Deployment Scenarios for Vehicles with Higher-Order Automation

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10.1 Introduction and Background

Tragically, traffic accidents continue to be an everyday aspect of motor vehicle operation as evidenced by statistics. In the United States, for instance, there are approximately 33,000 traffic fatalities per year [1]; in Germany, the figure is roughly 3300 [2]. Vehicle automation, or the gradual delegation of driving from humans to computers, promises to drastically curtail the frequency and severity of accidents. Beyond that, automating vehicles will improve the overall coordination among them, improving the efficiency, comfort, convenience, and safety of personal mobility.

Automated highways and vehicles have been the subject of research and development for over five years now. The question is: how realistic is the vision of humans delegating driving to computers in the near future? Currently, several different development routes are apparent. On one side, the established auto industry is developing "driver assistance systems" with automated driving as the ultimate goal. Meanwhile, non-automotive technology companies from the IT sector have identified automated driving as a new business area for their core products, while recent start-ups are harnessing advanced technology to edge their way into the field of automated personal mobility. A closer look reveals that the players listed above have varying strengths and product goals, but are all driven by a common mission: to shape a new model of personal mobility that is safer, more efficient, more comfortable, and more convenient. This chapter will draw a comparison between these development trends and players.

The development trends will be treated as distinct deployment scenarios, each one a potential projection of how the introduction of vehicles with higher-order automation

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might play out. The scenarios were developed primarily by extrapolating publicly available knowledge on the state of the art for automated vehicles and projecting progress forward, while accounting for the outside factors of infrastructure, economics, and technology.

10.2 Definition and Scope

Automated vehicles, also known as “autonomous,” “driverless,” or “self-driving” vehicles, are currently the subject of extensive discussion in the general public, are being researched by universities, and developed by the auto industry. This article focuses on road vehicles, paying particular attention to passenger vehicles and to some extent trucks. It excludes trains, aircraft, and ships.

In general, the vehicles under consideration are operated on public roads; however, the discussion of synergies will also address vehicles that operate in restricted areas such as company premises, amusement parks, or pedestrian zones. Distinct from public roadways, possible usages in these restricted and/or partially public areas are salient because they allow us to observe critical interactions between automated vehicles and the public, which is ultimately to the advantage of their deployment in general road traffic. The individual implementation scenarios cover such cases in more detail.

This chapter will follow the taxonomy of automated driving and automated vehicles defined by SAE International as J3016 [3], which distinguishes between assistance, partial automation, conditional automation, high automation, and full automation.

To highlight the area under focus, this chapter introduces the term “higher-order automation,” which encompasses driving with conditional, high, or full automation. These categories merit emphasis because the step beyond the partially automated scenario—the point at which the driver no longer has to monitor the vehicle or system continuously—entails a fundamental change in what it means to drive a car. The radical shift is that the driver can then pursue other tasks during the trip besides operating the vehicle. Finally, a “driverless” vehicle would not even require a human driver whatsoever. This will pave the way to utterly new models for the operation and enterprise of personal mobility.

10.3 Development Trends in Automated Driving

The motives for deploying automated driving—safety, efficiency, extended mobility, comfort, and convenience—can be observed for various trends in this field. The individual aspects are apparent to varying degrees and depend considerably on the intended deployment area and purpose of use. The sections below will examine this in more depth by discussing the currently observed development trends. To start off, the next three subsections describe the deployment scenarios, reflecting the current discourse among both experts and the general public.

10.3.1 Continuous Improvement of Driver Assistance: Evolutionary Scenario

One of the principal players in automated driving is the auto industry, comprising both vehicle manufacturers and system suppliers. The auto industry has been concerned foremost with advancing driver assistance systems, or technology that supports the driver in operating the vehicle. Over nearly four decades, such systems have been introduced to both passenger and commercial vehicles, assisting drivers with longitudinal and, increasingly, lateral control. These systems include anti-lock braking systems (ABS), electronic stability control (ESC), adaptive cruise control (ACC), and lane-keeping assist, among others.

Figure 10.1 shows a timeline for the deployment of these systems. To date, these have emphasized increasing safety and, in some cases, comfort and convenience. The "evolutionary scenario" refers to the steady increase in the use of advanced driver assistance systems followed by successive steps towards vehicle automation and a corresponding reduction in the driver's responsibilities. This is one of the three deployment scenarios to be compared in this chapter.

