of modularity embedded in product architectures	modular product architecture		standardized interfaces	tradeoffs between integrality and	synergistic specificity	recombination	mathematical model	automobile industry		organizational design
		degree of modularization		component standardization	coupling index		product variety	modularization function	elevator manufacturing industries		
		product interfaces		substitutability	cost and benefit implications		components' redesign	easily separable components			
		new components development		managing interface specifications			de-coupled interfaces	decomposing product designs			
		product architecture		new product development			economies of scale	theoretical model			
		degree of modularity					outsourcing				

ID	PAPER TITLE	Modularization definition related concepts	Pre-conditions	Enabling factors	Critical factors	Limits	Advantages	Advancement / Innovational aspects	Application fields	Actors involved	Timeline
		supplier/buyer interdependence					strategic learning				
		standardization					recombination				
		component customization									
		modular components									
		module commonality									
		module boundaries									
		innovation typology									
150	Management of product architecture modularity for mass customization:	modular product architecture		complex systems decomposition	low cost		economies of substitution	mathematical model	management	suppliers	modular design
		mass customization		managing interface specifications	customer needs		product variety	modularization function	personal computer industry	competitors	
		outsourcing		substitutability	customization		transaction costs reduction	modular innovation	automobile industry	customers	
		modularization strategies		product architecture decomposition	limited imitation				elevator manufacturing industries		
		product modularity strategies		standardized interfaces	resources sharing						
		degree of modularity		component modularization	modules interface						
		product architecture		modular interface redesign							
		components' mix and match									

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		modular architecture									
		degree of modularization									
		value chain modularity									
151	The Modular Growth Design Problem	modular equipment size			customer needs			mathematical model		customers	design
					average annual cost						
					multimodule problems						
152	Introducing a platform strategy in product development	modularization		platform design	supplier-buyer relationships		product variety		automation systems	suppliers	modular assembly
		standardization		standardized interfaces	design interfaces		component variety reduction		automobile industry		
		platform strategy			flexibility		reduced lead time				
		product architecture					quality				
		modular architecture					greater productivity				
		organizational design					cost reduction				
							design simplification				
153	Planning for Product Platforms	product platform architecture			differences between modular and		components' reuse		automotive industry		product development
154	Toward a Product System Modularity Construct: Literature Review and	modular products		separability	design parameters		product variety	combinatorial modularity	software industry		design

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		components' commonality		standardized interfaces			reconfigurability	ease of disassembly	personal computer industry		
		function binding		loose coupling							
		literature review		product architecture decomposition							
		modularity in design		one-to-one mapping							
		modularity in production									
		types of modularity									
		function modules									
		production modules									
		modularity in use									
155	Architectures for product families	product family		standardized interfaces	tradeoffs between integrality and		product variety	allocation process			assembly
		technology modules		one-to-one mapping			flexibility				reuse
		product architecture					changeability				design
156	Module design with substitute parts and multiple vendors	standardized modules			fixed and variable costs		product development time reduction		electronics industry	vendors	modular design
		modular product designs			plant cost		product development cost reduction			suppliers	redesign
		theoretical model			economic competitiveness						development

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157	Design of assembly systems for modular products	modular products		component standardization			modular assembly	modularity algorithm	personal computer industry		assembly
		components' mix and match					agility of manufacturing				manufacturing
		product family									modular design
		modular product architecture									
158	Modular product design and product support	standardization			inventory costs	higher replacement/dis posal costs	modular products are easier to	cost model	automotive industry		modular design
					modules integration costs	higher design cost	manufacturing costs		electronics industry		assembly
159	Defining Modules, Modularity and Modularization	standardization		standardized interfaces	customer needs		rationalization	competitive performance	consumer electronics industry		design
		customization		interfaces' commonality	demand heterogeneity		flexibility	independent testing	toys industry		manufacturing
		literature survey		between the physical and the			creation of variety	modules as carriers of knowledge			design reuse
		modular building blocks		defined component interfaces	perception of modularity from different points		complexity reduction	intellectual reuse			
		modular products					similarity	interchangeabilit y			
		platform design					resource efficiency				
		systems architecture					product variety				
		system's functionality					testability				
		self-contained functional unit									

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		combination of modules									
		mass customization									
		non-module									
		modular structures									
		non-physical modules									
160	Modularity and Commonality Research: Past Developments and	commonality	competitive industry environment	function allocation to physical	optimal modular design	performance degradation		rapid innovation	software industry		product development
		combinatorial modularity	information structure	interfirm networks	assembly costs reduction		more flexibility in the manufacturing	innovation diffusion			process development
		components' mix and match			inventory costs		parallel testing	materials recycling			modular design
		measure of modularity			maintenance		flexibility gain				manufacturing
		product family					ease of disassembly				modularity in design
		organizational modularization									modularity in use
		degree of modularity									modularity in production
		product architecture									
		similarity									
		learning organizations									