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BMW AG: The Digital Car Project (A)

"Looks great," thought Chris Bangle as he walked by a picture of the new BMW 3-Series which was about one year away from its scheduled 1998 launch in Germany. Bangle, a former Wisconsin native, who became the company's director of worldwide design at age 35, glanced at his watch. In just 30 minutes, he would meet with other senior managers about project recommendations that might revolutionize the way cars had been designed over the past eight decades at BMW. The meeting was in the inner sanctum of BMW's research and engineering building, the *Forschungs-und Ingenieurszentrum*, known locally as the "FIZ" (pronounced "fits"). Built in 1987, this massive building centralized the work of 40 facilities previously scattered through Munich. All work from product concept to pilot production occurred in the FIZ. But only a privileged few out of the five thousand who worked in the building had ever visited this corner of the company where the meeting was to be held.

Bangle pulled out his card key that would let him pass through a sleek space-age security system that resembled an oval chamber. After negotiating a push card entry system, a set of doors slid close behind him and another set opened up to reveal the styling area—a world of future visions, inhabited by many life-size clay models of cars under development that would eventually come to life on roads of the next millennium.

BMW had weathered several storms over the past century, almost spluttering out of business thrice. On one humbling occasion in the firm's early history, it survived by using its machinery to manufacture cooking pots and pans. Now BMW rode high, outperforming many other European auto manufacturers. It had become one of the few European companies consistently making both cars and profits. Yet, BMW had one of the slower product development cycles when compared to its international competitors—a problem if it wanted to retain its technological leadership and cater to fickle customer tastes.

Thus far, BMW's cars had been designed along the lines of fine Bavarian craftsmanship that stretched back for centuries. Designing BMW cars had involved months and sometimes years of painstaking iterations between hand-drawings and hand-built clay models. This process was especially belabored during the creation of a new car platform, which for a given series was launched only every seven or eight years, as compared with derivative, incremental models that were released every year or so.

Professor Stefan Thomke and Research Associate Ashok Nimgade prepared this case. HBS cases are developed solely as the basis for class discussion. Cases are not intended to serve as endorsements, sources of primary data, or illustrations of effective or ineffective management. Some data has been disguised for purposes of confidentiality.

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Bangle wondered if today's meeting would help decide about doing away with this almost entirely, and begin work from computer models only as required by the new development system that called for a 50% time reduction. He was sure that many middle managers would cringe at the thought. But the decision that had to be made was one of managing organizational change: how should BMW roll out its new and unproven development system?

Many in the top brass pondered privately about whether BMW was ready for change. Its current success, after all, might prove a potent roadblock to change. Bangle's colleague Dr. Hans Rathgeber, the head of body development, had pointed out that BMW was "blessed with very good products, but – because change comes easier when a company is on its knees—cursed by lacking a crisis!" The day's crisis, thus, was that there was no crisis. Perhaps too many BMW engineers and managers worked with a business-as-usual mentality.

Just a few months ago several of the BMW designers had sat through a pre-screening featuring their 7-Series flagship car in the major motion picture, *Tomorrow Never Dies*. Several had watched proudly, as British Intelligence senior product developer "Q" stated to secret agent James Bond: "Here's the insurance damage waiver for your beautiful new car. . . . Your new BMW 750, with all the usual refinements. . . ." And many had suffered along with their silver 750iL through a rain of blows from a sledgehammer, several machine gun volleys that had blown out the windshield, and a plummeting fall several stories before a crash-landing into a car-rental agency. Some designers had winced to see the rapid destruction of the beautiful contours of a car that had represented several years of toil under BMW's old product development plan that involved thousands of people from product conception to market release.

Today, Bangle, like all senior BMW managers remained aware that a mistake anywhere along the long chain of critical points involved in product development for the new models might cause ruination of a much slower but equally painful kind: market erosion. One did not even need to look much further beyond this part of Germany—described as the "silicon valley of the automobile industry"—to find worldwide competition. Just 150 miles up the *Autobahn*, plans were afoot at Daimler-Benz, BMW's best competitor, to launch a sleek new Mercedes-Benz S-Series model that might hammer away at the 7-Series car.

History of BMW

In 1916, Gustav Otto founded Bayerische Motoren Werke (translated Bavarian motor works), better known worldwide by its acronym BMW, to manufacture aircraft engines (see **Exhibit 1** for historical milestones). In 1923, with the Treaty of Versailles banning Germany from producing aircraft, BMW lowered its sights to the ground. In just six years, one of its motorcycles would set a world speed record of 134 mph.

By the 1930s, however, it became apparent that the more sedate automobiles would replace motorcycles as the preeminent mode of transportation. To establish itself quickly in this market, BMW bought the license for a small British Austin model. Over the next few decades, BMW drew on its expertise in high-performance engines and aerodynamic design to manufacture world-class automobiles. The legendary BMW 328 sports car, which debuted in 1936, won numerous international race events, helping set the pace for BMW for ensuing decades as a prominent manufacturer of sporty roadsters. (It remains a tribute to BMW craftsmanship that over 200 of the 462 BMW 328 automobiles made still lived on in the mid-1990s.)

For all its engineering triumphs, however, BMW remained a niche player in the developing automobile industry. In 1951, when the firm started car production in Munich, it made egregious marketing errors. First, it produced prestige limousines that, in the post-war economy sold just 19,000 units over 14 years. The company only compounded the losses from this model through a tiny three-wheel “bubble-car” that reached the market just when an economic upturn boosted the demand for more comfortable transportation.¹

In 1959, the company’s weak financial position almost led to a takeover by its traditional rival Mercedes-Benz in Stuttgart. This was the third time the company’s very existence was threatened. (The other two times had followed the world wars.) Only a \$1 million investment by Herbert Quandt, one of Germany’s wealthiest and most reclusive industrialists, who had slowly developed a majority shareholder position, rescued the firm. (The Quandt family in the mid-1990s still held some 60% of the company stock). In the 1960’s, BMW found its stride when it combined its high performance sports car engineering with the comfort of luxurious cars. This winning combination in just a little over two decades took the firm from sixty-ninth to eleventh place among Germany’s top corporations. Financial turnover in this period rose almost tenfold and the workforce sevenfold.

By the 1970s, BMW exported two-thirds of all its cars and three-fourths of all its motorcycles and had established subsidiaries on six continents. Its status as a manufacturer of dream cars was cemented through use of its cars in major motion pictures. BMW returned to its aerial heritage temporarily in the 1940s, when it helped develop rockets, and more permanently in the 1990s, through a jet engine manufacturing collaboration with Rolls Royce. Through all these decades, however, it retained its white-and-blue propeller logo that reflected its roots in the aircraft industry.

