BMW's 3-Series: Developing a Tradition

BMW's philosophy is to build driving machines that respond faithfully and enjoyably to their driver's commands while also providing the safety, practicality, style, quality, reliability, and durability that help make long-term ownership a rewarding experience. It was BMW's policy to develop new platforms for its series of cars every 7 to 8 years. New platforms were not simply modifications, but completely new structures. According to Friedrich Nitschke, manager for the BMW 3 series development project, there were three goals for the new 3 series platform that came to market in the 1999 model year. First, it was to generate the highest level of customer satisfaction in its class. Second, it was to utilize the best processes available within BMW. Third, it was to generate the most profit of any BMW series.

Developing the successor to the third-generation of 3 series was a real challenge, since it had been an extremely successful series. BMW's chief designer Chris Bangle explains,

> There are two ways of doing car design. Either it's a personality cult, where the designer runs the show and the car is just an ego toy, or the stylist is more the curator of a heritage and tradition. Then, the challenge lies in understanding a marquee so well you become part of it. It's quite clear my job here is to perpetuate a set of icons.

The overall styling of the 3-series was especially important, and was a limiting factor in its design. Models built on the new platform had to look like a BMW and be recognizable on the highway. Focus groups were used to identify the basic design features that made a BMW recognizable, and those traits were maintained in its design. For example, the BMW logo and "double kidney" grill were key recognition factors. The 3 series position in BMW's product line set many of the basic characteristics for the new platform, and would determine the basic characteristics of the models using the new platform. For example, the dimensions, engines and transmissions became part of its target definition.

Building on Tradition

The Bayerische Motoren Werke (Bavarian Motor Works) was created in 1916 through the merger of an aircraft maker and a manufacturer of aircraft engines. BMW's first notable success was the 6-cylinder BMW IIIa engine, which in 1918 powered a biplane to 5000 meters altitude (16,405 feet) in just 29 minutes. Its impressive performance led to strong demand for BMW engines. In 1919, a BMW-powered biplane set a world altitude record of 9,760 meters.

In 1922, BMW produced a small engine for the Victoria motorcycle, and a big truck engine with an overhead camshaft, which was a very advanced feature at the time. BMW engineer Max Friz convinced management to enter the motorcycle business, too. He had designed a prototype using the BMW Boxer engine [a horizontally opposed twin-cylinder engine], rear-wheel drive, and a double-tube frame. The new BMW R32 motorcycle went into production in 1923. Its pioneering technology was still used in the R1100 series introduced in 1993 that includes four models today.

 The Peter Curtius Foundation provided funding for development of this case.

In late 1928, BMW acquired the Eisenach Vehicle Factory, in the city of Eisenach, some 200 miles north of Munich. A manufacturer of cars since 1899, Eisenach produced a single licensed model of England's little Austin Seven. As BMW's first automobile, it was known as the 3/15 or "Dixi." In 1932, a new, larger model called the BMW 3/20 was introduced. A year later, BMW introduced its first sports sedan, a 6-cylinder model called the 303. In 1934, the 303's engine was enlarged to 1.5 liter (from 1.2), and the model-naming system was instituted with the 315/1sports roadster. BMW's 6-cylinder engine was progressively enlarged, to 1.9 and then to 2.0 liters, and finally to 3.5 liters.

During the Great Depression and Europe's political turmoil of the Thirties, BMW established its reputation as a high-quality maker of sporty motor vehicles: compact, sporty sedans like the 326, the elegant 327 coupe and convertible, and the 328 roadster. Aerodynamic racing versions of the 328 were still winning famous races -such as Italy's Mille Miglia in 1939 - when war production brought this era to a close. After World War II ended in 1945, little was left of BMW but the name. The Eisenach plant, where all BMW cars had been produced, was now in the Eastern zone, which became East Germany. BMW rebuilt its bombed-out Munich plant and began production of motorcycles, then tiny hybrid cars, powered by motorcycle engines, called the Isetta. Within a decade, BMW introduced sedans and roadsters with V-8 engines, including the 507, one of the Europe's most coveted postwar collector cars.

BMW introduced the 1500 family car in 1962, with responsive overhead-camshaft 4-cylinder engine, front disc brakes and 4-wheel independent suspension. Germany's unlimited driving speeds encouraged BMW to introduce a performance model as well, thereby beginning BMW's modern sports-sedan tradition. The BMW 1500 spawned a smaller 2-door version and the 2002, which introduced Americans to BMW's sports-sedan concept. A new 6-cylinder generation, like the Bavaria sedan and 3.0 CS coupe, were introduced.

Since 1975, BMW has referred to its smallest line of cars as the 3-Series. The first 3 series achieved higher performance with its 6-cylinder engine. The second generation provided more choices, including 4-doors, convertible and touring models. The third generation, the most successful one, raised driving performance to even higher level, while providing quality equivalent to Mercedes-Benz. The fourth generation, in typical BMW fashion, would undergo a redesign each of the various models in the series. The first models to change were the sedans, next the coupe, then the convertible and hatchback, and finally the wicked M3 sports cars. This sequence of introductions allows BMW to extend the life of the design by stretching out introductions over the course of several years. The current 3 series design had been in production since 1990. The styling of the new 3-series would be similar to its 5- and 7-series cousins.

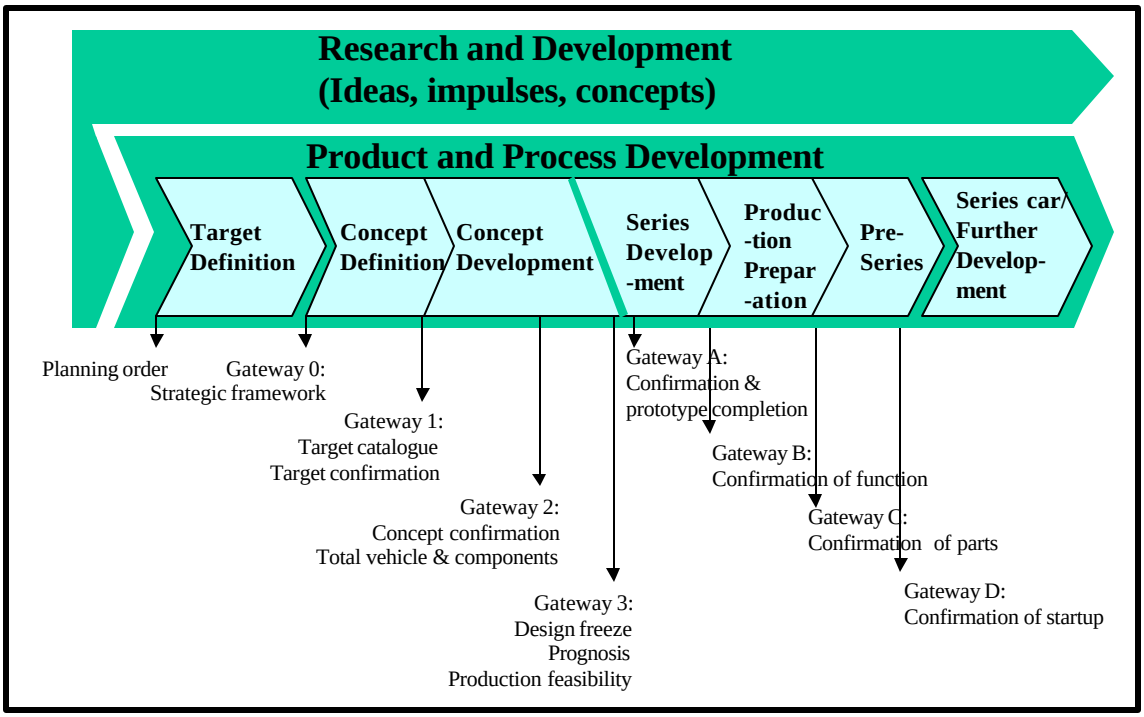
BMW 528i

BMW's Forth-generation 3-Series Platform Development

As one journalist said of the third generation 3 series models, "BMW's beautifully proportioned 3-series cars are still the design pacesetters in this realm" (i.e. small sport sedans). The challenge for Friedrich Nitschke in developing its fourth-generation replacement was to continue BMW's pacesetting tradition. In addition, Nitschke was given the task of implementing BMW's new planning system in developing BMW's 3 series replacement platform. He explained:

> I was given responsibility for developing the new 3-series BMW in 1993. This development process (Figure 1) was introduced in BMW for use in the new 3 series. The target definition gives the basic characteristics of the new platform for the series.

Figure 1: BMW's Product Development Process



Separate teams worked on developing model concepts to be introduced on the new platform. Models included two or four door versions of family and sporty cars. The 3 series included sedan, coupé, compact, touring, convertible, and M3 sports models. The current model lineup included:

3 Series Saloon (316i, 318i, 323i, 328i, 318tds, 325tds, M3)
3 Series Coupé (316i, 318is, 323i, 328i, 328i Sports, M3)
3 Series Compact (316i, 318tds, 318ti)
3 Series Touring (318i, 323i, 328i, 318tds, 325tds)
3 Series Convertible (318i, 323i, 328i, M3)

The new saloon (four-door sedan) would be the first model to be introduced in 1998, having a more powerful 166 horsepower 2.5-liter inline-six engine (323i models) or the 190 horsepower 2.8-liter inline six (328i models). The less powerful in-line four-cylinder engine was being dropped from use in the sedans. Over the next seven years, the other models would be replaced by the new platform, and then beefed up as an M-type model.

Setting the budget.

Based on BMW's experience within Europe, the USA, and Asia, the Marketing Department set the price range for the 3 series between DM 40,000 and DM 60,000, with the price for the compact 316i at around DM 42,000, and for the 328i sports sedan at around DM 60,000. At these prices, marketing estimated that between 2 million and 3 million cars could be sold over the platform life. After estimating the revenues generated from selling 3 million units, management determined the target profit level required for the series. With a revenue prediction and profit goal determined, the top-down target cost budget for the project was set as shown in Figures 2 and 3. Mr. Nitschke explained:

> This strict product development process was introduced with the 3 series in 1994. We would not start the development of the 3 series until we were sure that we could make money with this car. That means that the plan's cost and target cost needs to be nearly equal. In the past, we might have some difference, but we would start the R&D process in hopes of finding ideas to reduce costs. Therefore, we wouldn't meet target profits and would have to implement cost reduction projects as soon as we introduced the new car.