For the first time in production vehicles, the auto industry is currently launching a suite of systems that automates both longitudinal (acceleration, braking) and lateral control (steering), with driver monitoring still to be introduced—in other words, a partially automated system. This suite of systems, often called a "traffic jam assistant" [4–6], presents a setting that combines adaptive cruise control (automated longitudinal control) with lane-keeping assist (automated lateral control) and thus automates control of the vehicle along both longitudinal and lateral axes in slow-moving traffic. In this mode, the driver's role is merely to supervise the system and intervene if needed.

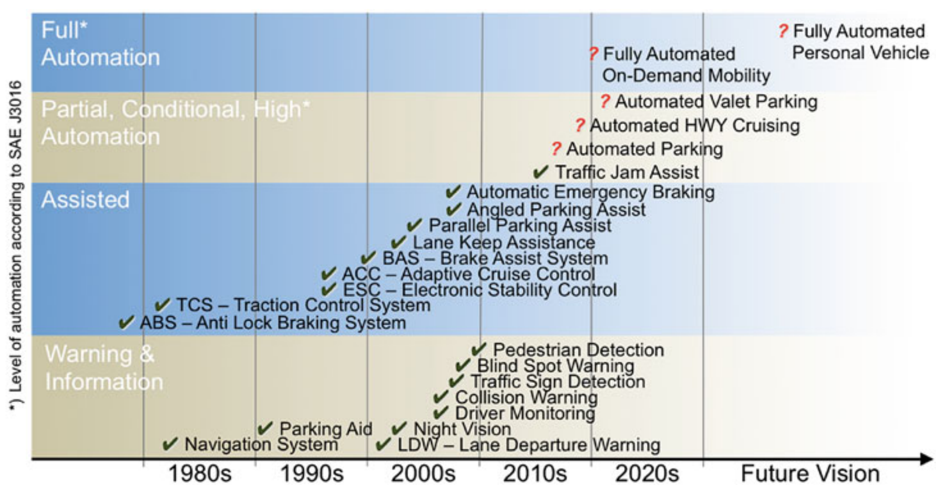

Fig. 10.1 Timeline for the deployment of advanced driver assistance systems with the vision of fully-automated driving (levels of automation as defined by SAE J3016 [3]). Copyright belongs to author

The next anticipated development stage is the increasing automation of parking. Today there are already many production vehicles that substantially facilitate the processes of both angled and parallel parking [7]. However, these systems tend only to take over the task of steering, the part that many drivers find more difficult, leaving them in control of the accelerator and the brake. As such, these present-day systems fall under the category of assisted driving. In the near future, a growing number of partially automated parking solutions are expected to offer not only system-controlled steering, but acceleration and braking as well. Then the driver's role is merely to monitor the system, for instance by pressing one button throughout the parking process—which remains a signal of the driver's attention and responsibility [8].

The recent past has witnessed statements by various automakers announcing the year 2020 as the target for "autonomous" driving [9–11]. Since the term "autonomous" does not have a set definition according to organizations like SAE International, the automation level implied by these announcements cannot be stated with certainty. Still, it is fair to assume that their functionality would move significantly beyond partial automation and maybe even enter the realm of high automation. In such a design, the driver would not even need to take over in an emergency within specifically defined use cases and zones, for the system is able to perform all driving tasks on its own including responding to unforeseen circumstances.

These announcements, often accompanied by public demonstrations of vehicles with higher-order automation, also show that many well-known automakers and system suppliers are currently working on designs to propel the evolution of driver assistance towards higher-order automation [10, 12, 13]. To that end, in keeping with the mission described at the beginning, traffic safety is treated as the number one objective with further increases in efficiency, comfort, and convenience seen as added benefits.

However, it is hardly possible to make predictions beyond the target date of 2020. Even though several market analysis reports and even some automakers themselves have raised prospects of full automation by 2025 [12], this should be seen more as a possible milestone in the evolution of driver assistance toward automated driving, and not as a reliable forecast of when particular system capabilities and features will be available. Due to their far-off time horizon, projections of that scope should be considered with caution.