In 1996, BMW employed more than 116,000 persons worldwide and sold its products in 140 nations ranging from the United States to the Fiji Islands. It had a turnover of DM 52.3 billion in 1996, its best year in its history thus far (see **Exhibit 2** for selected financials and operating data). By the end of June 1997, BMW’s deliveries of new cars rose 10% over the past year worldwide, with 62,000 units in the United States alone.² Despite its impressive growth over the past few decades, BMW in the mid-1990s had a world market share of only 1.5%. BMW viewed itself as a “manufacturer of unique automobiles for a clearly defined, exclusive and demanding clientele all over the world.”³ To expand into other niches, without diluting its solid brand name, the company acquired the British Rover Group in the 1990s.

Although sports and luxury cars remained BMW’s flagship products, it also made sedans and models for the broader markets. In the 1990s, BMW made several major series of automobiles which, following European tradition, were numbered rather than named (see **Figure 3** for pictures of 7, 5 and 3-Series models):

- The 7-Series, the company’s luxury limousines (1996 sales totaled about 51,000 cars). Competitors included the Mercedes-Benz S-class, the Audi A8, Toyota’s Lexus LS400, and GM’s Cadillac Seville.
- The 5-Series, consisting of BMW’s “core” middle-range luxury performance cars (1996 sales totaled about 190,000 cars). Competitors included the Mercedes-Benz E-class, the Audi A6, Toyota’s Lexus GS300, Ford’s Lincoln LS6, and Chrysler’s 300M.

¹ J. Dornberg, June, “Life in the fast lane: Bavarian Motor Works.” *International Management*, V. 48(5), June 1993.

² BMW AG *Presse*, September, 1997.

³ W. Reitzle, “How to Shape a World Brand.” Speech at Harvard Business School, November 16, 1995.

- The 3-Series sports sedans (1996 sales totaled about 400,000 cars). Competitors included the Mercedes C-class and the Audi A4.
- The low-volume 8-Series sports coupes.
- The roadster series (e.g. Z3) and the new "Sport Activity Vehicle" (SAV) X5 (to be launched in 1999)—both manufactured in BMW's Spartanburg, South Carolina plant.

BMW also made a line of motorcycles. Introduction of many technological innovations such as side airbags generally started with the 7-Series, since this was the most expensive line and could absorb the costs of early innovation. From here, innovations trickled down to the 5-Series and 3-Series cars. All segments were viewed by automotive executives to be very competitive, with more automotive products and firms entering in the next few years.

Automotive Competition in the 1990s

According to BMW Executive Chairman, Bernd Pischetsrieder, "When historians look back on the motor industry in 50 years' time, they will say that the mid-1990s was a period of fundamental change." This time period had seen development of a consumer's market. In 1996, the European market sported some 50 car brand names, with about 300 different base models and virtually thousands of derivatives. The European market production capacity of 20 million overwhelmed the total yearly sales of 14 million.

"We've entered the biggest buyer's market in history," commented Ford's chairman, Alex Trotman, "... the customer revolution." Customers demanded more choices while wanting to pay less. This had led to a rise in second-hand and almost new car sales along with an upsurge in generous financing schemes for new car purchases. Car manufacturers had to respond with acceleration of new model development and an increase in model variations. To worsen matters, Japanese, Korean, and U.S. automakers waited in the wings for lifting of all European Market barriers by 1999. Ford's Trotman admitted that "I keep a collection of old bonnet ornaments from defunct auto companies in my office. They serve as a reminder that the world doesn't own anyone a living, and doesn't owe any company its business."⁴

As a response to these rapidly changing markets, automakers all over the world placed an increased emphasis on speeding up development as a competitive weapon. The Japanese had led the way, aiming to reduce their traditional 50-month development lead times by over 30%, even though they were not known for technological advancement so much as for producing reliable cars. In the United States, auto firms such as Chrysler were trying achieve a similar feat. In recent years, intense pressures from international competition to reduce product development time had also reached Europe and BMW.

The whims of customers in the mid and upper luxury car market made the competitive environment even harder to predict. In the early 1990s, German luxury carmakers found that "cost-be-damned" over-engineering might not be rewarded. Consumers, for instance, found the \$127,800 Mercedes S-Series model of 1991 too large and unwieldy. Mercedes-Benz had designed this car for tastes of the early 1980s, but partly because of its long product development cycle it floundered on the quicksand of consumer taste.⁵ Japanese carmakers were quick to strip away market share from

⁴ A. Lorenz, "Cars on a collision course." *Management Today*, August, 1996, pp. 66+.

⁵ R. Serafin, "Mercedes-Benz of '90s includes price in its pitch." *Advertising Age*, November 1, 1993.

these overpriced models and break into the coterie of car manufacturers that included well-known firms such as Mercedes, BMW, and Jaguar. Japanese luxury cars had started to win international automotive awards, but, as the following passage from 1996 illustrates, the pendulum of consumer taste was reversing course:

Toyota's Lexus LS400 was the epitome of vehicular correctness. [It] was so quiet and smooth that it was more like an appliance—a horizontal elevator. The Lexus had its 15 minutes of fame. Then the yen gained strength, as did the tastes of affluent American car buyers. Suddenly, as fast as you could say, “. . . start your engines!” Mercedes-Benz and BMW roar to the front of the line for speed, power, and status. . . . These high-end German cars are not transportation for the timid. With their top-gun cockpits, super firm seats, and beefy controls, they demand driver involvement.⁶

The shift in market trends, however, favored BMW disproportionately. Its appeal to younger, affluent buyers interested in performance, handling, and physical activity, and the sheer fun of driving boosted sales to the point where, for the first time in history, BMW unit sales surpassed that of Mercedes-Benz, its longtime rival.

The competition between BMW and Mercedes-Benz, while spurring both companies to higher levels of excellence, could at times prove personalized and acerbic. The head of sales at Mercedes-Benz, Dieter Zetsche, admitted, “with our emphasis on comfort, safety, and longevity, we were becoming like Rolls-Royce”—overpriced and technologically out-dated, “we didn’t realize that the world had changed.” Much soul-searching at Mercedes-Benz led to plans for radical changes in the Mercedes lines, including the very successful E-Series and a new and radically redesigned S-Series model to be launched in 1998 that industry observers perceived as a serious threat to BMW’s current 7-Series model.⁷

Product Design and Engineering at BMW

A successful design is not characterized by the ability to create a brief sensation, but by the influence it exerts on subsequent designs in the years that follow.