Market Inputs

The concept definition phase of development relied on market inputs. Market inputs and analysis (Figure 4) included data on appeal, customer satisfaction measures, product benchmarks, product reverse engineering, customer call center inputs, market studies, product tests, patents, conjoint analysis, SWOT analysis of the competition, etc. The third generation 3-Series models were compacts, but offered minimal passenger comfort. Some customers had complained about the 3-series' cramped rear seat and sub-par interior. The hard plastic interior was heavily criticized. In fact, as a result, BMW faced new competition from Lexus, Infiniti and Mercedes simply because buyers couldn't justify spending upwards of $40,000 on a car that had a second-rate interior.

Conjoint analysis was an important input in establishing priorities for the new 3 series. As shown in Appendix 1, safety and road behavior were considered the two most important factors in purchasing a new vehicle. Since the early 1990s, BMW had invested heavily, producing the safest and best driving machine on the market (Exhibit 1). BMW set its standards for these factors by benchmarking (Appendix 2) the existing 3 Series, the Mercedes C series, the Audi 90, and, for noise, the more expensive Lexus. Mr. Nitschke explained:

> A goal for the new 3 series is to be one of the quietest cars in its class. As of 1994, Lexus didn't have a direct competitive model, so we looked at the large Lexus for its noise control. Our target was to reach that level of quiet in the new series. The existing 3 series is also a benchmark model, since we want to improve on it. It is good to drive, but the space is restricted and the cockpit isn't great. It is nice, but we will improve the value to the customer. These were the inputs from the market.
>
> This strict product development process was used the first time with the 3 series in 1994. It took about six months to complete the planning phase. We would not start the development of the 3 series until we were sure that we could make money with this car. When we didn't meet the target profits during the design phase, we had to implement cost reduction projects in the manufacturing process of the new model.

The parts portfolio analysis considered what parts in the car have high importance to the customer and how old they are. As Mr. Nitschke explained:

Figure 2: Integrated Market-oriented Top-down Target Cost Management

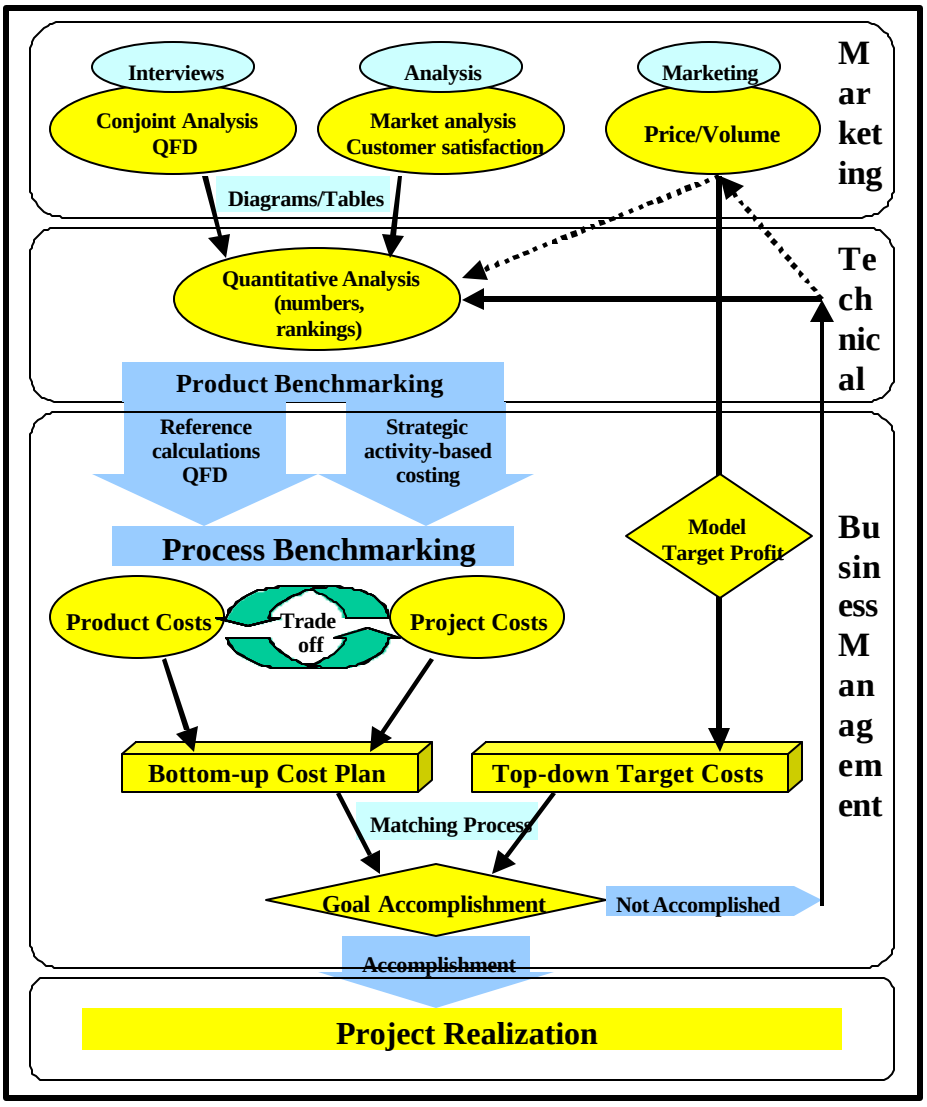


Figure 3: Target Cost Budgeting Model

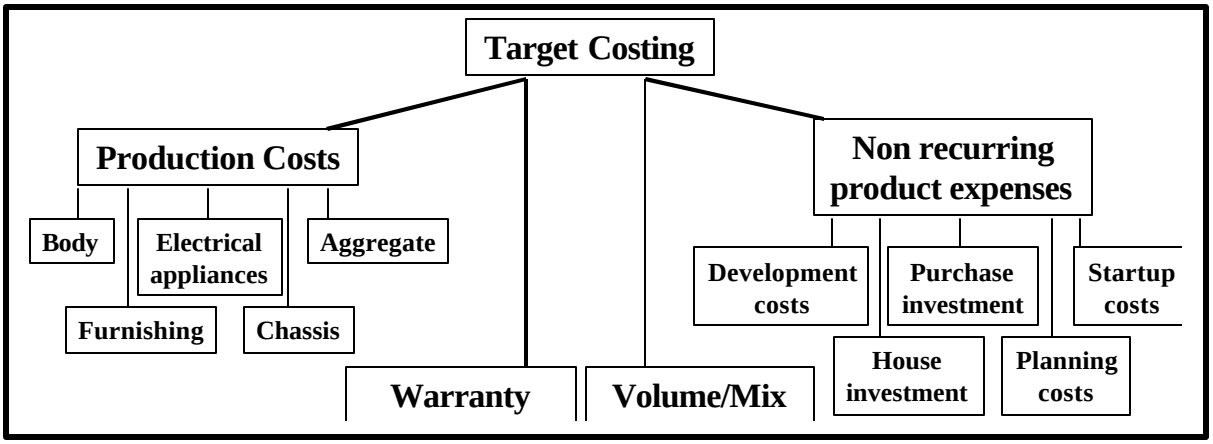
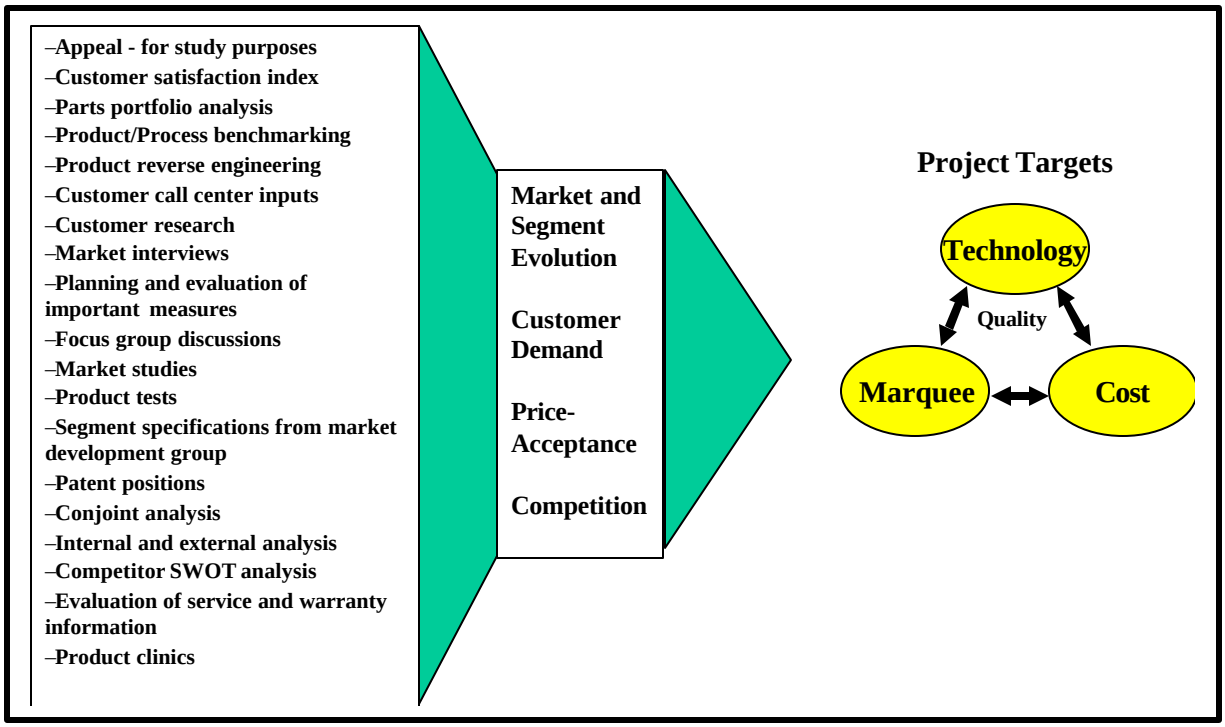


Figure 4: Marketing Instruments and Input Data for Top-down Cost Control



> We consider what parts must be new, and what parts we can take from the previous 3 series, or from the 5 or 7 series. More interior space was a target that resulted from prior owner responses, as was the need for a more luxurious interior. The suspension is an important item in determining the interior space. Changes in rear and front suspension provide more interior space. Since we have a rear wheel drive, we can push the front suspension closer to the front of the car. This is one of the reasons that the interior space is larger. We can also bring the engine behind the front suspension to give the car a more balanced weight ratio between the front and the rear. We also decided to add two centimeters to the length and three centimeters to the width to give additional interior space. Many of the characteristics that the customer does not see, like the basic structure, can be carried over from the previous model.