Under the evolutionary deployment scenario, we can assume that it would take quite a while for a significant share of vehicles on public roads to have higher-order automation even if such vehicles were for sale as mass-market vehicles by 2020. In the past, it has usually taken around 15–20 years before a technology like ABS or ESC becomes a standard on all new vehicles or is at least available as an extra option [14]. Since the vehicle fleet is generally only replaced over the course of 20 years [15], we should hardly expect most vehicles to run without driver interaction in the foreseeable future under the evolutionary development scenario. Accordingly, this scenario is a more longsighted but also more predictable approach, particularly in comparison to the scenario described next.

10.3.2 Redesigning Personal Mobility: Revolutionary Scenario

Since 2010, non-automotive technology companies [16] have been known to be working on automated vehicles. Unlike the evolutionary scenario pursued by the auto industry and described above, these businesses are promoting a revolutionary scenario with the stated goal to "prevent traffic accidents, free up people's time, and reduce carbon emissions by fundamentally changing car use" [16]. It can be concluded based on such announcements and published design descriptions that these players are not pursuing the continuous improvement of driver assistance towards automated driving, but rather a disruptive leap straight from today's traffic pattern, with human-driven vehicles, into a scenario in which the driver hands over control to the system completely. Obviously this vision is one of fully or at least highly automated driving.

The key design feature from non-automotive technology companies is the inclusion of artificial intelligence. In other words, the functionality of automated driving is implemented by means of learning algorithms rather than the closed arithmetic designs that tend to be pursued by the auto industry. This approach attempts to close the gap between a purely analytical system operating within narrow boundaries and a rule-based system mimicking human behavior. The reason for using learning systems of that kind is that they can improve their features, such as object recognition, over time and learn from the user's behavior and preferences. Those are rather unusual traits for a vehicle from the auto industry, which conventionally introduces a product with its full range of features that then remain static and unaltered. In the computer industry, by contrast, it is standard to introduce a product and then steadily extend its range of functions, whether through learning algorithms or periodic software updates.

Whereas the deployment strategy under the auto industry's previously discussed evolutionary scenario seems relatively straightforward, the same is not necessarily the case in this revolutionary scenario. After all, these are players from the IT industry with no prior experience with automobiles [17–21], and they are pursuing a highly complex goal in an area outside their specialty that may not fit well with their core business. Although it is public knowledge that these firms have already driven several hundred thousand miles in vehicles with higher-order automation [22], their ultimate product goals remain unclear. To date, the players pursuing this revolutionary scenario have made scant mention of tangible plans for any launches on the market, and it is unsure whether these non-automotive technology companies intend to establish themselves as vehicle manufacturers [23, 24]. So far, a range of deployment deadlines have been estimated [25, 26], which in conjunction with other observations in the field give way to the following deployment scenarios.

It is conceivable that the test drives of vehicles with higher-order automation that are currently underway will serve as a platform for the acquisition and subsequent usage of maps and images aiding automated driving. The non-automotive technology companies could then offer services and online software products as part of automated driving and thus propel vehicle automation forward on a broad level. If so, the associated mapping and graphical information could be furnished for broader use, which would be more consistent with a continuous rather than a revolutionary deployment of automation.

However, once the vehicle is driving self-sufficiently without the need for supervision, the goal of those non-automotive technology companies might be for the driver to consume the products from their core business, i.e. online services. In that case these players' strategy would be taking quite a long-term view focused on revenue in their core business: the attempt to conquer the remaining segments of the market—transportation—as part of connected lifestyle. In other words, if the drivers were surfing the web or using social media during the trip, that would make them potential customers for online services just as much as any other computer user.

Another deployment scenario that seems a better match for the industry's tendencies and also allows for a revolutionary development can be deduced from the industry's public design descriptions [24], press releases [22] and patents [27]. On that basis, the deployment of vehicles with higher-order (perhaps even full) automation for services such as the transportation of passengers [28–30] and goods [31] appears possible even within the near future. One credible possibility could be the introduction of vehicles with higher-order automation as competitors of conventional taxis. Press releases [22] and media reports [24] seem to favor a deployment scenario along those lines, though they provide only sparse details about the true objectives and development stage of the technical implementation. This use case is described in this book under the category "vehicle on demand."