—Chris Bangle, Director of Worldwide Design

Automobile development in the 1990s entailed literally thousands of steps involving 20,000 to 30,000 components from screws to lamps to upholstery that had to be coordinated to produce a final product. This five-year process relied on the work of thousands of designers, skilled craftsmen, and engineers, as well as numerous specialized outside vendors. To simplify matters, however, an automobile can be thought of as having two major components: the “package” and the “skin.” The term “package” refers to the components involved in propelling the automobile. This basically involved whatever is under the hood in addition, of course, to wheels, axles, steering, climate control, and exhaust. The skin refers to what the buyer first sees in the showroom: the exterior, the seating, and the layout of the dashboard. In the initial phases of car development, design of the package and skin could proceed in parallel, with ongoing communications and “negotiations” between engineers and designers managing both processes. The centralization of car development at BMW through placing everyone in the FIZ building had smoothened this process of communications—and had led to similar initiatives at other car manufacturers.

⁶ A. Taylor III, “Speed! Power! Status!” *Fortune*, June 10, 1996, pp 46+.

⁷ Ibid.

BMW viewed design as the link between its past and future. Thus, BMW designers sought to retain a familiar resemblance between all its models. Consistent design features included the dual circular headlights and the “double kidney” grille in the front of the car. Traditionally, design for a proposed model started with manual renderings on paper using traditional artistic media ranging from watercolor to pencil to charcoal. In this brainstorming (“Design Concept”) phase the company explicitly sought through a competitive process a large variety of concepts (which typically fell into four self-explanatory directions labeled “revolutionary,” “evolutionary,” “aerodynamic,” and “classic”) from in-house designers and sometimes external industrial designers.

Next the firm worked toward a “refinement” of its design choices by whittling down the choices. To this end, the design department made small (1:2.5) clay models of several favored initial concepts. Finally, based on feedback from senior management, the department made a few life-size models of leading contenders. These clay models were milled with computer-guidance so precisely that, once painted, an inexperienced observer could not tell a finished 1:1 clay model apart from a real car.

These clay models also served to create an “excitement” among personnel involved with auto development; in the words of Peter Ratz, a manager responsible for the technology interface between design and engineering, “nothing takes the place of seeing the real thing.” Typically, it took about 12 weeks to go from initial concept to a finalized clay model, a process that was repeated at least 4 to 5 times with intermediate clay models before arriving at a final design concept. Each 1:1 clay model cost upwards of \$150,000 and could be produced in about a month, but in as little as two weeks for all-stops-out emergencies.

Once the design was frozen, a scanning device would capture the geometry of the final clay model digitally—a process that generally took over a day and could be done over the weekend. Once captured digitally, however, the design models could be made available to engineering in the form of computer-aided design (CAD) models. The computer models also sped up refinements in the design process itself. For instance, if a designer ground down one curve or lay on more clay to build up another curve, computer guidance could ensure that corresponding changes on the other side of the car would match to within half a millimeter or so.

Recent advances in computer-aided styling (CAS) were aimed at making the power of computers available to designers up to the early brainstorming phases. CAS allowed for work at resolutions of one-hundredths of millimeters—an order of resolution greater than engineers traditionally worried about. The ability of CAS to accurately predict the course of lines of reflection also helped convince skeptics about its potential utility. In addition, a major advantage to working digitally from the very beginning was in allowing for direct data links to computer-aided design (CAD), allowing for parallel development with engineering. Working with clay models, in contrast, required laser scanners to “digitize” information about the clay models. This process of data conversion usually necessitated time-consuming fine corrections by hand.

But even with all the potential advantages of CAS, BMW prided itself on its *handcraftsmanship*. In fact, for Bangle himself noted that “cars are not machine-produced, they are machine-reproduced—a human hand makes every surface.” Not surprisingly, BMW’s designers, generally came from art schools or industrial design schools, and its model-makers were skilled craftsmen who perfected their trade through many years of apprenticeships. Working alongside them were over a dozen “color and trim” craftsmen and designers (including fashion designers). Working with physical models was an integral part of their training and often defined the emotional experience of a designer (see **Exhibit 4** for designers at work). Thomas Platt, general manager of advanced design, underscored the emotional side of using physical models by pointing out “that computers are an indispensable tool for simultaneous thinking and working but there will be a point where you want to touch what you love.”

BMW designers prided themselves on the emotions that good design would create: the way light sparkled off the surfaces of their cars, and the way the lines of contour flowed. Three properties with enough mystery for a café full of artists guided car design at BMW: *Flächengenauigkeit*, the precision of the surface; *Flächenspannung*, the surface “stress”; and *Reflektionslinien*, the lines of reflection. The BMW design philosophy held that the contour lines should never be interrupted, even when running across transition points (such as from body to door). Furthermore, the company prided itself on the number of distinctive curves the side of a car possessed when viewed in cross-section (see **Exhibit 5** for a comparison with other cars).

While many automakers had just one or two design surfaces running down the side of a car, interrupted by a metal strip, BMW sought to create a subtle interplay of multiple surfaces that could not be easily created on a digital computer. “While all car makers use the very same sheet metal, and while anyone can bend sheet metal,” Ratz, a manager and design engineer with 13 years’ experience at BMW, could claim with some pride, “we practice the *artful* deformation of sheet metal.” All these elements created what the firm felt was the finest expression of human artistry. A customer, thus, paid for a BMW not just with the wallet but also with a commitment that came from the heart.

After exterior design was complete, the CAD data moved to Andreas Weber’s group in body engineering. His group bore responsibility for making the exterior design functional and manufacturable. It made the surfaces “more precise” by filling in gaps in design. For example, Weber’s group would figure out where the screws should go into the taillight that had been designed, or if the design affected the door functioning. The group, like other BMW engineers, operated at the level of fractions of millimeters to ensure that the final assembled product would function with silky precision.

Weber also worked with many other groups within body engineering to ensure that the design concept chosen could achieve its desired functionality such as crashworthiness and vehicle dynamics. For example, the design data was handed over to Dr. Holzner’s group, who would perform crash simulations to get early feedback on potential safety problems—months before data from the first prototype crash was available. One of engineering’s evolving objectives, though not stated explicitly, was to identify and solve functional and manufacturing problems as early as possible (a concept known as “front-loading”). Once design commitments were made, changes such as tooling could cost millions of dollars and often led to significant delays in the development schedule.