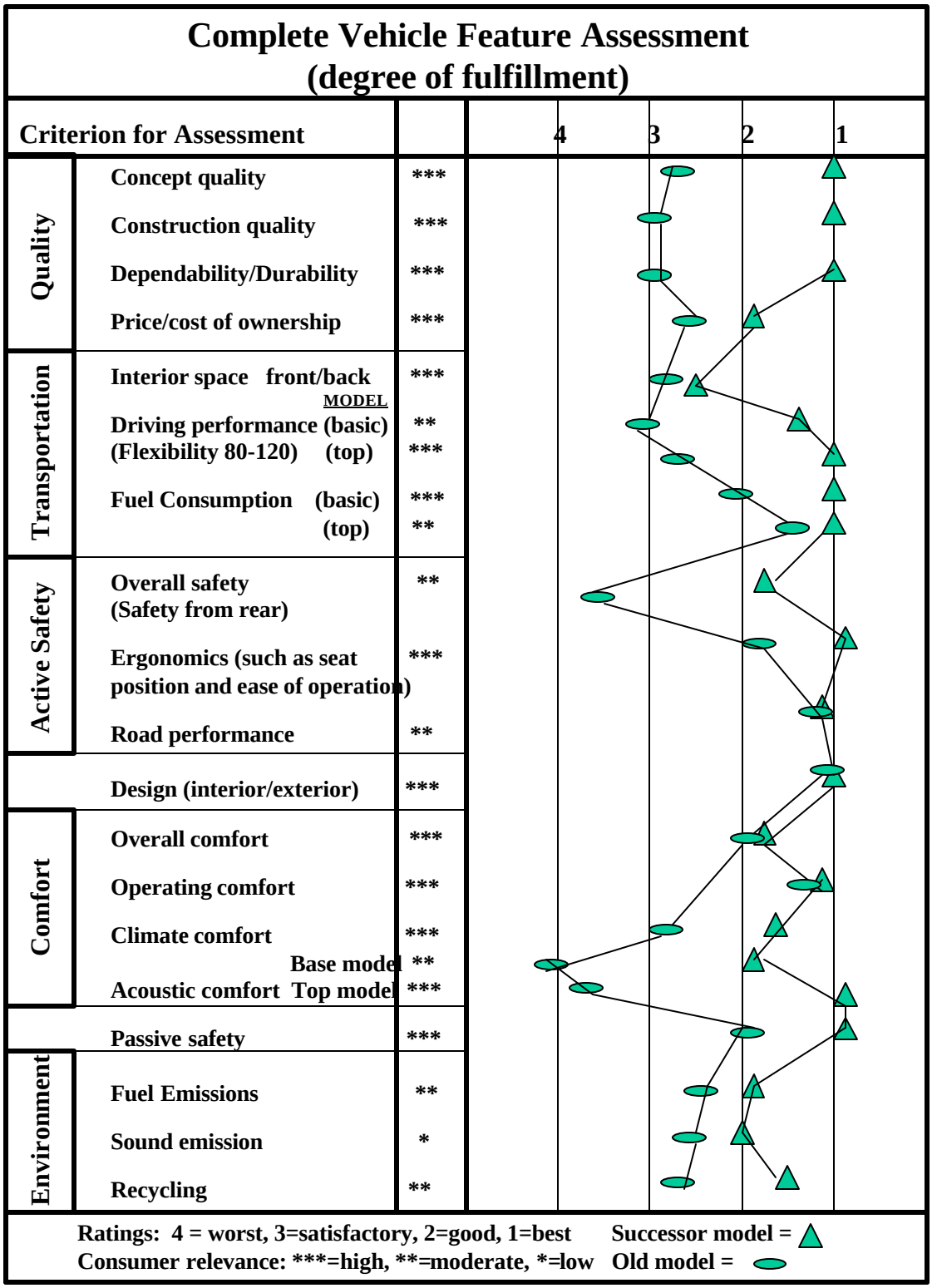
The resulting technology analysis provides the characteristics of the new model (Figure 5). Nitschke continued:

> We look at the competitors' noise levels, aerodynamics, etc., and create in our head what is needed for the new car to be better than the old one. We consider quality, transportation, safety, comfort, and environmental features. We then compare each feature against the old car or competitors' cars to determine what we need to do in each category. In quality, we need to be best in class. In space, we just want to be marginally better. Everybody knows what the key points are for improvement in the new car. Our customer inputs have made that clear.

The target definition included more interior size and higher quality appointments. According to Dr. Anton Heiss, team leader for manufacturing,

> The old 3 series had a problem getting feet under the rear seat. It also felt cramped, so we needed more space between the front seats. We decided to add space to the rear and between the passengers. We also decided that the styling of the dash needed to give a more open feeling.

Figure 5: Next Generation 3 Series Profile



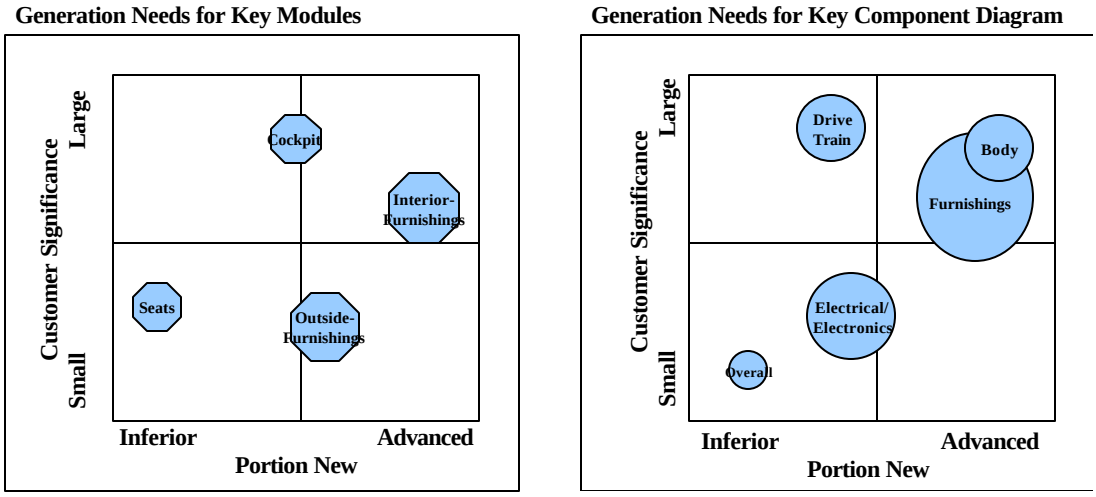
The agenda also included discussion of leather trim and optional leather upholstery, power seats and windows, an on-board driving computer, alloy road wheels, ABS brakes,

dual airbags, and air-conditioning. The team also wanted it to achieve the USA's highest safety rating.

In assessing technologies, each of the major modules and components was analyzed. The portfolio analysis determined priorities for improvements (Figure 6). Nitschke continued:

> We evaluate each component to determine what is good enough, and what must be improved. We create a summary of each area. We know that the body must be new. The customer can see that it is new, and not a face lift. All parts for the skin must be new. There are about 80 such parts that will be new. In the structure, we know that the new safety laws and crash tests require some new parts. The old structure will not pass these new tests. The impact tests and roll over tests will be more stringent in the future. In California, the tests are required. We then determine what parts of the structure must be new, and what can be used from the old model, or taken from the 5 or 7 series. To improve quality, a determination has to be made on what parts must be new and what is good enough, so that there is no real quality problem.

Figure 6: Component/Module Portfolio Analysis



After the priorities for improvement were established, the costs of making changes had to be determined. Table 1 provides the technology framework used to assess all the parts and determine the costs related to planning, R&D, and investment. A vehicle includes about 4000 different part numbers, or 13,000 total parts. An engine, for example, uses the same parts for each cylinder. The technical framework organized each of the 4000 parts into modules and their key components. For example, the interior area includes the cockpit and seats. The seat is one module, and the frame for the seat is one component. Each component includes a number of parts. The part ID number for each module and component was identified.

For example, Nitschke's team had to decide if the back seats from the 3 or 5 series could be used in the new platform. Each part had to be analyzed to determine if it could be used from the prior 3 series, incorporated from the 5 or 7 series, acquired from a supplier, or developed new. Nitschke explained:

> We identify the ID for each part, and then decide what action is needed. The inside hood, for example, can be used for the new series, but the hinge must be new. Of the 335 parts in Table 1, we will create 212 new parts. The airbag generator can be used from the 5 series, so that saves planning, R&D, and investment costs. This analysis lets us

determine at an early stage the cost required for development, R&D, and investment in each technology area.

We haven't pre-determined how much technology will be transferred from the 5 or 7 series. When we tried to do that in the past, it didn't work. The market moves too quickly to determine what parts might be used in a later series. We had developed a new seat for the 5 series that can be used in the new 3 series. The marketing analysis tells us what features we need.