One variation of automated taxicabs is the idea of delivery services with higher-order automation, such as food deliveries [32–34] home delivery from local retail outlets [31], or deliveries of any sort of products ordered online [18]. Designs for those kinds of applications have already been demonstrated publicly. Based on strategic investments and acquisitions of the leading companies in these areas, the increasing automation of product delivery is a potential application of vehicle automation. Trials of "drones" for delivering goods [18, 32, 33] and automated garbage removal [35] may also point in that direction (Chap. 16).

Even though many questions remain unanswered, this decade may yet see a large step towards higher-order vehicle automation. This may seem minor and very limited at first (for example, fully automated taxis in one neighborhood), but its implementation area could grow rapidly along with its market share. Announcements by leading companies support the hypothesis that vehicles with higher-order automation will be rolled out before 2020 [22].

By starting with a limited deployment, non-automotive technology companies would have the opportunity to start gathering ample experience and data in the near-term, including the public reaction to these novel concepts. That would pave the way for them to apply their insights to expansion on a regional, national, and finally global scale. A deployment strategy of this sort would be anomalous for the auto industry and could even damage the reputation of a company that tried it. For non-automotive technology companies, however, it is standard practice. Indeed there are examples from past product launches where it has even benefited companies' reputations, as a limited introduction entails a certain kind of exclusivity [36, 37].

10.3.3 Merging Personal Mobility and Public Transportation: Transformative Scenario

Another deployment scenario for automated driving involves implementing transportation paradigms that provide slow-moving passenger vehicles, for example in urban areas. Consumers could summon such vehicles using a smartphone app and ride them over relatively short distances (see the use case “vehicle on demand”). Key drivers behind these types of schemes tend to be high-tech start-ups but may also include transportation service providers, municipalities and operators of facilities such as amusement parks. Their goal is to combine the advantages of personal mobility (independence and flexibility) with those of public transportation (efficient use of energy and space) in order to achieve the mission described at the beginning with a priority on reducing urban traffic congestion (Chap. 9).

Start-ups are motivated to enter these areas in order to develop new business models and deploy new technologies. In particular, companies from unrelated sectors can use image processing, object recognition, and route planning systems—which are already in widespread modular use—to implement transportation models with higher-order automation within a limited geographical range. The arrangements often proposed for market introduction are slow-moving and limited-area vehicles intended to serve what is known as the “first or last mile,” complementary to private automobiles or public transportation. To name one concrete example, these types of solutions could be used to reach bus and urban rail networks in areas where a regular schedule is not feasible due to inadequate infrastructure or financial limitations. Another example might be a “park-and-ride” system, whereby users drive their cars to a parking lot on the perimeter of a city or amusement park and transfer to a locally run transportation service. These arrangements would be favored for use primarily in places where private cars are not convenient or permitted or where buses with set schedules are not flexible enough.

These transportation solutions would compete with conventional taxis but be more affordable, comfortable, and innovative from the standpoints of both users and operators [38]. Based on their features, these arrangements have also been called automated mobility on demand (AMOD) systems. They represent an individualization of public transportation with the aim of transforming traffic in urban areas (Chaps. 9, 11). Companies’ incentive to introduce such arrangements is to gain access to new business areas or extend their range within existing markets. Currently, the taxi industry’s business model has comparatively high labor costs. Automated vehicles’ reduced need for human resources is anticipated to boost profits [38], though it would be accompanied by a reduction in employment in the sector.

It is quite conceivable that, by merging personal mobility and public transportation, automated vehicles will usher in a transformation of urban street traffic. Since these systems are only intended for a limited geographical range and would operate at low speeds, the difficulties are correspondingly reduced, and they would be much easier to implement in the near term than the first two scenarios discussed here. As such, it seems realistic that various cases of AMODs will be rolled out with limited scope by 2020.

Some early examples of the transformative scenario are already being implemented or are scheduled for the near future [24, 39–43]. It should be noted that a number of cities have conditions consistent with these use cases, allowing the operation of AMOD systems on a trial basis at the least. During the trial period, it remains to be seen whether residents will take advantage of the services and whether this will develop into a profitable business model. Although the first implementations should be considered extended trials on the spectrum between public prototypes and actual commercial deployment, these cases represent the most concrete step to date towards the implementation of vehicles with higher-order automation. The two other scenarios (evolutionary and revolutionary) may well learn from these experiences.