Because making a car involves dozens of functional teams working together on thousands of components that must ultimately fit together, at some point the model design had to be “frozen.” Otherwise, engineers and designers would forever chase moving targets. Another reason for freezes stemmed from high tooling costs; single stamps or die could cost between \$20-\$30 million each. In BMW’s current development plan, the firm froze the package about 50% of total schedule and the design itself just two or three months after that. Occasionally, BMW’s pride in incorporating the latest technological breakthroughs into its new models would lead senior management to override these freezes.

Through the millions of man hours of work involved for each new car model, Dr. Reitzle, head of products and markets, stressed the importance of remembering the ultimate goal of car development: “The thrill of BMW is based on characteristics such as *dynamism* and *performance*, *esthetic style* and *emotion*, as well as *innovation* and *perfection to the last detail*. The harmony of the overall concept has always been BMW’s guiding factor and target.”⁸

⁸ W. Reitzle, “How to Shape a World Brand.” Speech at Harvard Business School, November 16, 1995.

The Evolution of Product Development at BMW

Since the 1970s, two generations of product development regimes could be delineated at BMW based on total development lead time, the entire time it took from initial concept development to market launch, and the number of major prototyping cycles. BMW developed all 3, 5, and 7-Series models using these processes (see **Exhibit 6** for average development times in the automotive industry):

- *The old process:* This system of product development dominated in the 1970s and 1980s (see **Exhibit 7a**). But because of the long lag times, the last car developed under this 72-month-long process was launched in the mid-1990s. The plan allowed for three major prototyping cycles with each cycle involving a generation of dozens of physical prototypes with increasing degrees of fidelity. A high-quality physical prototype could exceed one million dollars and often required months of superb craftsmanship by BMW's many prototype builders. During each prototyping cycle, functional and manufacturing problems could be identified via testing and solved while an increasing number of design and financial commitments were made to suppliers and manufacturing. For example, a critical variable during design engineering—the time from concept freeze to market launch—were the relatively long lead times it took suppliers to manufacture dies for pressing sheet metal during production. While the early release of design specifications to suppliers could speed up development, it had to be balanced against the very high cost of making design changes to such dies. The last cars developed under this development process belonged to the current 5-Series, which won not only numerous international awards but also commercial success.
- *The current process:* This system took root in the early 1990s entailed a 60-month-long process (see **Exhibit 7b**). The plan allowed for only two major prototyping cycles but for the first time started to take advantage of rapidly emerging computer simulation methods to identify potential design problems earlier in the development schedule ("front-loading"). For example, a vehicle's crashworthiness could be simulated and improved well before the results from the first actual prototype crash test became available—a milestone that came relatively late under the old development plan. However, much of the potential of computer-aided technologies remained untapped in the current process, which was modeled after the old hardware-driven process. The first cars emerging from this process was to belong to the new 3-Series, scheduled to be launched in 1998, and were already receiving very positive reviews from automotive journalists around the world.

Through the past few decades, BMW generally came out with new platforms every seven to eight years, but with only incremental or derivative model changes from year to year (for instance, converting a sedan to a station wagon by primarily modifying the rear end of the vehicle). Some industry observers likened the emergence of a new platform to "punctuated evolution," whereby the fossil records remained fairly constant for long periods of time only to be disrupted by dramatic evolutionary changes over short periods of geologic time.

Contributing to the long spans of time between platform changes was the meticulous handcraftsmanship that went into BMW products—a process that relied far less on outsourcing than at other firms. Compared to other firms, the company had higher fixed costs because of its significantly smaller volumes per model. Thus, BMW traditionally sought to squeeze sales from each model for a longer time than many other carmakers. This strategy, however, hinged on the ability to develop cars whose lives outlasted competitors' products. With competition increasing the rate and quality at which "fresh" models were introduced, designing products with seven to eight year life cycles was becoming a very difficult—if not impossible—challenge indeed.

In recent years, BMW started to feel the pressure of the changing market dynamics in all its product segments: sales volumes were getting smaller for each model because changing customer demands required increasingly differentiated markets. When BMW surveyed the international arena, it found, not surprisingly, that its current five-year development plan lagged behind other industrial competitors in Japan and the United States. While the Japanese tended to make fewer changes between consecutive models, their new strategy also emphasized the leverage of shorter development times to allow them to cover more market niches and market whims. To be more aggressive in all of its market segments, BMW had no choice but to substantially increase the productivity of its development pipeline.

In surveying the market, BMW found that *engineering lead time*, the time required from concept freeze to product launch, had remained remarkably constant at 40 months from the 1970s through the early 1990s among many other European and U.S. firms. Forty months appeared like an impenetrable barrier as the four-minute mile had been for runners for decades. To work around this barrier, some car manufacturers tried to overlap the planning with engineering phase. Many competitors had also started adopting the practice of reducing the complexity of their newer models by creating derivatives of platforms. Starting in the early 1990s, top managers from BMW made a series of benchmarking visits to leading companies from other industries worldwide. These included visits to Canada to Bombardier, the manufacturer of jet skis, boats, and airplanes and to France to Dassault, which had pioneered the widely used three-dimensional computer-aided design (CAD) system CATIA. By the mid 1990s, however, no matter which way they looked, BMW's senior managers found that change was in the air not only in the automobile industry, but in many other manufacturing industries as well. In short, the time was ripe to create a faster, third generation system for automobile development.

Reengineering Automotive Development

In the mid-90s, senior management approved a bold target for slashing product development time by 50% percent. A more modest goal, such as 20% or even 30%, management felt, would have had BMW chasing a moving target. After all, leading competitors in the United States and Japan were reported to aim at total development times between 30 and 40 months.⁹ In the race to develop cars faster, this ambitious target should take BMW from the tail end of the pack to the front end.

Shortly after this decision, senior management assembled a reengineering task force to examine how to reduce lead time and cost for product development. The task force concluded that rather than think about some grand development plan for process planning, the firm should focus on streamlining key engineering processes. The task force identified five key process areas—body, climate control, fuel supply, test engines (power train), and acoustics—that accounted for about 90% of the critical processes in the product development timeline. Thus was launched a “reengineering” effort focusing on these areas and that would also entail needed organizational changes.