Table 1: Technical Scoring Framework

Module	Code	Supplier	Name	Technical Description	Part count	Same part	New part	Change factor	Plan cost	R&D cost	Invest-ment
10	1234		Outer sidewall	New development	100	2	98	0.5	200	300	3000
20	1235		Front hood	Develop new hinge	50	10	40	1	100	20	100
			"	Use from predecessor							
30	1236	Webasto	Sliding roof	New development	50	0	50	0.8	50	10	1500
40	1237		Airbag generator	Use from 5 series	20	20	0	0	0	5	0
40	1238		Battery w/holder	Use from predecessor							
			"	Develop new holder	5	1	4	0.2	20	10	200
40	1239		Inner lighting	Use from 7 series	10	10	0	0	0	50	0
50	1240		Heating	Use from predecessor,	100	80	20	0.5	200	300	2000
			"	Modify (some change)							
Summary:					335	123	212		570	695	6800

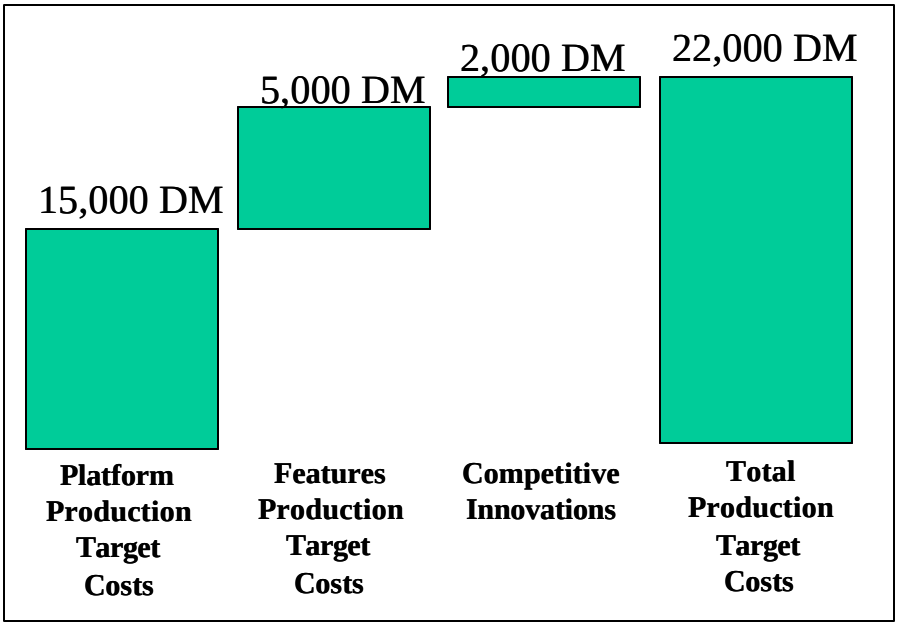
The technical analysis includes the basic vehicle and its standard features. A small budget remained for features that may be included later, but were not specified. The budget (Figure 7) provided DM 2000 for new innovations. Since the concept definition phase was 36 to 40 months before launch, some flexibility was needed. According to Nitschke,

> If we think the car is good enough, we don't need any innovation expense. However, the research department has lots of ideas for new features. The only problem is that they must be able to bring them to high quality within the time needed for launch. If we need two years for development, then we may be able to include those features in the new car. If the quality is not good enough, we don't want it.

BMW's goal for the basic model is to have the best quality and crash performance in its class. That is part of the basic cost. We want the highest safety ratings in this class of car in crash and roll over tests. The basic safety in terms of brakes, steering, frame, etc. is built into the basic car. Some of the innovation money can be spent for safety, and not just gimmicks. Additional side impact airbags can come out of the innovation cost.

It is difficult to determine what is a good feature, and what is a gimmick. The rain detector, for example, was originally developed for the 7 series, but the marketing department said it wasn't a feature that customers wanted. They said that customers would consider it a gimmick or a toy. Then Mercedes Benz introduced a rain detector, so marketing said we had to have it. In the third generation 3 series, customers loved the automatic dimming of the interior lights after you close the door. So that feature will be in the fourth generation 3 series. We usually have more ideas for innovations than we have budget. How do you decide what is right for this car?

Figure 7: Target Cost Budget for New 3 Series



The development teams had to also consider the additional options that would be available for the new series. Other BMW series offered additional features like a sonar distance device (for crunch-free parking), automatic traction control, limited slip differential, metallic paint, sunroof, an anti-theft device, powered front seats with settings memory, and CD players.

Cost Control

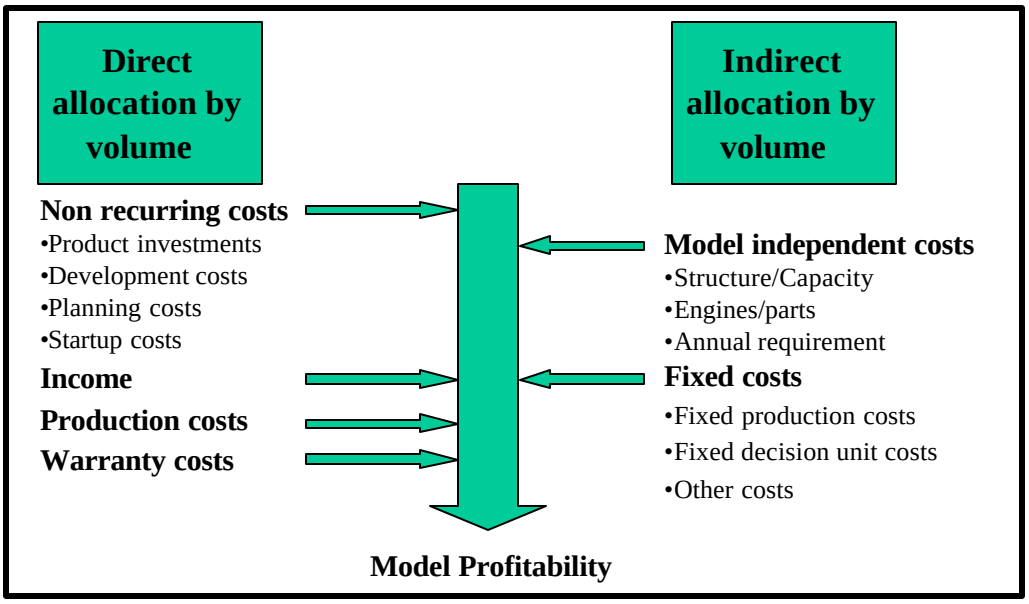
With 75% of the cost of a new series being determined during the planning phase, BMW's new planning process had high visibility. The model profitability is determined after all direct and indirect costs are estimated (Figure 8). Direct costs include the project costs from planning, development, investment, and start-up. Income, variable production costs, and warranty costs are also direct costs. Indirect costs include overhead costs. These bottom-up planning costs are then compared against the top-down target costs, and model profitability levels established by top management. Nitschke continued:

After we complete the technical analysis, we total the planning costs, the R&D costs, and the investment costs. We then have a matching process against the marketing goal. We had a difference of between 15 to 20%. We budgeted DM 2000 for innovation, but we don't know what that will be.

We have some cost drivers that we can change. One is technology. To make a new suspension required investment costs of some DM 200 million, but if we carry over some of the old parts the investment costs are only DM 80 million. We look at what we can carry over to lower our total costs. On one hand, we need no R&D and investment for old parts. On the other hand, the seat of the 5 series costs DM1000, but we have a budget of DM 800 for the 3 series. You have to develop a new seat to realize the DM 200 difference. We look for ways to save investment and R&D, but the cost of an existing part may actually be higher.

In 1994, the matching process took 2 to 3 months.

Figure 8: Costs Affecting Model Profitability



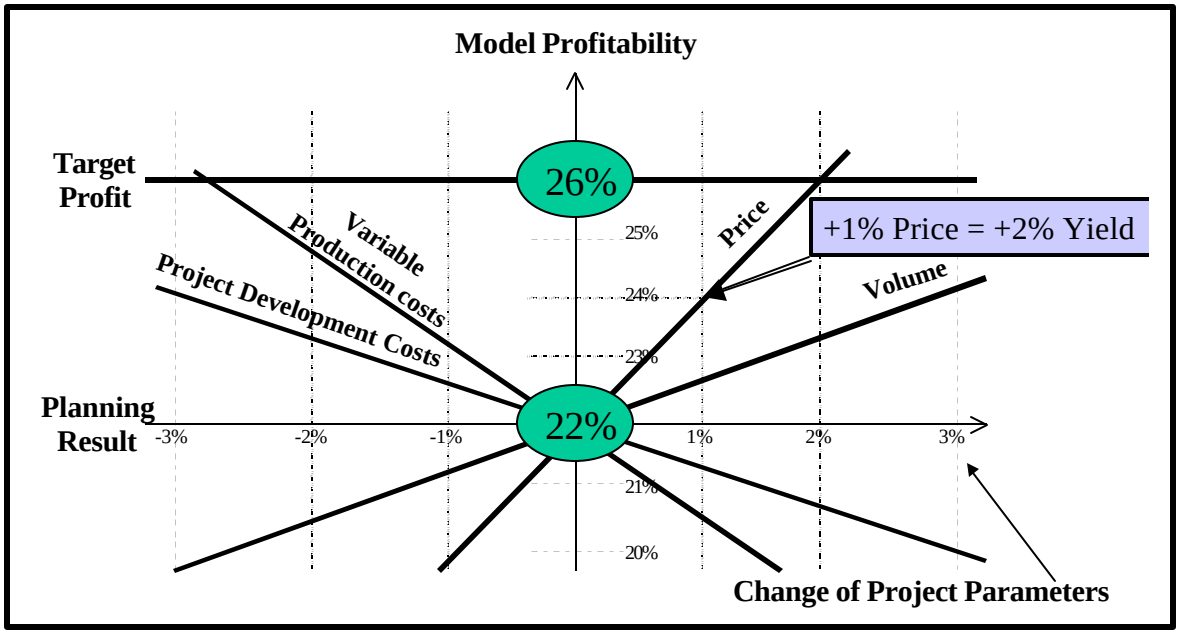
The actual model profitability was determined through a complex computer analysis. This sensitivity analysis (Figure 8) was used for the matching process. For example, the model profitability figure is the overall profitability of the car. Top management had set a goal for all models to generate a high profitability level. Since the initial bottom-up cost plan exceeded the top-down target by nearly 20%, Nitschke's team had to find ways of improving profitability. Nitschke explained:

We first ask marketing if they could charge a higher price or sell more cars because of our technical improvements. Of course, marketing said this was impossible, so we had to deal with the planned cost factors. In our sensitivity analysis, an increase of 1% in price (say to DM 40,400) can increase the model profitability by 2%. When we have lower project costs of about 1%, we can increase the model profitability by nearly 1%. With this analysis, we can determine if it is better to change the part cost, or the investment cost. For example, when we have a low volume car like the 8 series, it is better to reduce investment and R&D costs, rather than reducing part costs. A model like the 3 series, with estimated sales of 3 million units over its life, it is better to reduce the parts costs. Therefore, this sensitivity changes with each model.

