Online-Appendix zu

„Discussion of automotive trends and implications for German OEMs”

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Appendix

Appendix 1: *KPIs BMW AG 2010-2019*

KPI/Year	2010	2015	2019	CAGR '10-'19	Sources
Revenue (billion)	60.477	92.175	104.210	6.23%	BMW AG (2011, 2016, 2020)
Operative income (billion)	5.092	9.593	7.411	4.26%	BMW AG (2011, 2016, 2020)
Operative margin	8.42%	10.41%	7.11%	-1.86%	Calculation
Retained earnings (billion)	23.447	41.027	57.667	10.52%	BMW AG (2011, 2016, 2020)
R&D expenses (billion)	3.082	4.271	5.952	7.59%	BMW AG (2011, 2016, 2020)
R&D margin	5.10%	4.63%	5.71%	1.27%	Calculation
Employees	95,453	120,726	126,016	2.64%	BMW AG (2011, 2016, 2020)

Appendix 2: *KPIs Daimler AG 2010-2019*

KPI/Year	2010	2015	2019	CAGR '10-'19	Sources
Revenue (billion)	97.761	149.467	172.745	6.53%	Daimler AG (2011, 2016, 2020a)
Operative income (billion)	7.273	12.739	4.050	-6.30%	Daimler AG (2011, 2016, 2020a)
Operative margin	7.44%	8.52%	2.34%	-12.04%	Calculation
Retained earnings (billion)	20.553	36.991	46.329	9.45%	Daimler AG (2011, 2016, 2020a)
R&D expenses (billion)	4.850	6.560	9.662	7.96%	Daimler AG (2011, 2016, 2020a)
R&D margin	4.96%	4.39%	5.59%	1.34%	Calculation
Employees	260,100	284,015	298,655	1.55%	Daimler AG (2011, 2016, 2020a)

Appendix 3*: KPIs Volkswagen AG 2010-2019*

KPI/Year	2010	2015	2019	CAGR '10-'19	Sources
Revenue (billion)	126.875	213.292	252.632	7.95%	(Volkswagen AG, 2011, 2016, 2020a)
Operative income (billion)	7.141	-4.069	16.960	10.09%	(Volkswagen AG, 2011, 2016, 2020a)
Operative margin	5.63%	-1.91%	6.1%	1.98%	Calculation
Retained earnings (billion)	35.461	69.039	96.929	11.82%	(Volkswagen AG, 2011, 2016, 2020a)
R&D expenses (billion)	6.866	11.583	14.306	8.50%	(Volkswagen AG, 2011, 2016, 2020a)
R&D margin	5.41%	5.43%	5.66%	0.51%	Calculation
Employees	399,381	585.,242	641.838	5.41%	(Volkswagen AG, 2011, 2016, 2020a)

Appendix 4: *Market share development of German OEMs in China 2010-2019*

Company/Year	2010	2015	2019	Sources
Daimler (sales in thsd.)	160	400	694	Daimler AG (2011, 2016, 2020a)
Daimler (%)	1.2%	2.0%	3.1%	Calculation
BMW (sales in thsd.)	172	464	725	BMW AG (2011, 2016, 2020)
BMW (%)	1.3%	2.3%	3.3%	Calculation
Volkswagen (sales in thsd.)	1,925	3,542	4,229	Volkswagen AG (2011, 2016, 2020a)
Volkswagen (%)	14.2%	17.3%	19.0%	Calculation
Others (sales in thsd.)	11,343	16,094	16,552	Calculation
Others (%)	83.4%	78.5%	74.6%	Calculation
Total (sales in thsd.)	13,600	20,500	22,200	BMW AG (2011, 2016, 2021)

Appendix 5*: Market share development of German OEMs in Europe 2010-2019*

Company/Year	2010	2015	2019	Sources
Daimler (sales in thsd.)	636	773	992	Daimler AG (2011, 2016, 2020a)
Daimler (%)	4.7%	5.4%	6.3%	Calculation
BMW (sales in thsd.)	791	1,000	1,084	BMW AG (2011, 2016, 2020)
BMW (%)	5.9%	7.0%	6.9%	Calculation
Volkswagen (sales in thsd.)	3,332	3,062	3,627	Volkswagen AG (2011, 2016, 2020a)
Volkswagen (%)	24.9%	21.6%	23.0%	Calculation
Others (sales in thsd.)	8,641	9,365	10,097	Calculation
Others (%)	64.5%	66.0%	63.9%	Calculation
Total (sales in thsd.)	13,400	14,200	15,800	BMW AG (2011, 2016, 2021)

Appendix 6: *Market share development of German OEMs in the United States 2010-2019*