Senior management next sought to recruit involvement of functional managers in these identified five areas by asking them to contemplate the hypothetical scenario, “what would have to happen to all of our products/processes if we were to cut product development time in half?” To ultimately achieve the daunting new product development cycle (see **Exhibit 8** for a rough plan), three changes in BMW's car development system would have to take place: increased parallelization of design tasks, elimination of some design iterations such as physical prototyping, and quicker completion of the remaining design iterations. These changes would entail increased coordination of efforts of in-

⁹ Julie Edelson Halpert, “Kicking Digital Tires on Cars of Tomorrow,” *The New York Times*, Dec. 5, 1997.

house engineers and craftsmen as well as outside suppliers. Helping BMW was that it had been the first major automaker to place all employees—numbering some 5,000—involved with product development together in one research and engineering center.

1. *Increased parallelization of design tasks:* The challenge here was to allow development of various components of product development to proceed in parallel. This entailed coordinated teamwork, with each team passing on information on the component it worked on to other teams in a timely manner. Parallel processes required the coordination of efforts made possible by computerization of design. Through computer simulations, “virtual cars” that existed only in computer memory and not in the real world, could be tested in parallel with on-going design activities. The world of virtual reality also provided a logical venue for coordinating the efforts of different functional divisions of a company such as between design and design engineering. But this meant not only reorganizing the way different groups worked together but also the difficulty of changing habits that had worked so well in their old sequential development plan.

Experience at BMW had shown that engineers were often loath to release less than perfect data. To some extent, it was in each group’s interest to hold back and monitor other groups’ output. The earliest group to submit its data to a central database, after all, would quite likely have to make the most changes since it would have enjoyed the least amount of feedback from other areas. But delay on part of only one team could derail the entire schedule, just as delay by an obsessive sauce chef could spoil an entire banquet. For example, BMW’s crash simulation group found its reengineering efforts stymied because the sideframe designers hesitated to release design data. It turned out that the door subgroup only wanted to release perfect data, as it had been accustomed to in the days of sequential development. Only after convincing the door subgroup that its early, rough data would suffice did the crash simulation group get the needed design data but with a six-month delay. But in the new development process, a six-month delay could derail the entire development program. Crash simulation and design engineers both learned that an appreciation and understanding of each other’s needs and activities had to be patiently built over time. It was not at all clear that the many of the other areas had learned the same lesson.

2. *Elimination of some design iterations:* A process as complex as developing a new car model, provides opportunities for pruning unnecessary design iterations. For instance, the widespread use of computer-aided testing for functionality and manufacturability helped to substantially decrease the number of physical prototypes needed in the past. Interestingly, while the number of prototype-driven design iterations would decrease, the total number of iterations would increase substantially if one counted the thousands of additional low-cost and quick iterations that would be carried out using computers only. But would only one generation of prototypes before market launch—as the new plan called for—be sufficient to identify all potential design problems? Even though many auto firms were trying to achieve one prototype generation only, BMW did not know if any of the firms actually succeeded at it.
3. *Quicker completion of the remaining design iterations:* Every remaining design step from prototype development to tooling simulation would have to be sped up. In many cases, this could be achieved at the tactical level through setting more stringent deadlines. For example, traditionally the engineering group released data for tools manufacturing in about 10 months; the goal now became 6 months. In many cases, the process of shortening steps involved proactively searching for problems that might arise downstream. Would a late design change involving a taillight, for instance, cause a tooling headache several months hence? But most of all, computer simulation itself allowed engineers to iterate more quickly. For example, design-build-test cycles of a new safety concept could be carried out via crash simulation in a matter of days or weeks as opposed the many months it had taken to design, build and crash prototype vehicles.

Top managers concurred that without the direct involvement and support of functional managers, the reengineering effort had little chance of success. A friendly rivalry developed between different areas to see which team could come up with the best development process. According to Dr. Rathgeber, the head of body development, "We were ready to adopt anything that would make us faster as long as it was not at the expense of quality." It was Rathgeber's reengineering team, which had been meeting weekly, that came up with the plan eventually selected by senior management.¹⁰

After acceptance of the new plan, senior management charged the other four development areas to follow and work on the many details and methods development required to make the plan work. The new development system—code-named "Digital Car"—heralded the widening role of computers in car development at BMW—a development that could potentially cast many departments in turmoil.

The Digital Car Project

Although much thought had gone into the digital car task force proposals, most middle managers and engineers found it hard to break away from daily business to press for reengineering changes and start investing in the building of necessary functional capabilities (such as training and new methods development involving computer-aided technologies). Functional managers, in particular were simply too busy with the daily demands of development work necessary to bring the next BMW models to life. Thus a year went by without much progress on implementing the new development system.

Senior management understood how frustrated engineers and designers must feel with the company struggling toward slashing development time by half while simultaneously attending to routine matters. But this did not concern them at the moment, given the mandate to boost productivity and efficiency. A Paris luncheon during a benchmarking visit to Dassault—the corporate jet manufacturer that had also developed the CAD system named "CATIA" used by BMW—provided an informal venue for several top-ranking executives to discuss BMW's future direction. The key role that computer-aided styling, design and engineering would play in the company's future plans, however, could equally well have justified this venue. In any case, the Dassault meeting would prove to jump-start BMW's quest for change.

At the Dassault luncheon, fueled by fine French wines, several executives boldly proposed testing feasibility of the new development system on a real development project. This project, they concurred, should entail so much risk and suffering that no cautious manager would ever block it. After much heated discussion, some executives proposed using the latest and revolutionary 7-Series platform that was already one year into development using BMW's current five-year process. The project would serve as a psychological Rubicon—once crossed, there would be no turning back for managers and engineers.

Other executives favored a much more cautious approach that emphasized the need to carefully build new development capabilities before betting the company's future on an unproven process. They argued that 7-Series project management had already invested a year of time and effort into incrementally improving a proven system of development that had produced some of the world's

¹⁰ This team was led by Dr. Rathgeber and represented several groups including package design (Pregl), in-house consulting (Osada, Dr. Grote, and later Stuhel), exterior design technology (Ratz), exterior design engineering (Weber), body stamping (Dr. Pfrang), tool design engineering (Bölsterl), body structure design engineering (Lüdke) and CAE (Dr. Finsterhölzl), prototyping (Baumann), prototype testing (Martin), and manufacturing planning and engineering (Dr. Mayer, Drasch).

finest cars. Furthermore, failure of the overly ambitious Digital Car development system might reflect unfairly upon any BMW division involved. As an alternative, they proposed to use a new derivative model—the 3-Series Touring station wagon—as a pilot project to manage and drive organizational change. The derivative project was based on the nearly completed 3-Series platform, involved little technical risk and could be used as a learning laboratory. Problems with the new and unproven process could be limited to the Touring station wagon and thus would not put the entire company at risk.