This matching process was central to the new planning process, and required serious reevaluation of the planned costs. Nitschke explained:

> Until we actually start the development process, the car is simply in our heads. We must complete the planning phase within six months, or we delay the actual development.
>
> Since the first matching had higher costs, we looked again at parts that could be carried over. We wanted to develop a new suspension, but the old suspension was very good. Instead of developing a new suspension, we decided to reduce the weight of the old one. We decided to change the material of some parts, by using aluminum and magnesium rather than steel. That saved some investment and R&D costs.
>
> We began the actual development phase with 5 to 6% higher planned costs than target, but decided to develop some new process that would hopefully recover those costs in production and purchasing. For example, we brought some suppliers into the development team as model life suppliers. Five years ago, we had suppliers compete for contracts, so they never knew who was the model life supplier. As a result, we couldn't bring them onto the development team. Now we asked suppliers to compete on concepts, and the supplier with the best concept is chosen as the model life supplier. Now our supplier actually develops the seat. Some of the purchasing people don't like this approach, since they prefer to push the price down with competitive bidding. When Lopez (Opel's ex-purchasing manager) moved to VW, he started a process that VW still uses to push its suppliers to reduce prices. We hope that our new approach will save money in the long run. For example, since our suppliers are on the development team, we ask them to make changes without adding additional costs, and they usually agree. Before, any change provided opportunity for the suppliers to raise their prices. By launch, we hoped to meet the 26% model profitability goal.

Figure 8: Sensitivity Analysis for Model Profitability



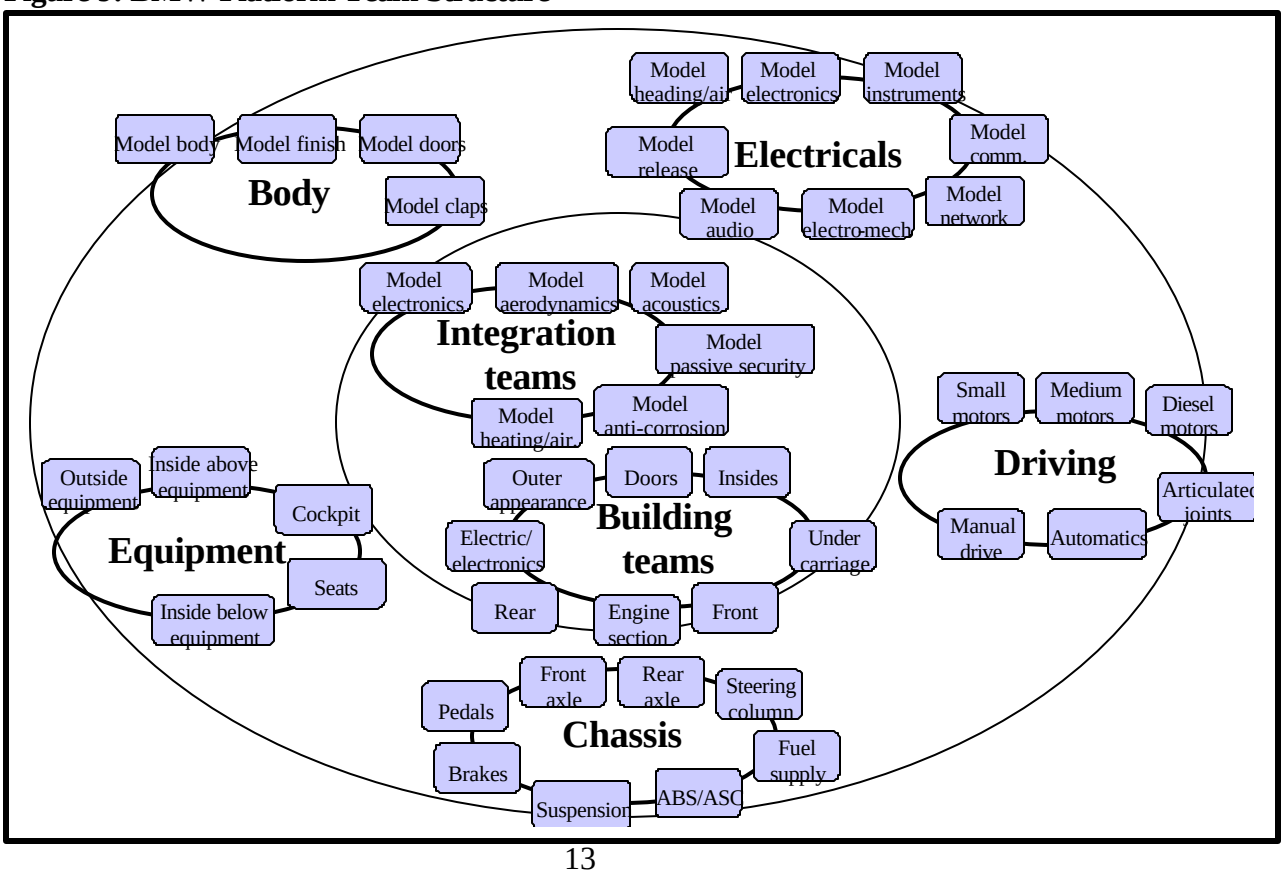
Platform Organization

BMW has platforms for its 3, 5, and 7 series, and for its special cars. The technical qualifications for each area are found in the Centers of Competence (COC). COC provides engineering for bodies and chasses, suspension, engines, electrical and

electronics. COC engineers, as well as suppliers, are assigned to a platform team (Figure 9). Nitschke explained:

> BMW doesn't have an organization with permanent people assigned to a platform. Each COC transfers people onto the platform team for a series, and then they return after the series is completed. After 2 or 3 months of being back in the COC to get additional training, they get another platform assignment. The COC is the home base for our engineers, where they develop their skills, and then bring their special knowledge to the platform.
>
> Typically, the COC engineer will push the newest technology into a platform. The platform team can reject a technology because it is too expensive. For example, I can't put the expensive brakes from the 7 series into a Rover 200. The platform team is working with the brake supplier to get the brakes we need, though we might require that the technology be developed in the R&D center for the Rover 200 brakes. When an outside supplier provides components for a series, we include them on the platform team.
>
> We bring manufacturing into the process about 18 months before launch. They are involved during the technical phase. Technology and production experts told us that we needed a new line to build the body-in-white. We have a special GK-8 department of 10 people that work with us to provide interface between R&D and production. About 12 months before production, the team went to the plants. We split the team because of the 3 series higher output volume. We included managers both from the Regensburg and Munich factories in the process, since we planned to start production in Regensburg and then, three months later, begin in Munich. The press shop and body-in-white shop is in Regensburg. Most stamping comes from the Regensburg and Dingolfing plants. There is a larger 9500-ton press in Dingolfing, which is our largest plant. The paint shop and assembly line was the responsibility of Munich. Munich is an hour closer to the R&D center than Regensburg. When we have a technical problem and need an expert, Munich is only ten minutes away.

Figure 9: BMW Platform Team Structure



BMW's research and development center (RDC) employed nearly 5,000 engineers, designer, technicians and support personnel in one of the world's largest advanced automobile development facilities.

To encourage innovation and new approaches, BMW developed the "RDC Meile," a model of science and technology that forms a framework for virtually every RDC function and activity. Since studies have shown that engineers develop 80% of their ideas in private conversations with their colleagues, the individual offices and workstations for each department are no more than 50 meters away from each other. The idea of streamlining communication has been applied to the management structure, too, thereby reducing the length of decision-making paths. The five buildings and 90,000m^2-floor space that comprise the RDC are completely linked in a massive data communications network. At the heart of this is a CRAY X-MP/28 a supercomputer and 800-plus CAD/CAM and CAE terminals for development of new designs and technologies of tomorrow.

The New 3 Series Platform

The old 3 series models had little commonality in parts, except for the engines, transmissions and floor structure. The development team wanted more commonality between the new 3 series models in order to reduce costs of manufacturing and improve overall quality. Although transmissions and engines were largely carried over from existing models, the chassis was totally new. According to Heiss:

> For the new 3 series, we decided to have more common parts. Everything up to the instrument panel will be the same for the sedan, coupe, and touring models. Also, the sunroof is the same. The doors for the convertible will be the same as on the coupe. That is more than in the past. All the skins are totally different between the models.
>
> All of the discussion about what will be carried over and what will be new are styling issues. We decided that we had to have different styling for each model. On one hand, nobody wants to have totally different cars. Every car has to be almost the same shape. But it is impossible to have the same front with the same windscreen, and have a body with a new shape. You have to change the windscreen angles and curves to fit the coupe or convertible styling. That requires a totally new greenhouse (cabin) for each model. We didn't want to make compromises in keeping the look of a BMW, so we must produce a new skin and give it a proper shape. We want each model to look like a BMW, and not a Toyota.

To increase rear-seat passenger room, the all-steel body was about 1.6 inches longer. In addition, new front seats were developed that gives more space beneath them for rear seat passengers to put their feet. The added weight of the larger frame was held down to 60 lbs. through the use of aluminum, particularly in the suspension and front sub-frame assembly. The planned rollout of the new sedan models was scheduled for the second quarter of 1998. The coupe model was planned for a year later. A touring wagon and 3.4-liter M3 was to follow in 2000, with the compact and convertible models in the following year. M-tuned editions would then supplement models to keep the cars exciting through the seven-year life of the new series.

The new 3 series platform added advanced safe driving technologies to meet future safety requirements. First, it was one of the most balanced cars on the road with a near 50/50

ratio between front and rear weight distribution. Second, while it was a rear wheel drive, it also included all-season traction and an antilock braking system (ABS). BMW's cornering brake control (CBC) is a further development and expansion of the antilock braking systems for braking maneuvers on curves. CBC regulates the pressure in the different wheel brake cylinders for optimal breaking. BMW's advanced ABS system includes a recirculating pump in the hydraulic unit that becomes active in emergency braking situations. This dynamic brake control (DBC) assures maximum deceleration and the shortest stopping distance. A new rear axle drive system architecture and suspension improves driving performance and body reinforcement. About 20 percent of the axle and suspension parts are made of aluminum to save weight and improve driving comfort. The features for the new BMW 323i sedan models are shown in Exhibit 2.

