IFAMD Market Commentary 01/2020

- How e-mobility, autonomous driving and car sharing interact -

What is the connection, if any, between the current megatrends of the automotive industry – the fade-out of the combustion engine, the collective dream of completely autonomous driving, and the automobile manufacturers' modern business model of being 'mobility providers'? At first glance, these three trends are entirely unrelated. Yet they are mutually dependent, and a game-theoretic analysis reveals an astounding insight.

Think what you like of the emissions scandal ('Dieselgate'), but the days of the combustion engine are numbered. As the source of propulsion, the electric motor with its simple magnet rotor has unbeatable advantages over the ensemble of cylinder, piston, camshaft and gearbox. The electric motor is vasty cheaper to produce and at the same time more durable. With e-mobility, vehicles exceeding the 300,000-mile mark over the course of their lives will become the norm. This alone will have dramatic effects on the turnover and margins of the entire automotive industry.

Even if word gets out that CO_2 is not the only risk to the environment and that battery-powered vehicles are likewise terrible polluters in their own way, the electric motor remains the single forward-looking concept. What will continue to require some thought is the form in which energy is stored and then released again in the vehicle. Thus, the combustion engine is being replaced not so much by the electric motor but rather by the battery itself, which is responsible for releasing the chemically stored energy. Anyway, we are in a sense using 'e-mobility' merely as a label to indicate an environmentally superior alternative to traditional automotive technology, thus avoiding any discussion as to whether hydrogen fuel cells for example are perhaps in fact the better way to go. Knowing that this is a gross simplification, we will assume here that vehicles powered by electric motors are free of emissions and therefore always superior from an environmental point of view. In the game-theoretic analysis, the 'player' to whom we assign strategies and playoffs is in a sense the environment itself or, as it were, the 'political will' to protect the environment: The available strategies are 'making the transition to e-mobility' versus 'sticking with combustion engines', and the payoff is quite simply the emissions reduction.

The second player is the consumer. Listening to some people today, one might actually believe that very soon our roads will be populated exclusively by autonomous robot vehicles and all problems will be solved: no more congestion, no accidents, no more need for a driver's license, and the time of travel may even be used for emails or for a nap. Few people would pass up an opportunity like that. Two years ago, we already shared some thoughts on the implications of such a scenario for everyday road encounters and ultimately for society as a whole in our Market Commentary No. 12/2017, entitled "A differentiated approach to the dream of automated driving". The present reflections shall only consider – again quite simplistically – the desire for the realisation of autonomous driving as a strategy for consumers. In the end, their willingness to pay for this new opportunity will exceed the enormous R&D investment required for its implementation – this at least appears to be the belief held by the marketing strategists in the

automotive industry, who currently pin their hopes on autonomous driving across the board. Whether autonomous driving constitutes the realisation of a product in the sense of the make-and-sell or rather the sense-and-respond strategy according to marketing guru Philip Kotler appears to be merely an academic chicken-and-egg question. We will assign the consumer a slightly higher payoff in case autonomous driving is implemented because the value that he attaches to this opportunity evidently exceeds his willingness to pay for it – this is downright immanent to the concept of willingness to pay. Yet will autonomous driving really be implemented only if its cost falls short of the willingness to pay, or is there a third effect? The game-theoretic analysis will tell us.

The third player, finally, is the automotive industry itself. While at first glance the issue of the functionality of autonomous driving is still purely a question of marketing strategy – again in line with Kotler, we consider product definition to be a task for marketing strategy here –, we shall think of the mission – 'to build cars' versus 'to provide mobility' – and thereby ultimately the decision about the business model as an active strategy choice for the automotive industry as a player. Meanwhile Volkswagen is communicating the new self-image very actively and has even ditched its slogan "Das Auto" ("the car"). BMW and Daimler, too, are now pursuing this path, in cooperation with the Car2Go platform, which was recently renamed ShareNow. This goes far beyond the original idea of sharing a ride, which was simply to save miles by putting more people in a car. The auto industry will rather aim for the modern young consumers who no longer want to have their own cars but who are not to be lost as customers.

But what, then, is the interconnection between these three players and their respective strategic options? Is the scenario in which autonomous electric cars roam the streets exclusively on demand, without belonging to any particular user, really to be desired? Let us approach this situation from the perspective of game theory:

We have identified three players, each of whom has two alternative strategies: The political will for environmental protection with the options 'combustion engine' and 'e-mobility', the consumers with 'human driver' and 'autonomous driving', and the automotive industry with 'build cars' and 'provide mobility'. Combining all options, we obtain a cube with eight constellations, each of which represents a set of payoffs for the three players.