Due to the generally rather favorable conditions, it is anticipated that various individual city governments and operators of amusement parks, shopping malls, and other large-scale facilities will introduce automated transportation systems in the short term. On that basis, it also seems very likely that as the list of successful role models lengthens, by the end of this decade the field will already have a broad range of experiences to draw on and automated vehicles will have won the acceptance of their users and other people on the road. Despite the inherent simplifications—in view of the limited geographical range and low travel speeds—the evolutionary deployment scenario can also extract lessons from it to apply to the use of automated vehicles on public streets and highways. Even the limited use case of high or full automation with AMODs will furnish significant insight into the interaction between automated vehicles and other road users (including conventional vehicles, pedestrians, and cyclists) as well as the necessary safety/security measures and infrastructure requirements for later deployment on public roads. It is likewise fair to assume that the initially limited ranges of AMODs will expand over time. Accordingly, an automated transportation arrangement will gradually spread out onto public roads where it will interact with conventional and/or automated private vehicles.

10.4 Comparison of Scenarios

Now that the previous section has presented the deployment scenarios individually, the following section will compare them on several levels. As demonstrated above, these scenarios have both differing and shared objectives in terms of the advantages for users, commercial operators, and road traffic at large. The section below will spotlight differences in more detail but also draw attention to commonalities.

10.4.1 Systemic Comparison

The systemic comparison of the three deployment scenarios summarized in Table 10.1 provides an overview of the use cases for driving with higher-order automation,

Table 10.1 Characteristics of the deployment scenarios under consideration

	Evolutionary	Revolutionary	Transformative
Degree of automation	Partial/conditional	Conditional/high/full	High/full
Geographical range	Unlimited	Regional	local
Operated by	Laypeople	Trained personnel and/or laypeople	Trained personnel
Usage	Individual/private	Individual/private or public	individual/public
Ownership	Individual/private	Central/commercial	central/commercial

comparing and contrasting each scenario's objectives, potential implementations, and business models.

As described at the beginning, all three scenarios share the objective of raising the safety and efficiency of road traffic as well as increasing mobility and convenience. Beyond that, they exhibit increasing specialization in terms of the intended usage of a vehicle or assistance system. For example, when it comes to private cars, driving with higher-order automation will initially only be offered for highways or parking, in other words, specific driving situations. Likewise, new transportation arrangements will only be deployed at first in restricted areas such as shopping malls or amusement parks, in other words specific geographical ranges. This would result in a more distinct specialization of driving or system features than is currently the case. Today, private vehicles are expected to be usable by "anyone, anywhere, anytime." In other words, as long as they have a driver's license, anyone can drive a car no matter the time or place. With the advent of driving with higher-order automation, users may face a scenario in which the use of a vehicle is more limited or case-specific, requiring a mental adjustment.

These limitations are highlighted in Fig. 10.2, which contrasts the degree of automation with the geographical range. These two factors are perhaps the most crucial characteristics for classifying automated driving and allow us to draw an effective comparison between

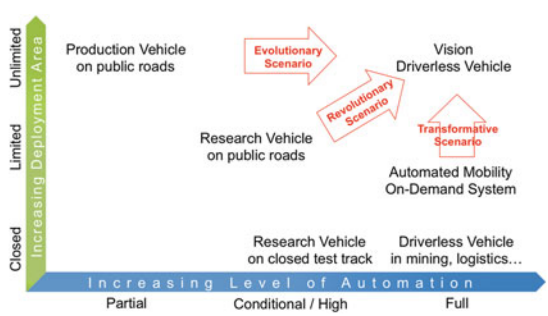

Fig. 10.2 Potential implementations for automated driving by degree of automation and geographical range. Copyright belongs to author

the three deployment scenarios presented here. The evolutionary scenario, entailing ongoing advancements to driver assistance systems, is intended for an unrestricted geographical range such as “all highways” or “any parking space.” On the other hand, it only offers a comparably low level of automation to start out with. By contrast, the revolutionary scenario, which aims at redesigning personal mobility entirely, and the transformative scenario, which provides for the merging of personal mobility and public transportation, both imply a very high degree of automation. Both cases would conceivably involve the rapid development of fully automated technology, albeit within a limited geographical range such as a particular neighborhood, a shopping mall, or an amusement park. For the sake of simplicity, one might say that the evolutionary scenario is moving toward the goal of full automation with the strategy of an “unrestricted geographical range but limited automation,” whereas the revolutionary and transformative scenarios are pursuing the approach of a “restricted geographical range but unlimited automation.”