After much debate, the executive group decided to make the final project decision the topic of a larger senior management meeting after their return from Paris. Dr. Rathgeber later pointed out the high stakes involved in reducing development time by half: “Developing a new product with a new process is dangerous. We didn’t know how to develop a car in such a short time, but many felt that the longer we waited, the longer people would find reasons not to do it!”

In the back of their minds, however, many BMW managers wondered how long it would take to build up capabilities for digitizing automobile development. Would just a couple of years suffice? Even the swift-moving Japanese car manufacturers, after all, had built up critical capabilities gradually over the past decade. The challenge, after all, was not the procurement and installation of state-of-the-art computer hardware and software but the patient development of new capabilities and changes to processes and organization in order to leverage the opportunities that new technologies would offer. Would applying intense pressure within the firm, however, make up for lost time or simply demoralize developers?

Aware of the latest senior management discussions at the Paris meeting, Chris Bangle reminded himself that BMW’s loyal customers did not care about the company’s processes as long as it produced attractive and exciting high-performance cars. As Bangle walked to the senior management meeting in the inner sanctum of BMW’s research and engineering center, he took another look at the latest design sketches of the next generation 7-Series sedan and 3-Series Touring station wagon.

Exhibit 1 Historical Milestones

Automotive History

1885	First automobiles powered by internal combustion engines developed in Germany by engineer Karl Benz (followed in 1886 by compatriot Gottlieb Daimler).
1916	Bayerische Motoren Werke (BMW) founded to manufacture aircraft engines.
1923	Treaty of Versailles leads BMW into manufacturing ground-based transportation, starting with motorcycles.
1959	BMW's weak financial position, after several marketing errors, almost leads to a takeover by its traditional rival Mercedes. German industrialist Herbert Quandt rescues firm with personal investment.
Early 90s	Entry of the Japanese (such as Lexus) as serious contenders in the luxury car market.
1995	For the first time ever, BMW's unit sales overtake Mercedes.

Reengineering Project

Mid-90s	Decision to reengineer current 60-month development process because of changes in competitive landscape. Task force identifies five key process areas (body, climate control, fuel supply, engines, acoustics) that account for 90% of critical path activities.
1997	Dassault visit in Paris: decision made to use real project to drive changes towards a new 50% faster development plan. Project code-named "Digital Car". Decision point: should a derivative (3-Series Touring station wagon) or platform project (7-Series sedan) be selected for the new "Digital Car" development system?

Source: BMW AG

Exhibit 2 BMW Selected Financials and Operating Data

	1995	1996
Production (units)		
Automobiles—BMW	595,056	639,433
Automobiles—Rover Group	503,526	504,125
Motorcycles	52,653	48,950
Workforce	115,763	116,112
Income Statement (million DM)		
Net Sales	46,144	52,265
Automobiles	33,547	37,966
Motorcycles	731	744
Leasing	5,044	6,054
Other (spare parts, accessories, etc.)	6,822	7,501
Germany	13,862	14,621
United Kingdom	8,242	8,930
Rest of Europe	10,088	12,218
United States	6,177	8,228
Asia	5,291	5,574
Other markets	2,484	2,694
Increase in inventories and own work capitalized	1,189	696
Total Value of Production	47,333	52,961
Other operating income	1,814	2,078
Net income from investments	91	69
Net interest income	220	204
Total Revenues	49,458	55,312
Material costs	27,397	31,057
Personnel costs	8,846	9,844
Depreciation on intangible and tangible fixed assets	2,877	3,002
Other operating expenses (administration, distribution, warranty, etc.)	8,444	9,248
Interest expense from lease financing	527	501
Net Income Before Taxes	1,367	1,660
Taxes	675	840
Net Income	692	820

Source: BMW Annual Report 1996.

Exhibit 3 Major BMW Models (3-, 5-, and 7-Series) in the Late 1990s

BMW 7-Series



BMW 5-Series



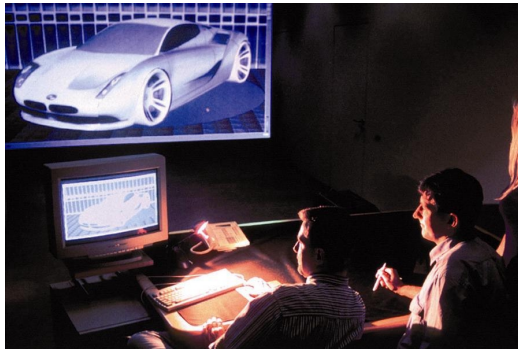
New BMW 3-Series



Source: BMW AG

Exhibit 4 BMW Designers and Craftsmen Using Manual Renderings, CAS and Clay Models

Designer preparing hand sketches for brainstorming design concepts.



Designers using computer-aided styling (CAS) for group brainstorming.



Craftsman working on clay model of concept car.

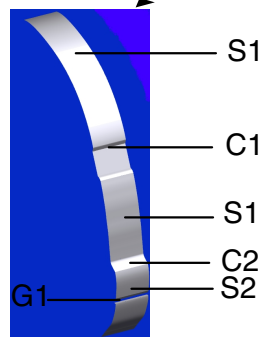


Designers and craftsmen making refinements to clay model of concept car.

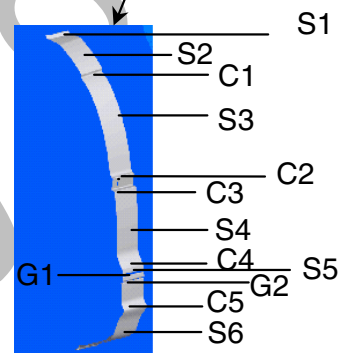
Source: BMW AG

Exhibit 5 Comparison of Exterior Designs

Compact Car (about \$13,000)



BMW 3-Series (about \$27,000)



Legend: S: basic surface
C: character element
G: gap

Number of design elements ("design complexity"):

• Basic design surfaces	2 (Sx)	6 (Sx)
• Additional elements	3 (Cx + Gx)	7 (Cx + Gx)
TOTAL	5	13