Company/Year	2010	2015	2019	Sources
Daimler (sales in thsd.)	220	359	313	Daimler AG (2011, 2016, 2020a)
Daimler (%)	1.9%	2.1%	1.8%	Calculation
BMW (sales in thsd.)	267	406	376	BMW AG (2011, 2016, 2020)
BMW (%)	2.3%	2.3%	2.2%	Calculation
Volkswagen (sales in thsd.)	257	607	654	Volkswagen AG (2011, 2016, 2020a)
Volkswagen (%)	2.2%	3.5%	3.8%	Calculation
Others (sales in thsd.)	10,856	16,128	15,757	Calculation
Others (%)	93.6%	92.2%	92.1%	Calculation
Total (sales in thsd.)	11,600	17,500	17,100	BMW AG (2011, 2016, 2021)

Appendix 7: *Autonomous driving Index Part 1*

Company	Strategy/ambition	Score	Patents	Score	Field testing	Score	Sources
Daimler	> Cooperation with Bosch (on level 4/5) and BMW on level 4 (however broken relationship)	3	392	2	> 12 testing vehicles	1	Bloomberg (2020a), Bardt (2019)
BMW	> Level 3 roll-out in 2021 > Level 4 research with Daimler planned (however broken relationship)	2.5	612	3	> Over 3 million miles covered with around 140 7-series tested in United States West Coast, Germany, Israel, and China	4	Bloomberg (2020a), Bardt (2019)
Volkswagen	> USD 2.6 billion investment into Argo AI > Strong partnership and joint research in Level 4 AVs	2.5	1,101	5	> Argo AI with 100 vehicles fleet	2.5	Bloomberg (2020a), Bardt (2019)
Tesla	> Tesla autopilot (level 2) already in place however doubts about level 5 announcements	4	n/a	n/a	> Current Tesla owners consistently train autopilot when engaged or in shadow mode > 1 billion miles driven by 2018	5	Bloomberg (2020a)
Toyota	> USD 4 billion investment into autonomous driving, including USD 400 million into partnership with Pony.ai Inc.	2.5	548	3	> Few own test vehicles but Pony.ai Inc. covered more than 100,000 driverless rides (1 million kilometers) using 100 test vehicles	3	Bloomberg (2020a), Bardt (2019)

Appendix 8: *Autonomous driving Index Part 2*

Company	Strategy/ambition	Score	Patents	Score	Field testing	Score	Sources
General Motors	> Acquisition of Cruise provides > General Motors with leading position	3.5	640	3.5	> Cruise with over 200 test vehicles and 2 million miles driven since 2016	4	Bloomberg (2020a), Bardt (2019)
Volvo	> Level 3 introduction in 2022 > Significant R&D expenses (1.2 billion in 2019) > Strong focus on inhouse development but also partnerships with Zhejiang Geely Holding Group Co and Uber (buying self-driving companies from Volvo)	3	14 in 2017	1.5	> Field testing in Sweden as well as through partnerships with Uber	4	Bloomberg (2020a), Bardt (2019)
Nio	> Nio Autonomous Driving (NAD): High resolution camera and sensors and very strong computing power in ET7 > Promising to be 8 times more powerful than Tesla Autopilot	4	n/a	n/a	n/a	n/a	Moloughney (2021)

Appendix 9: *Connectivity Index Part 1*

Company	Model	Price [EUR]	Connectivity/app services	Score	Sources
Daimler	A-Class	37,800	+ Very good services (voice recognition, call quality, calendar etc.) + Good "Mercedes me" functionalities - Only USB-C compatible	4	Bender et al. (2020)
BMW	The 1	48,900	+ Very good services included (Real time traffic data, connected music, OTA-Map update) + Comfortable usage due to excellent "BMW Connected " app - high price for "connected package"	4	Bender et al. (2020)
Volks-wagen	Golf VIII	35,000	+ App "We Connect" with some good services (Navigation, Traffic) - Limited functionalities (no Email Service, no calendar, no fuel costs service)	2.5	Bender et al. (2020)
Tesla	Model 3	54,000	+ Over-the-air updates + Several features included (browser, Spotify and route/charge planning) - Voice recognition with minor problems - High price for "Premium package" after free first year	4	Bender (2020)
Toyota	Toyota Corola	36,090	+ Small price - Only basic information available via app (fuel consumption, location)	2.5	Bender et al. (2020)
General Motors	Cadilllac XT 5	48,800	+ Easy connection with Android and Apple phones - "MyCadillac" app with limited features	3	Waasen (2016)
Volvo	Volvo V90	49,700	+ Good integration of Apple Carplay and Android Auto + Variety of apps available - No E-Mail or calendar function and no browser	3	Bender and Ekmen (2020)
Nio	Nio ES 6	46,000	+ App offers maintenance and “NIOPower” services + Real-time chats with other NIO customers or employees + App with highest ranking in OEM category - Configured for Chinese market with mainly Mandarin symbols	4.5	ADAC (2020a), Nio Inc. (2021a)