One particularly interesting aspect illustrated by the comparison in Fig. 10.2 is the fact that the revolutionary scenario does not especially stand out on either axis compared to the evolutionary and transformative scenarios, yet overall it is the scenario that most closely approaches the ideal of a fully automated vehicle with unrestricted usage. Thus this scenario seems most consistent with the paradigm of “anyone, anytime, anywhere,” as it combines a comparatively large geographical range with comparatively high automation.

In regard to the transformative scenario, the question of who would operate the vehicles deserves special attention. It is anticipated that trained, specialized personal would monitor the vehicles’ operation or at least inspect them on a regular, perhaps daily, basis. As such, that scenario is highly distinct from the model of a privately operated car, which is generally operated by laypeople and rarely requires the attention of specialized personnel except for occasional maintenance or servicing. For that reason, the “anyone, anytime, anywhere” model poses a particular challenge for the evolutionary scenario, because it would require extremely high dependability even without ongoing supervision by specialists. Notwithstanding, the revolutionary and transformative scenarios prove to be helpful in preparation for the advent of individually used private cars with higher-order automation, since the operation of such vehicles under specialists’ supervision would lead to useful insight early on.

One potential use case for vehicles with higher-order automation, which is quite significant but cannot be directly attributed to one of the three development scenarios, is the prospect of an automated platoon on highways. In this use case, a number of vehicles that are otherwise used individually join together into a virtual train by means of a common communication infrastructure. This allows longitudinal and lateral control to be automated, although it would also require a special communication standard and only vehicles compatible with it could be included. At least at the beginning, the first vehicle in such a platoon would be driven by a professional driver; all the vehicles following it would not require any ongoing supervision and the drivers would only need to intervene in exceptional cases [44].

The scenario of an automated vehicle platoon brings together various traits of the evolutionary and transformative scenarios that make an implementation of such a scheme within general road traffic seem likewise realistic for the near future. On the one hand, this scheme would pose a near-term opportunity for an implementation of vehicles with higher-order automation, as the potentially limited object and situation recognition capabilities could be augmented by the lead driver's performance and experience. On the other hand, it may pose additional issues, such as the logistics of how to join and leaving the platoon, passing by other vehicles, and adhere to the legal following distance.

10.4.2 Technical Comparison

The systemic comparison has already revealed several differences among the deployment scenarios, which also have divergent requirements for reliability or, more precisely, the completeness and availability of the technology needed. Since the evolutionary scenario focusing on individually used private cars must function for any layperson without temporal or geographical limitations, it gives rise to different technical requirements from those of the transformative scenario, for instance, where a fully automated vehicle might be operated exclusively in a geographically limited zone under professional supervision. Furthermore, the number of vehicles in question and the corresponding number of system components may vary greatly, which bears an impact on the technology to be deployed.

To generalize, the evolutionary scenario requires sensor and processor components that are highly failsafe (i.e. redundant and equipped with fallback systems), low-maintenance (i.e. self-calibrating and self-monitoring), and cost-efficient (i.e. mass-produced) in order to guarantee maximum availability (see Table 10.2). The transformative scenario, however, favors specialized, highly accurate, and individually configurable systems that enable maximum automation despite an early implementation deadline, even if that means more work preparing the infrastructure. What makes the infrastructure for the transformative scenario especially labor-intensive are its need for a communication system that

Table 10.2 Qualitative comparison of the system requirements for the three deployment scenarios under consideration

	Evolutionary	Revolutionary	Transformative
1.1.1 Reliability	++	++	+
1.1.2 Accuracy	+	++	++
Configurability	0	+	++
Maintenance needs	−	+	++
1.1.3 Operator supervision	–	+	++
System cost	−	+	++

Legend ++ (high), + (significant), 0 (neutral), − (low), – (not applicable) allows the safe and coordinated operation of fully automated vehicles as well as the need for a maintenance and supervision crew to ensure the vehicles' functional safety by servicing them regularly as needed.