Cost Reduction Strategy

As the new 3 series entered the development phase, Dr. Anton Heiss was given the task of bringing the new model to market within the cost targets. Since the initial design phase had not met the target cost levels, the factory had to look for significant improvements. Heiss explains:

> This was the first series where we brought manufacturing people into the process at the beginning of the planning process. This was very helpful. At the beginning, we started with a 5 or 6-person team one year before the platform team was founded. We had one from marketing, one from finance, one from styling, one from general car integration, one from interior and ergonomics, and one from driving characteristics.
>
> At the beginning of the project, I did all the feasibility studies for manufacturing. What can we do, and what is feasible to manufacture? Second, I studied the manufacturing problems of the old 3 series to find solutions from the manufacturing point of view. We wanted to avoid all the old problems. The third job was to calculate the investment for the new manufacturing line. At the beginning, it was a rough estimate, determining what new tools were needed in comparison to the existing line. Once we decided on the new version of the 3 series, we made more detailed studies. We came up with all the manufacturing requirements, what is in the new car, and then began with styling the new model. For body-in-white, we set targets for the number of welding points. The number of parts used for body construction affected that.

After studying the old assembly line, Heiss found over 950 items or processes that needed to be changed or fixed. In planning assembly of the first prototype, about 600 were addressed. About 200 were not worth the cost or investment of the improvement. The philosophy was to handle parts or assemblies only once, or complete them in a single line. While assembly only accounted for about 10% of total cost, Heiss and his team had cut those costs by over 10%.

Changing Competition

As BMW's new 3 series prototype was about to be completed, a major competitor, Audi, introduced its new benchmark model for 1996, the Audi A4. *Car and Driver* magazine named the A4 one of the Ten Best 1996 cars (see Appendix 3 for one reviewer's comments). In fact, *Car and Driver* gave the new A4 a one-point higher rating than BMW's 1996 328i, which continued to set the benchmark for styling in its class. This model was central to Audi's strategy of directly attacking BMW's product line. Having hired away several of BMW's marketing executives, Audi was now introducing series with numbering systems similar to BMW but always symbolically one number higher.

The Audi A4 was targeting the BMW 3 series. The Audi A6, introduced in 1995, was targeting BMW's 5 series.

The Audi A4's design was very competitive with the BMW 3 series. The A4's standard items included cruise control, anti-theft system, automatic climate control system, AM/FM/cassette and rear defogger. It included power windows and locks and dual power outside mirrors--along with a power driver's seat and tilt/telescopic steering wheel to make drivers of various sizes comfortable. The wheel was even leather-wrapped. Enhanced safety items included dual air bags, anti-lock brakes and side-impact protection that met 1997 federal standards. It also included 5-m.p.h. bumpers, rear headrests and a headlight-washer system. The primary complaints of reviewers came from the limited legroom in the rear seats, the poor cup holder design, and the difficulty in putting the stick shift into reverse. The biggest concern to Nitschke was the A4's price tag, about $4900 less that BMW's 328i (see Appendix 4). Nitschke's team felt added pressure, since supplier prices had increased as technical improvements were made during development. While the new 3 series was 24 months from launch, Nitschke saw Audi's A4, Mercedes C-class, and the new Lexus CS300 as new benchmarks for the 3 series.

Besides the lower price, team members were surprised with the A4's driving characteristics. It handled better than expected for a front-wheel drive car. He explained:

> The old Audi 80 had been our original benchmark, but the A4 quality is much better, and the interior appointments and suspension system are much better. The old 80 had been a conservative car that was considered the choice of civil servants. The A4 is a serious competitor and is a well-developed car. We need to reevaluate our budget for innovations to determine how we can respond to the A4. The budget has between DM 500-1000 still available for innovations.

The team discussed whether or not to redesign the new 3 series for more significant cost reduction, but was concerned that a redesign would delay the launch and negatively affect the final quality of the new model. Moreover, as shown in Figure 10, revisions and major alterations to the prototype could significantly affect the model's profitability. The development cost for the new series and the new sedan were part of the target costing process. Significant alterations to the models or to the platform could easily add an additional 25% to the overall development cost. These cost tradeoffs had to be considered as part of the development process. However, new competitive entries also put pressure on the new 3-series to stay competitive for the coming decade, since the series would be in the market for seven years.

Customer wants would obviously vary according to their reason for purchasing the car. The team wanted to make sure that the new 3 series would surpass the A4 and compete head-on with the Mercedes C-class in buyer satisfaction. They decided to review existing technology and innovations that could be included in the new model. Given the A4's lower price, they had to review what features to include in the base model to justify the nearly $5000 higher price of the BMW, and decide what options consumers would pay extra for. R&D had developed a remote keyless entry with 2 stage unlocking power door locks. Drivers could press the button once to open the driver's door, or twice to open the other doors and the fuel filler flap. BMW's new remote locking system could also include a power remote trunk release. Cadillac had recently introduced a similar system. The 5 and 7 series power driver's and front passenger's seats had 3 memory settings that could

be included. A smart key system could be programmed to remember the seat settings for each driver.

Figure 10: Cost Drivers in Developing the New 3 Series

Main activities	Cost Driver	Technologies				
		Driving	Chassis	Body	Furnishings	Electricals/ Electronics
1. New series	First release	300	200	300	100	400
2. Model revision	First release	300	200	300	100	400
3. Alterations prior to series start.	Alterations	70	50	60	30	70
4. Alterations after series start.	Alterations	70	50	60	30	70

Nitschke also had the option of raising the safety level of the new 3 series by using innovation funds for the HPS (head protection system) airbag. The highly accredited American Insurance Institute for Highway Safety crashed two 5 series BMW's sideways against an obstacle at 20 mph (approx. 35 km/h). In the car without the HPS airbag, the collision would have been fatal. Using the HPS airbag, on the other hand, injury rates were one-fifth those of cars without the system, ensuring the driver's survival. The president of the AIIHS, Brian O'Neill rated BMW's 5 series system as exemplary: "This first of its kind head protection system from BMW demonstrates what can be done to protect people in serious side impacts." Installing BMW's inflatable tubular system (ITS) for the HPS was another potential feature that could be added to the new series for about 150 DM.

The cost parameters would be affected by changes to the new 3 series in light of the Audi A4's introduction. Of course, the 1996 benchmark models had now been introduced, and could be used to assess the new design (Appendix 4). The question now was, "How far should the team go in altering the 3 series model to be competitive?"

Exhibit 1: BMW Safety Developments

BMW's internal safety development goals were established through 1999. They were planned for introduction in each successive year. Planned safety technologies include:

By 1999: *Dual Stage Deployment System* for front airbags on future 5 and 7 series models to deploy front airbags according to crash severity: as gentle as possible, as powerful as necessary.

By 1998: *Navigation/Mayday System* will offer an automated distress call system with a navigation system. A touch of a button transmits the location of the vehicle and automatically opens up a direct line to a live person at BMW's Roadside Assistance Group for emergency response.

By 1997: *Head Protection System* concealed behind the headliner, above the front doors and within the A-pillar, inflates to become a structural part of the car by forming a straight line diagonally across the side window. When inflated, each unit forms a hollow, flexible, essentially airtight tube (inflatable tubular system) about 5 feet long and 5.1 inches in diameter. It is planned for introduction on the 1998 7 series models.

Rear side airbags are an extension of ASAP (Advanced Side Airbag Protection). Available beginning with the 1998 7 series models.

Battery safety terminal (BST) avoids short circuiting of the high amperage starter circuit in the event of a collision. BST is actuated by the airbag control unit and uses a pyrotechnic charge to separate the starter cable from the battery in a crash.

By 1996: *Driver and passenger side airbags* ASAP (Advanced Side Airbag Protection) system employs a large-area inflatable bag in each front door. Front side airbags protect the thorax in side impacts. It will be introduced in the 7 series.

In 1994: *Dual Threshold Deployment system* is an "intelligent" safety system. When the safety belt is used, the airbag will not deploy at a lower crash severity, but only at the higher crash severity, where airbags are more effective.

Passenger seat occupancy sensor recognizes if the seat is occupied or not. If the seat is not occupied, the airbag won't go off in the event of a collision, thus saving the expense of unnecessary replacement.

Interlocking door anchoring system anchors a diagonal aluminum reinforcement bar to the body pillar in the event of a serious side impact. Thus the front door is "hooked into" the B-pillar, the rear door into the body's rear quarter -- helping hold the body side together as a unit for significantly increased strength. The system is designed so that after most impacts, elastic "snap-back" of the system releases the hooks and the doors can be opened.

Exhibit 2: Planned BMW 3-Series Sedan Features

The Drive Train: 2.5L I6 DOHC SMPI (2.5 liter, inline 6 cylinder, dual overhead camshafts) with variable valve timing 24- valve engine, a 5-speed manual transmission; 80-amp battery; 80-amp alternator; rear wheel drive, traction control, 3.07 axle ratio; stainless steel exhaust; front independent strut suspension with anti-roll bar, front coil springs, rear independent multi-link suspension with anti-roll bar, rear coil springs; power rack-and-pinion steering with engine speed-sensing assist; 4 wheel disc brakes with 4 wheel antilock braking system; and a 16.6 gal capacity fuel tank.

Styling: front and rear body-colored bumpers with black rub strip; black bodyside molding, rocker panel extensions; monotone paint; sealed beam halogen headlamps with daytime running lights; additional exterior lights including center high mounted stop light; driver's and passenger's power remote body-colored folding outside mirrors; front and rear 15" x 6.5" steel wheels; P195/65HR15 BSW AS front and rear tires; inside under cargo mounted compact steel spare wheel; air conditioning with climate control, air filter, rear heat ducts.

Interior Features: AM/FM stereo with seek-scan, cassette, CD changer pre- wiring, in-dash CD pre-wiring, 10 speakers, theft deterrent, and window grid diversity antenna; child safety rear door locks; cell phone pre-wiring, 1 power accessory outlet, driver's foot rest; instrumentation display with tachometer, water temp gauge, in-dash clock, exterior temp, systems monitor, trip odometer; warning indicators include oil pressure, water temp, battery, low oil level, low coolant, lights on, key in ignition, low fuel, low washer fluid, bulb failure, door ajar, trunk ajar, service interval, brake fluid; dual airbags, door mounted side airbags; ignition disable; tinted windows, power front and rear windows with 1-touch control; variable intermittent front windshield wipers, rear window defroster; seating capacity of 5, front bucket seats with tilt headrests, driver's and passenger's seat includes 6-way direction control; rear bench seat with adjustable rear headrest; front height adjustable seatbelts with pretensioners; leatherette seats, leatherette door trim insert, full cloth headliner, full carpet floor covering; interior lights include dome light with fade, illuminated entry; steering wheel with tilt and telescopic adjustment; dual illuminated vanity mirrors; day-night rearview mirror; full floor console, mini overhead console, locking glove box with light, front cupholder, driver's and passenger's door bins; carpeted cargo floor, carpeted trunk lid, cargo tie downs, cargo light; chrome grille, black side window moldings, black front windshield molding, black rear window molding and body-colored door handles.