Source: BMW AG

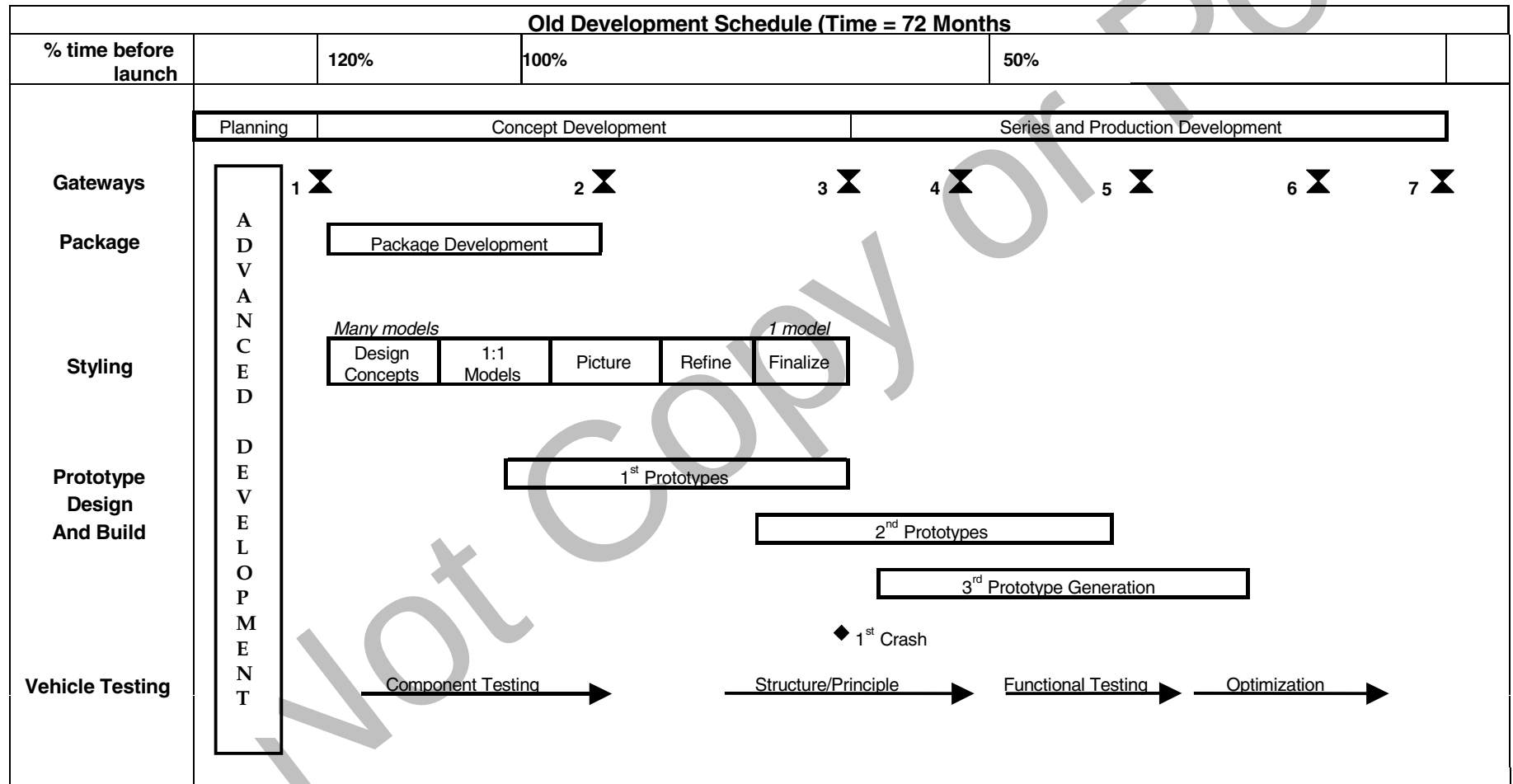
Exhibit 6 Research on Global Automotive Development Performance

Average Automotive Development Times
(in months; not adjusted for product complexity)

	Japan	United States	Europe
<i>Late 1980s</i>			
Total Lead Time (months)	<u>43</u>	<u>62</u>	<u>61</u>
• Planning	14	23	20
• Engineering	<u>30</u>	<u>40</u>	<u>42</u>
• Planning/Engineering Overlap	1	1	1
<i>Early 1990s</i>			
Total Lead Time (months)	<u>51</u>	<u>55</u>	<u>58</u>
• Planning	18	19	23
• Engineering	<u>32</u>	<u>40</u>	<u>42</u>
• Planning/Engineering Overlap	-1	4	6
<i>Definitions:</i>			
• Total lead time: months from the start of concept development to market introduction. • Planning lead time: months from the start of concept development to formal product approval. • Engineering lead time: months from the start of detailed design engineering to market introduction.			

Source: K. Clark and T. Fujimoto, *Product Development Performance*, Harvard Business School Press, 1991; D. Ellison, *Dynamic Capabilities in New Product Development: The Case of the World Auto Industry*, Unpublished PhD Thesis, Harvard University, 1996.