The requirements for the revolutionary scenario, in which automated vehicles are deployed within functional and geographical limitations, lie somewhere in between the technical requirements of the evolutionary and transformative scenarios, as it implies the use of a centrally operated and professionally maintained fleet of vehicles that is not necessarily subject to ongoing supervision. Thus it requires highly failsafe and precise systems that would presumably lead to comparatively high cost.

The implementation of a communication infrastructure for vehicles with higher-order automation is especially significant for the deployment scenarios. Communication both among vehicles and between vehicles and infrastructure could be employed to exchange data on vehicle positions, vehicle speeds, and other parameters, which would then be used for routing or perhaps for a central vehicle coordination system. The trend toward automated vehicles in the industry would therefore benefit from another current trend which is toward connected vehicles. In that context, it is also particularly significant that there are government initiatives in various countries aiming to lend momentum to the development of vehicle-vehicle and vehicle-infrastructure communication [45–48].

10.4.3 Regulatory Comparison

The three scenarios can also be differentiated by the regulation that would apply to them. Since the vehicles under the evolutionary scenario are intended to be operated on public roadways without any geographical or temporal restrictions, their use must be subject to the corresponding traffic regulations. As a result, it remains unclear at this point which legal jurisdictions allow automated vehicles to be operated under their purview and to what extent they may be automated.

In the case of the transformative scenario, however, the circumstances are somewhat different. Particularly due to the anticipated geographical restrictions of use—initially outside of public roadways as well as other areas with unrestricted access (instead favoring locations such as shopping malls or amusement parks with their own access rules)—a special set of regulations may be implemented. That means that either special rules will be established for the area where the automated vehicles are operated, access to it will be restricted to a specific group of people, or everyone who enters the site will be required to declare their consent. The final arrangement in particular would make operations considerably easier, as the operator's liability or mandatory supervision requirements could be regulated based on specific needs.

In terms of legal requirements, the revolutionary scenario falls in between the evolutionary and transformative scenarios. If we assume that such systems are initially limited to a certain geographical area, such as a neighborhood or a particular highway segment, the area would be subject to general road traffic regulations but there could conceivably be special additional rules, such as targeted restrictions, authorizations, or liability regimes that would apply solely to that route.

In terms of applicable regulation, it is also important to keep in mind how regulators treat vehicle automation in their own jurisdictions. In the United States, for example, some states (the pioneers being Nevada, Florida, and California) have instituted regulatory frameworks governing the operation of vehicles with higher-order automation, albeit in many cases only for trial runs so far. Meanwhile on the federal level, the National Highway Traffic Safety Administration (NHTSA) has urged caution and recommended a coordinated introduction alongside vehicle-vehicle communication [49]. The government of Japan has expressed its advocacy of the strategic objective of automating road traffic and has offered to support the industry to that end [50, 51]. In Europe, governments remain cautious when it comes to automation—apart from ongoing participation in research ventures [44, 47, 48, 52–54]—though it is anticipated that the topic will received intensified attention in the years from 2015 to 2020, as evident already from the earliest proposed legislation [55] (Chap. 25).

10.4.4 Comparison of Corporate Strategies

The description of the deployment scenarios above has identified the lead players and categories of companies involved in each of the three cases. The evolutionary scenario appears to be pursued more so by established vehicle manufacturers and system suppliers, while the revolutionary scenario is favored by non-automotive technology companies from the IT industry and the transformative scenario is advocated by start-ups and service providers.

Table 10.3 presents the three categories with the companies' characteristics, objectives, and strategies. Thus established automakers can draw on experience and processes allowing them to implement development projects related to automated driving with appropriate planning certainty and see them through all the way to the product launch. This is primarily rooted in the evolutionary approach, where the existing development, production, and sales processes are extended to a new class of product (automated driving). That model makes it rather difficult for them to deploy completely novel products or processes. Another characteristic of the auto industry is that its existing market positions and company histories lead it to proceed in a manner perceived by outsiders at times as rather cautious.