The more expensive 328i version will offer additional or alternative equipment to the basic 323i version. For example, the 328i drive train would include a 2.8 liter I6 DOHC (in-line six cylinder with dual overhead cam) with variable timing 24-valve engine with a 2.93 axle ratio. Styling included additional exterior front fog/driving lights; driver and passenger heated power remote body-colored folding outside mirrors; front and rear 16" x 7" silver alloy wheels; and a full-size conventional alloy spare wheel. Interior features would include a steering wheel with radio and cruise controls; an instrumentation display with trip computer; variable intermittent front windshield wipers with heated jets; center armrest with storage, 6-way power seat for the driver and passenger; leather-wrapped gear shift knob; front and rear interior reading lights; leather-wrapped steering wheel with tilt and telescopic adjustment and 2 seat back storage pockets.

Planned Optional Equipment

Option Name	*Invoice*	*MSRP*
Metallic Paint	$405	$475
Leather Upholstery	$1,235	$1,450
Transmission: 5-Speed Automatic Includes driver's selectable shift and 3.46 axle ratio.	$1,140	$1,200
Rear Side Airbags	$325	$385
Power Glass Moonroof	$895	$1,050
Wood Trim	$425	$500
Fold Down Rear Seats with Ski Bag	$490	$575
Heated Front Seats	$425	$500
Park Distance Control (328i)	$300	$350
Xenon Headlights Includes auto-leveling feature.	$425	$500
Onboard Navigation System (328i) NOT AVAILABLE with in-dash CD player..	$1,675	$1,800
In-Dash CD Player Replaces cassette.	$170	$200
Harman Kardon Sound System Includes 12 upgraded speakers with 2 subwoofers, upgraded amplification and vehicle-speed-sensitive equalization.	$575	$675
Premium Package (328i) Includes power glass moonroof, leather upholstery, wood trim, 4-way power lumbar support, auto-dimming mirror and rain sensing wipers. NOT AVAILABLE with sport package.	$2,465	$2,900
Sport Package (328i) Includes 17" x 8" alloy wheels, 225/50R16 performance tires, sport suspension, 10-way manual sport seats and 3-spoke sport leather-wrapped steering wheel. NOT AVAILABLE with premium package.	$1,150	$1,350

Appendix 2: Comparisons of Benchmark Vehicles

1994 Audi 80 CS 4-Door Sedan

New In This Model Year
'90 convertible model w/V6

Pros
High level of security
Excellent brakes
Excellent ergonomics
Very solid

Cons
No Data

Ratings	
Reliability Rating	**Very Good**
Safety Rating	**Very Good**
Comfort Rating	**Very Good**
Roominess Rating	**Good**
Drivability Rating	**Excellent**
Visibility Rating	**Very Good**
Interior Size	
Cargo Capacity	**14 cubic ft**
Seating Capacity	**5 passengers**
Front Head Room	**35.7 inches**
Rear Head Room	**36.3 inches**
Front Leg Room	**42.2 inches**
Rear Leg Room	**32.5 inches**
Exterior Size	
Length	**180.3 inches**
Width	**66.7 inches**
Height	**54.3 inches**
Wheelbase	**102.8 inches**
Curb Weight	**3,241 lbs**
Fuel Economy	
City Mileage	**18 mpg**
Highway Mileage	**26 mpg**
Fuel Tank Capacity	**17.4 gallons**
Technical Features	
Horsepower	**172**
Number of Cylinders	**6 cylinders**
Displacement	**2.8 liters**
Engine Type	**Gasoline**
Engine Location	**Front**
Drive Train	**Front-Wheel Drive**
Transmission	**Manual**
Brakes	**All Disc**
Original Warranties	
Basic Warranty	**36 months 50,000 miles**
Powertrain Warranty	**36 months 50,000 miles**
Corrosion Warranty	**120 months Unlimited miles**

1994 BMW 3-SERIES 325I 4-Door Sedan

New In This Model Year
New cabriolet version

Pros
Good looks
Sophisticated cabriolet
Super M3 version (not in US)
Rigid body
Engine performance

Cons
Finish could be better
Austere interior
Radio is average
Poor acceleration (318i auto)
Could use more equipment

Ratings	
Reliability Rating	**Very Good**
Safety Rating	**Very Good**
Comfort Rating	**Very Good**
Roominess Rating	**Good**
Drivability Rating	**Excellent**
Visibility Rating	**Excellent**
Interior Size	
Cargo Capacity	**10 cubic ft**
Seating Capacity	**5 passengers**
Front Head Room	**38.1 inches**
Rear Head Room	**37.3 inches**
Front Leg Room	**41.1 inches**
Rear Leg Room	**34.0 inches**
Exterior Size	
Length	**174.5 inches**
Width	**66.8 inches**
Height	**54.8 inches**
Wheelbase	**106.3 inches**
Curb Weight	**3,086 lbs**
Fuel Economy	
City Mileage	**20 mpg**
Highway Mileage	**28 mpg**
Fuel Tank Capacity	**17.2 gallons**
Technical Features	
Horsepower	**189**
Number of Cylinders	**6 cylinders**
Displacement	**2.5 liters**
Engine Type	**Gasoline**
Engine Location	**Front**
Drive Train	**Rear-Wheel Drive**
Transmission	**Manual**
Brakes	**All Disc**
Original Warranties	
Basic Warranty	**48 months 50,000 miles**
Powertrain Warranty	**48 months 50,000 miles**
Corrosion Warranty	**72 months Unlimited miles**

1994 Mercedes-Benz C-CLASS C280 4-Door Sedan

New In This Model Year
All new model

Pros
Fresh styling
More powerful engines
Improved comfort
More rear seat room
Exemplary handling

Cons
Complicated air-conditioning controls
Seats still hard
Tires noisy at high speed
No manual transmission

Ratings	
Reliability Rating	**Very Good**
Safety Rating	**Excellent**
Comfort Rating	**Very Good**
Roominess Rating	**Very Good**
Drivability Rating	**Excellent**
Visibility Rating	**Very Good**
Interior Size	
Cargo Capacity	**12 cubic ft**
Seating Capacity	**5 passengers**
Front Head Room	**37.2 inches**
Rear Head Room	**37.0 inches**
Front Leg Room	**41.5 inches**
Rear Leg Room	**32.8 inches**
Exterior Size	
Length	**177.4 inches**
Width	**67.7 inches**
Height	**56.1 inches**
Wheelbase	**105.9 inches**
Curb Weight	**3,350 lbs**
Fuel Economy	
City Mileage	**20 mpg**
Highway Mileage	**26 mpg**
Fuel Tank Capacity	**16.4 gallons**
Technical Features	
Horsepower	**194**
Number of Cylinders	**6 cylinders**
Displacement	**2.8 liters**
Engine Type	**Gasoline**
Engine Location	**Front**
Drive Train	**Rear-Wheel Drive**
Transmission	**Automatic**
Brakes	**All Disc**
Original Warranties	
Basic Warranty	**48 months 50,000 miles**
Powertrain Warranty	**48 months 50,000 miles**
Corrosion Warranty	**48 months 50,000 miles**

Appendix 3: 1996 Audi A4 Review

Ich Denke Ich Bin In Lieber, I think I'm In Love

By B. Grant Whitmore

Although I-40 west of Flagstaff, Arizona isn't much like the Autobahn, if you squint your eyes when entering Kaibab National Forest the smell of the pines may convince you that you have been transported to the old country. Particularly if you exit at Williams. Williams is the town where tourists stop before turning north on their way to the Grand Canyon. Germans love the Grand Canyon as evidenced by the multitude of Wagnerian travelers found in the local food and gas mart. They also seemed to be pretty impressed with my set of wheels. I couldn't blame them; I was spending the week in an Audi A4.

I know many Americans are afraid of getting behind the wheel of an Audi, lest they find themselves hurling through the back of their garage and into their swimming pool. But really folks, the unintended acceleration problem was never a problem, merely a circumstance of Americans not understanding German gas and brake pedal placement. Many Americans are also afraid of Audi's scattershot reliability. To address this concern, Audi has a three- year/50,000 mile warranty that includes everything, even scheduled maintenance. Now that we have laid these fears to rest, let's discuss the real issues of the A4.

The Audi A4 is one of the most beautiful cars I have laid eyes on this year. My wife thinks it looks like an art deco toaster but I don't care; the A4 has a shape unlike any other vehicle on the road. The designers have fashioned a car that feels larger on the inside than on the outside, with plenty of room for four adults and their belongings. Audi must also be complemented on the design of their doors. After years of sliding into cars that had openings barely wide enough to accommodate my six-foot one-inch height and two-hundred pound frame, it was refreshing to step into a car that has doors that open to a point almost perpendicular to the car itself. We are certain that this feature alone could make this the upscale car of choice among families with toddlers and those that are tired of trying to get their groceries in and out of a portal that is marginally larger than a mail slot.

Once inside the A4, drivers and passengers alike will revel in the car's luxurious interior. Exceptionally supportive leather seats cushion the ride for all passengers. Walnut inlays in the dashboard, center console and doors convey a feeling of opulence not generally found in a car that costs less than $30,000. An optional Bose music system will play your favorite songs as sweetly as they are heard in the best concert halls in the country. The A4 has seating for five, although it is unlikely that you would want to put five adults in this car for anything other than a quick trip around the corner. Seating for four, however, is comfortable despite the smaller than average area for the rear passenger's legs. The reason for this feeling of spaciousness may have to do with the

outstanding shoulder and elbow room, not to mention the expansive views afforded out of the A4's large greenhouse. The result is that rear seat passengers feel like they have more room than they really do. Pretty sneaky, huh?