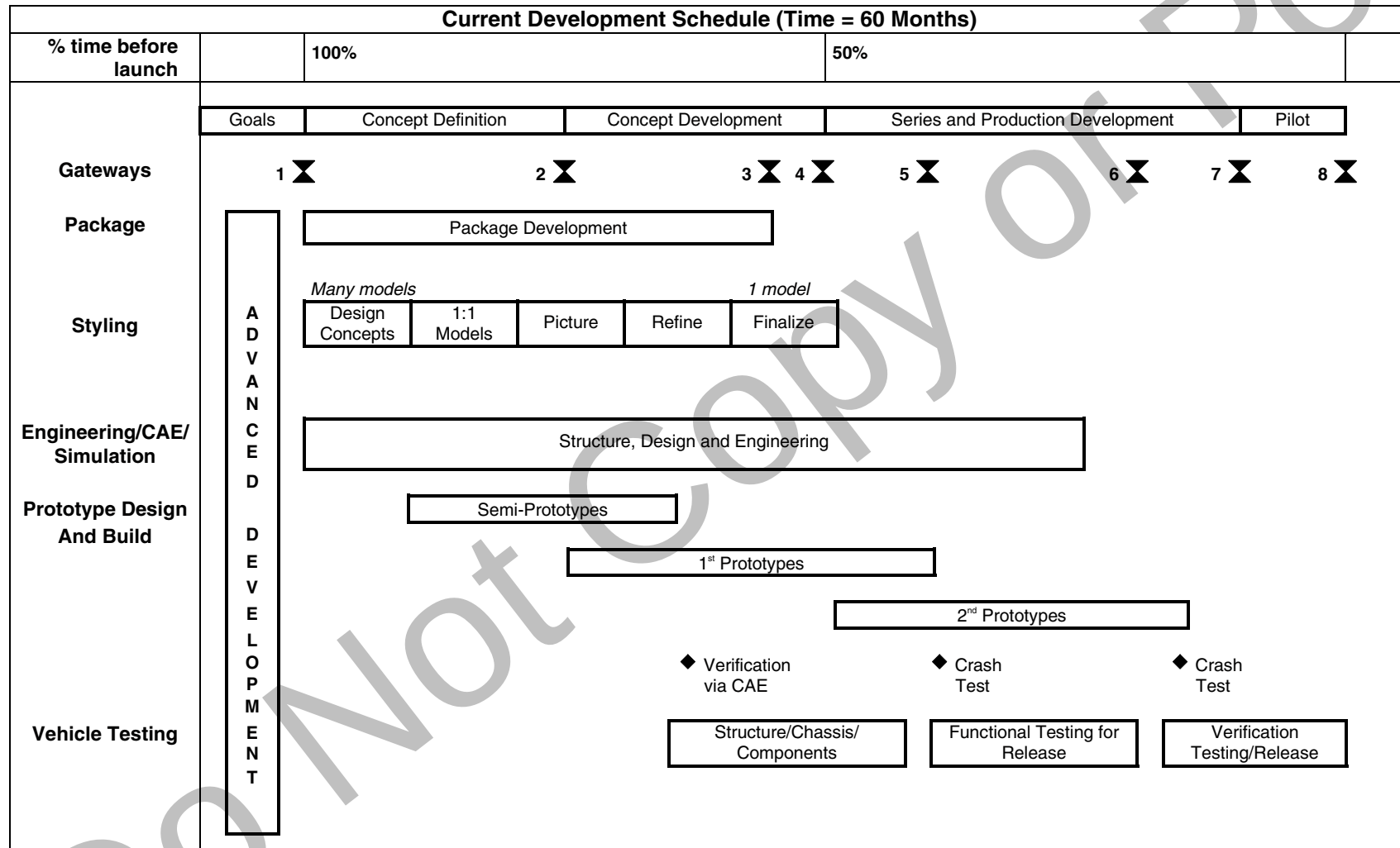
Exhibit 7a Old Development Schedule—Selected Activities (1970s to late 1980s)



Note: Advanced development runs in parallel to project level activities and is typical in automotive development.

Source: BMW AG

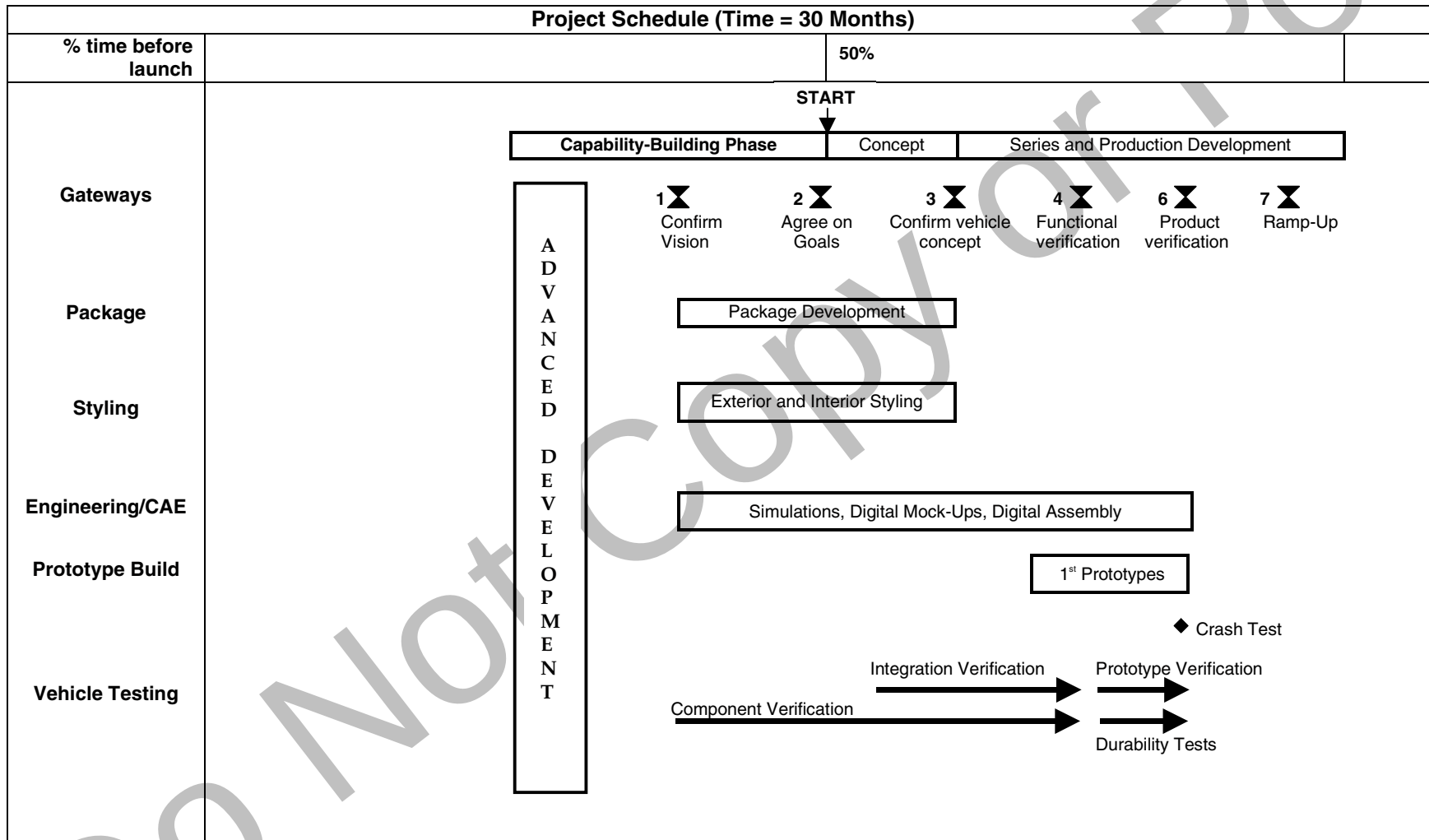
Exhibit 7b Current Development Schedule—Selected Activities (early to mid-1990s)



Note: Advanced development runs in parallel to project level activities and is typical in automotive development.

Source: BMW AG

Exhibit 8 New "Front-Loaded" Development Schedule—Selected Activities



Note: Advanced development runs in parallel to project level activities and is typical in automotive development.

Source: BMW AG