Appendix 10: *Connectivity Index Part 2*

Company	Model	Price [EUR]	Infotainment	Score	Sources
Daimler	A-Class	37,800	+ High-definition screens + Arbitrary configuration and exchange of displays - Features can also be overwhelming and challenging - High additional price	4	Bender et al. (2020)
BMW	The 1	48,900	+ High-definition screens (with split-screens and screen mirroring) + Head-up displays and multiple control options - Minor weaknesses with voice recognition speed and display size	4	Bender et al. (2020)
Volks-wagen	Golf VIII	35,000	+ Car can differentiate between driver and co-driver voices + Wireless Apple Carplay - Some features not intuitive - Minor software bugs	3.5	Bender et al. (2020)
Tesla	Model 3	54,000	+ New Tesla philosophy with reduced interfaces and one large screen + Dashcam function with camera from autopilot - No Apple Carplay or Android Auto available	4	Bender (2020)
Toyota	Toyota Corola	36,090	+ Head-up display + 7-inch cockpit screen + No additional fees - "Legacy" displays - Poor voice recognition	2.5	Bender et al. (2020)
General Motors	Cadilllac XT 5	48,800	+ Large screens with easy exchangeability + Very good sound quality - Basic and not very innovative functions - Poor live traffic	3	Waasen (2016)
Volvo	Volvo V90	49,700	+ Appealing user interface with two large screens + Good sound system + Good integrated apps - Voice control with weaknesses - Complicated due to missing short cuts	3	Bender and Ekmen (2020)
Nio	Nio ES 6	46,000	+ High-quality screens and head-up display + Interactive assistant "Nomi" supporting and entertaining driver and passengers - Knowledge in Mandarin required	3.5	ADAC (2020a), Nio Inc. (2021a)

Appendix 11: *Connectivity Index Part 3*

Company	Model	Price [EUR]	User experience	Score	Sources
Daimler	A-Class	37,800	+ Many features (very good voice recognition) - Sometimes overwhelming and difficult to use	3.5	Bender et al. (2020)
BMW	The 1	48,900	+ Many features with very good and intuitive usability - Small bugs within app	4	Bender et al. (2020)
Volkswagen	Golf VIII	35,000	+Apple Carplay, E-Call and further applications - Rather disappointing usage for customers - Limited functions and sometimes difficult to understand	2	Bender et al. (2020)
Tesla	Model 3	54,000	+ Very good navigation system + "Guard Mode" protects car from theft - Problems with voice recognition	4	Bender (2020)
Toyota	Toyota Corola	36,090	+ Basic Head up display (small) - Pixelated displays - Bad voice recognition	2.5	Bender et al. (2020)
General Motors	Cadilllac XT 5	48,800	+ Easy to use driver supporting displays and features - Limited functionalities	3	Waasen (2016)
Volvo	Volvo V90	49,700	+ Very good app capabilities due to Android Auto and Apple Carplay - Bad voice recognition - Minor flaws within navigation system	3	Bender and Ekmen (2020)
Nio	Nio ES 6	46,000	+ Very good services and entertainment provided by "Nomi" + Further good services from app - Further work required for market entry in non-Chinese countries	3.5	ADAC (2020a), Nio Inc. (2021a)

Appendix 12: *Electrification Index Part 1*

Company	Choice/availability	Score	CAM innovation power index	Score	Sources
Daimler	2 available (EQC + EQV), 2 Smart EV models, several PHEVs	3.5	26	2	Center of Automotive Management (2021), EV Database, 2021)
BMW	2 available (i3, ix4) + 1 concept (i4) + several PHEVs	2.5	18.8	2	Center of Automotive Management (2021), EV Database, 2021)
Volkswagen	2 Volkswagen (ID 3, ID 4) + 2 Audi E-tron (Sportsback, normal) + 1 Seat + Porsche Taycan	3.5	122.6	4.5	Center of Automotive Management (2021), EV Database (2021)
Tesla	3 models (S,X,3)	5	159.4	5	Center of Automotive Management (2021), EV Database (2021)
Toyota	Only large number of hybrids (15 million units sold)	2	5.3	1	Toyota Motor Corporation (2020)
General Motors	Chevrolet Bolt EUV announced for 2021/2022, Bolt EV (US)	1.5	40.2	3	Center of Automotive Management (2021), EV Database (2021)
Volvo	Volvo CX-40 + Polestar 2, strong PHEV position	3.5	36.6	3	Center of Automotive Management (2021), EV Database (2021)
Nio	2 SUV models (ES6, ES8), however only available in China	4	n/a	n/a	EV Database (2021)