This is all well and good, but we both know that the real reason people buy Audis is not to sit around in pampered comfort. Rather, people buy Audis to drive. The A4 helps drivers accomplish this endeavor by providing all of the necessary equipment. The A4's thick steering wheel is comforting and meaty; inspiring the confidence to hang in there when negotiating tricky switchbacks. Easy-to-reach stalks for the lights, cruise control and wipers flank the wheel. The instrumentation is directly in front of the driver, making it easy to keep track of the A4's vital statistics. All secondary controls are textured, allowing your fingers to walk right to them without much groping. The driving position in the A4 is wonderful, after spending several days behind the wheel we felt neither fatigued nor irritable. One of our editors did complain, however, that the gas and brake pedals were placed a bit too far to the right, causing his leg to push awkwardly against the center console. Also, the pop-up cupholders are not worth the plastic they are stamped on. Do yourself a favor and invest in one of the Octopus cupholders sold at the Pep Boys.

Our staffers had the chance to test the A4 on a wide variety of roads, at different altitudes and in varying temperatures. From the one hundred degree heat of the Phoenix basin to the winding state highways that lead to Nevada, our A4 never faltered. Negotiating slow-moving semis, Cadillacs and boat-towing pickups on their way to and from our nation's gambling capitol couldn't have been easier. Fast kickdowns by the A4's five-speed automatic transmission and nimble handling enabled us to spend most of our time viewing the slow-movers from our rearview mirror. Never once did we find ourselves in a situation wishing for more power or quicker acceleration. Even better, the engine never heated up despite the sweltering temperatures, hard driving and hilly terrain. The real test of the A4's driveability came on a trip to Madeira Canyon south of Tucson, Arizona. The drive to Madeira Canyon is not one that most take quickly and we admit that the scenery has slowed us down more than once. The 11,000 foot Mt. Writson looms overhead and the verdant valley offers plenty of trees and wildflowers to admire, but the chance to let the A4 flex its brawny shoulders on this desolate stretch of road's sensuous curves was more than we could bear. We dropped the hammer just off the freeway exit, wended a path through a few sightseers, and were off on a close approximation of Mr. Toad's Wild Ride. The Audi A4 comes equipped with a 172-horsepower 6-cylinder engine that moves the car quickly through its gears. The five-speed automatic provides capable acceleration and plenty of power when coming out of tight curves. Weighing only thirty pounds more than the Jetta, the A4 seems much more balanced than its lesser cousin. There is very little body roll in the A4, and the most off-camber of turns is unlikely to ruffle its occupants. Tire-squeal under hard cornering is kept to a minimum, and all but the loudest of noises are dampened by the A4's excellent sound insulation. Steering is precise, if somewhat light, and the car heads where directed with little prodding. Our tester was not equipped with the Audi's Quattro all-wheel drive system; thus power was transferred exclusively to the front wheels. Surprisingly this didn't inhibit the A4's fun-to-drive quotient. Torque steer is virtually eliminated by the A4's new multi-link front suspension. Understeer, a problem with most front-wheel drive cars when taken to the limit, was almost non-existent in the A4. Despite hard cornering and braking maneuvers we never experienced the front-wheel plow that we have seen in some of the A4's competitors.

Indeed, if more makers could give their front-wheel drive cars the quickness and precision of steering that our A4 exhibited, we have difficulty arguing that rear-wheel drive is inherently better for sporting sedans.

Obviously, Audi has spent a great deal of time making their cars fun to drive and pleasant to ride in; fortunately for us, they have also been making them exceptionally safe. ABS5, Audi's latest anti-lock braking system, is excellent at stopping the A4 quickly and smoothly on virtually any surface; it also serves as the backbone for the A4's all-new traction control system. Unfortunately the Arizona sunshine didn't allow us to test the system on truly slick surfaces, but given the efficacy of the brakes we're certain it's top-notch. Dual airbags, side door guard beams that help the car meet 1997 side-impact standards, fog lights, five-mph bumpers, an alarm system and head restraints at all outboard seating positions are some of the items that Audi includes to make sure that their customers are around for years to come. For additional security in bad-weather situations, you can equip the A4 with Audi's Quattro all-wheel drive system. Audi claims that with the Quattro system the car won't get stuck as long as one wheel is able to grip.

We feel that near-luxury car buyers owe it to themselves to take a look at the Audi A4. The styling is more attractive than anything being offered by Lexus or Acura, the luxury is equal to big American cars such as the Cadillac Seville or Oldsmobile Aurora, performance is on par with top sedans from BMW and Mercedes, and safety is close to Volvo standards. Better yet, the Audi A4 comes fully loaded for close to $30,000, a price these other cars can't even touch.

Appendix 4: Comparisons of Benchmark Vehicles

	1996 Audi A4 QUATTRO 4Door Sedan All-Wheel Drive	1996 BMW 3-SERIES 328I 4 Door Sedan	1996 Mercedes-Benz C-CLASS C280 4-Door Sedan	1996 Lexus ES 300 4-Door Sedan
				
General Information				
Model Year	1996	1996	1996	1996
Car Type	Sedan	Sedan	Sedan	Sedan
Number of Doors	4-Door	4-Door	4-Door	4-Door
Seating Capacity	5	5	5	5
Manufacturer	Audi	BMW	Mercedes-Benz	Lexus
Price				
Original Price	$28,050	$32,900	$35,250	$32,400
Fuel Economy				
City Mileage	18 mpg	20 mpg	19 mpg	20 mpg
Highway Mileage	27 mpg	27 mpg	26 mpg	29 mpg
Fuel Tank Capacity	16.4 gallons	16.4 gallons	16.4 gallons	18.5 gallons
Safety				
Safety Rating	Excellent	Very Good	Excellent	Very Good
Reliability				
Reliability Rating	Excellent	Excellent	Excellent	Excellent
Size				
Interior				
Cargo Capacity	14 cubic ft	10 cubic ft	12 cubic ft	14 cubic ft
Front Head Room	38 inches	37 inches	37 inches	38 inches
Rear Head Room	37 inches	37 inches	37 inches	37 inches
Front Leg Room	41 inches	41 inches	42 inches	44 inches
Rear Leg Room	33 inches	34 inches	33 inches	33 inches
Exterior				
Length	178 inches	175 inches	177 inches	188 inches
Width	68 inches	67 inches	68 inches	70 inches
Height	56 inches	55 inches	56 inches	54 inches
Curb Weight	3,228 lbs	3,120 lbs	3,350 lbs	3,374 lbs
Wheelbase	103 inches	106 inches	106 inches	103 inches
Technical Specifications				
Horsepower	172	190	194	188
Number of Cylinders	6 cylinders	6 cylinders	6 cylinders	6 cylinders
Displacement	2.8 liters	2.8 liters	2.8 liters	3.0 liters
Engine Type	Gasoline	Gasoline	Gasoline	Gasoline
Drive Train	All-Wheel Drive	Rear-Wheel Drive	Rear-Wheel Drive	Front-Wheel Drive
Most passenger cars have front-wheel drive, while most trucks and high performance have rear-wheel drive. Four-wheel drive is available for most trucks, sport utilities, and some cars.				
Transmission	Manual, Automatic	Manual, Automatic	Automatic	Automatic
Most manufacturers offer both automatic and manual options for each model. Almost all cars are available in automatic, while about 300 models are not available in manual.				
Brakes	All Disc	All Disc	All Disc	All Disc

Available Features				
Anti-Lock Brakes	Yes	Yes	Yes	Yes
Driver-Side Airbag	Yes	Yes	Yes	Yes
Passenger-Side Airbag	Yes	Yes	Yes	Yes
Air Conditioning	Yes	Yes	Yes	Yes
Cassette Player	Yes	Yes	Yes	Yes
Cruise Control	Yes	Yes	Yes	Yes
Power Brakes	Yes	Yes	Yes	Yes
Power Door Locks	Yes	Yes	Yes	Yes
Power Steering	Yes	Yes	Yes	Yes
Power Windows	Yes	Yes	Yes	Yes
Sunroof/Moonroof	Yes	Yes	Yes	Yes

Appendix 1: Conjoint Analysis of Critical Product Qualities and Components

Product Components / Product Qualities	Meaning	Body			Furnishings				Electricals				Chassis					Aggregate			Sum
		Body skeleton	Body skin	Doors/Hood/Trunk	Outter design	Inner design	Cockpit	Seats	Heating/Climate control	Instruments	Network	Electro-mechanical	Front axle	Rear axle	Springs/shock absorption	Wheels	Brakes	Engine	Exhaust	Gear unit	
Exterior design	7.3		2.2	1.5	1.8							0.4		1.5							7.3
Interior design	4.7			0.7		0.7	1.2	1.2	0.2	0.5						0.2					4.7
Seating comfort	4							4													4
Operating comfort/ergonomics	2.7			0.4			0.4	0.4	0.3	0.1	0.3	0.1	0.1			0.4	0.1				2.7
Inner acoustics	3.3	0.3		0.2	0.2	0.3	0.2						0.3	0.7				0.7	0.2	0.3	3.3
Heating/Air comfort	2.6					0.1		0.4	1.8									0.3			2.6
Gear shifting comfort	2.8																			2.8	2.8
Air flow/circulation	10.3		0.5		0.5									0.5				7.7	0.5	0.5	10.3
Acceleration	4.3		0.2		0.2									0.2			0.2	3	0.2	0.2	4.3
Speed limit	2.6		0.1		0.3									0.4			0.1	1.4	0.1	0.1	2.6
Gas consumption	8.6		0.4		0.4									0.4	0.4			6	0.4	0.4	8.6
Maintenance	7.7		0.4	0.4	1.2				0.4		0.4	0.4	0.4	0.4	0.4			2.3	0.4	0.8	7.7
Safety	20.5	5.1	1	3.1			3.1	3.1			2.1					3.1					20.5
Road behavior	14.6	0.7									0.7		2.9	5.1	2.9	1.5		0.7			14.6
Non-polluting	3.9	0.2	0.4	0.2	0.2	0.2	0.2	0.2			0.2							1.6	0.6		3.9
Sum	100	6.3	5.3	6.4	4.8	1.4	5	9.2	2.7	0.6	3.6	0.9	3.8	9.2	3.7	5.2	0.5	23.7	2.4	5.2	100