The auto industry's caution might be rooted in the fact that these companies have established and refined their reputations and brand images among customers over a period of decades, making their company names valuable assets worth protecting (Chap. 32). The companies' reputations can be rapidly jeopardized by unreliable or unsafe products, which

Table 10.3 Comparison of various corporate strategy characteristics for each of the deployment scenarios

	Evolutionary	Revolutionary	Transformative
1.1.4 Key player	Auto industry (manufacturers, suppliers)	Non-automotive technology companies	High-tech start-ups
Objective	Bolster market position; improve safety, comfort, and convenience	Explore new business models, extend core business	Create new services for urban mobility
Competencies, characteristics	– Testing, backup systems – Production – Distribution marketing/sales operated by – Maintenance	– Artificial intelligence – Digital mapping – Public trials – Unconventional products – Online services – New business models	– Image processing – Sensor technology – New products and business models – Lean, unconventional processes

can have a long-term impact on their commercial success. Along these lines, introducing automated vehicles prematurely is seen as an especially risky move. Indeed, such reservations are justifiable, as evidenced by numerous instances where automotive products failed to meet customer's expectations or aroused suspicions of safety risks and consumers proceeded to respond negatively to the associated brands [56–59]. Reservations of this nature, whether justified or not, may cause a delay in the market introduction of automated driving technology, which has strong safety implications and is centrally important to the public interest.

In contrast, such considerations are much less relevant for start-ups pursuing the transformative scenario, as these companies tend not to have long histories or an (automotive) brand image to protect. At the same time, they do not have years of experience developing, producing, and selling cars. This makes these companies better placed to develop and launch extremely novel products and services as required by the transformative scenario described above. In the event that a product fails to meet the market's expectations, these companies do not bear the risk of jeopardizing a company name that has been developed over time.

Moreover, start-ups are often able—or practically forced—to develop alternative processes and product solutions due to their frequently small size. For that reason, start-ups have more flexibility in the concepts of automated driving that they design and can pursue implementations with greater inherent risk. Yet the start-ups must also overcome the challenge that developing automated vehicles is often only feasible by means of a high capital investment due to the complexity of the systems and components involved. Likewise, it may take a relatively long time before a product is completed and generates any revenue. As such, these companies are often reliant on venture capitalists and their longevity can sometimes be uncertain.

Once again, the revolutionary scenario lies somewhere between the other two. As explained earlier, the players in this area are often non-automotive technology companies that have access to sufficient capital and can also capitalize on processes that have not yet been applied to automotive product development. For those reasons it seems plausible that a revolutionary scenario can be anticipated from that precise sector. In fact, this type of company has already begun gathering significant experience in transportation systems; for instance, one of the companies from the IT industry has already traveled over a million kilometers using vehicles with higher-order automation [22] and has prior involvement with the transportation of passengers [28] and goods [31].

10.5 Summary and Outlook

This chapter explored three scenarios for the deployment of vehicles with higher-order automation: the continuous evolution of driver assistance systems by the established auto industry, the revolution of personal mobility by non-automotive technology companies, and the transformative merging of private and personal mobility by start-ups and transportation service providers. At this point, these seem to be largely independent development paths that occasionally compete. However, in regard to the deployment of driving with higher-order automation, there are synergies to be exploited, particularly in the areas of infrastructure and public acceptance. It should also be noted that all three deployment scenarios ultimately work towards the same final scenario, which is for the vehicles that are currently driven by humans to be fully automated in the future, giving rise to new use cases and business models and an altered set of transportation behavior.

The differences between the scenarios highlight the likelihood of vehicles with higher-order automation being introduced in different geographical ranges with varying sizes and in varying regions. It is also anticipated that the scenarios will be introduced at different points, resulting in a staggered timeline. To generalize, it is fair to predict that the sequence of public introductions over the coming decades will lead from the transformative scenario to the revolutionary scenario and finally to the evolutionary scenario. The geographical range of these systems would grow from the local level to the regional scale and finally become global.

We can also expect that in addition to the fully automated, slow-traveling and limited-area transportation options that are currently being introduced in extended trials, there may be local fully-automated taxi services by the end of the decade, which will lead the way for the general operation of vehicles with higher-order automation on highways, country roads, and urban streets in the years after 2020. Over the next few decades, this development will allow us to exploit many opportunities to increase the safety, efficiency, convenience, and productivity of personal mobility. Beyond the clear synergies among the various scenarios, they also offer valuable links to the automation of other vehicle classes in settings that span from logistics centers and container ports to agriculture and mining, perhaps even robotic missions to explore far-off planets.

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