***Appendix 13**: Electrification Index Part 2*

Company	Model	Fast charge [kilometers/hour]	Score	Sources
Daimler	EQC 400 4Matic	440	2	EV Database (2021)
BMW	BMW iX3	560	3	EV Database (2021)
Volkswagen	ID4 Pro Performance	460	2	EV Database (2021)
Tesla	Model 3 Performance	920	5	EV Database (2021)
Toyota	No pure EV solution	n/a	n/a	-
General Motors	Opel Ampera (European version of GM's Bolt EV)	210	1	EV Database (2021)
Volvo	Polestar 2	510	2.5	EV Database (2021)
Nio	Nio ES6	Battery change model	5	ADAC (2020a)

***Appendix 14**: Electrification Index Part 3*

Company	Model	Range [km]	Score	Price [EUR]	Capacity [Kilowatt hours]	Price/kWh [EUR]	Sources
Daimler	EQC 400 4Matic	370	3	71,000	85	835.3	EV Database (2021)
BMW	BMW iX3	360	3	66,300	80	828.8	EV Database (2021)
Volkswagen	ID4 Pro Performance	400	4	44,500	82	542.7	EV Database (2021)
Tesla	Model 3 Performance	460	5	58,560	82	714.1	EV Database (2021)
Toyota	No pure EV solution	n/a	n/a	n/a	n/a	n/a	-
General Motors	Opel Ampera (European version of GM's Bolt EV)	335	2.5	42,990	58	741.2	EV Database (2021)
Volvo	Polestar 2	395	4	57,900	78	742.3	EV Database (2021)
Nio	Nio ES6	410	4	46,000	70	657.1	ADAC (2020a)

Appendix 15: *Shared mobility Index*

Company	Sharing Services	Score	Sources
Daimler	> Free floating carsharing platform "Sharenow" with 11,000 cars > "Mercedes me" app for private car sharing > "Free Now" for cabs and more shared solutions in cooperation with BMW	3.5	Share Now (2021) Reuters (2020)
BMW	> Free floating carsharing platform "Sharenow" with 11,000 cars > "Free Now" for cabs and more shared solutions in cooperation with Daimler	3	Share Now (2021) Reuters (2020)
Volkswagen	> "MOIA" for ridesharing > Free-floating platform "We share" > Exclusive partnership with Didi	3.5	Germis (2019) Shah and Shirouzu (2018)
Tesla	> First steps such as carsharing of Model 3 in United States however no existing larger service > Ambitious plans by Elon Musk	1.5	Donath (2020)
Toyota	> Recently founded European mobility platform "Kinto" with full-service-leasing and ride-sharing (further services to be evaluated) > Japanese mobility platform "Toyota share" mainly for rentals and leasing	3	Toyota Motor Corporation (2020)
General Motors	> Carsharing platform "Maven" shut-down in 2020 after 4 years of unprofitable business > Strong investment into Lyft	2	DeBord (2020) Klayman (2019)
Volvo	> Potential AV provider for Uber > Full-Service-Leasing package "Care by Volvo" > Car sharing platform "Sunfleet" 1,700 cars	3.5	Volvo Group (2018) Knieps (2019)
Nio	> Cooperation with China's second largest ride sharing platform Dida Chuxing announced > Currently no service in place	2	Zhang (2020)

Appendix 16: *Sales volumes and market capitalizations*

Company	Sales Volume (2020)	Market cap. [in billion USD][1]	Market cap./sales [USD]	Sources
Daimler	2,840,000	96.1	33,838	Daimler AG (2021a), Companies Market Cap (2021)
BMW	2,325,179	67.1	28,858	BMW AG (2021), Companies Market Cap (2021)
Volkswagen	9,305,000	166	17,872	Volkswagen AG (2021a), Companies Market Cap (2021)
Tesla	499,550	703	1,407,267	Tesla, Inc. (2021), Companies Market Cap (2021)
Toyota	9,528,438	213	22,354	Toyota Motor Corporation, (2021), Companies Market Cap (2021)
General Motors	2,547,339	86.3	33,878	General Motors Corporation (2021), Companies Market Cap (2021)
Volvo	661,713	49.1	74,201	Volvo Group (2021), Companies Market Cap (2021)
Nio	42,728	60.7	1,420,614	Nio Inc. (2021b), Companies Market Cap (2021)

[1] Based on April 15, 2021

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