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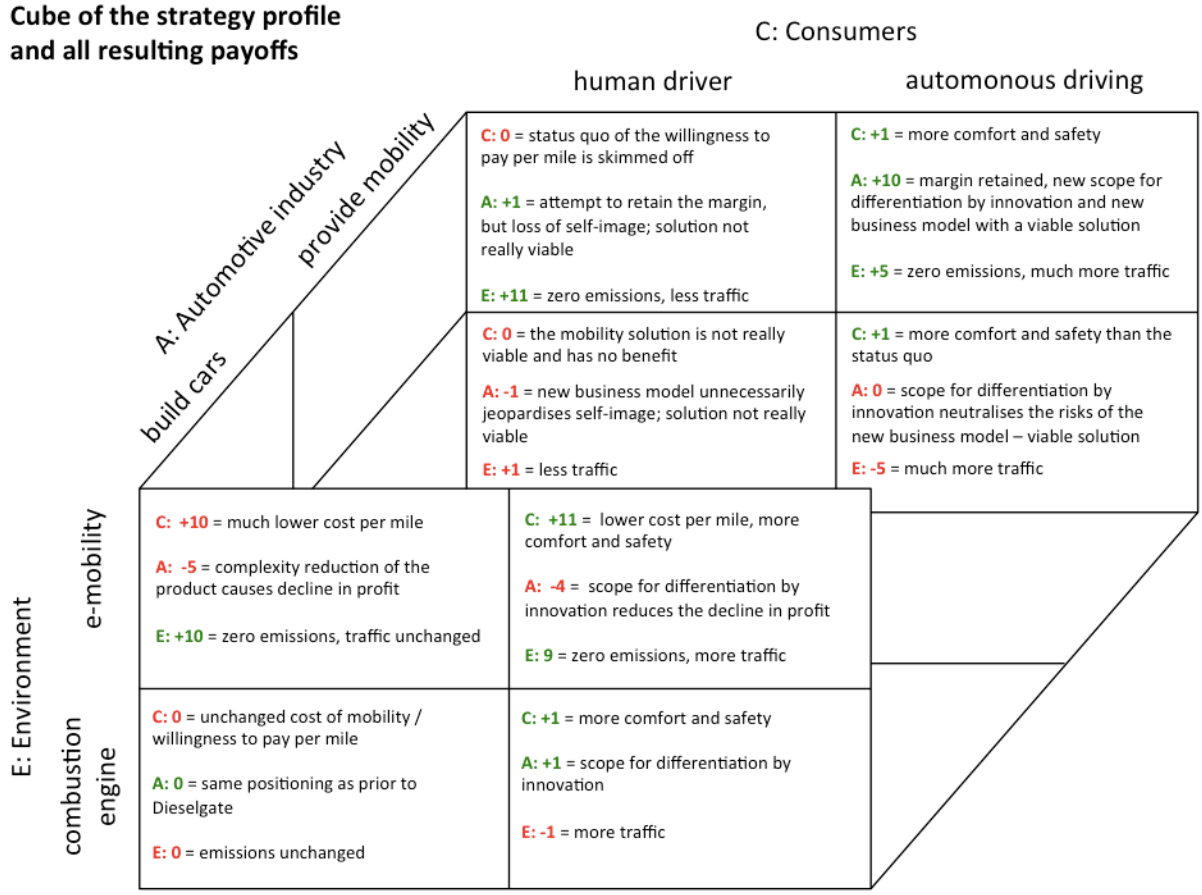
Cube of the strategy profile and all resulting payoffs



For the game-theoretic analysis, we now need to somehow quantify the 24 payoffs. This requires a multitude of debatable assumptions and computations, about which we will be as pragmatic as possible. A huge advantage of game theory is that exact and absolute payoffs are not required to obtain an insightful result. All we need is to get the payoffs right in relative terms. The most important aspect are in fact the deliberations by the individual players between the respective constellations at the two vertices along each of the 12 edges of the cube, assuming at the same time that the two other players – in a sense, ceteris paribus – stick to their choices (for the time being). This is exactly what we shall examine now:

Let us begin with the issue of e-mobility, which we already hinted at as the strictly dominant strategy above. Be it in the context of car sharing or not, regardless of whether or not the driver holds the wheel – zero emissions should always be considered the best option, which from the environmental perspective speaks in favour of e-mobility. However, comparing within each of the two planes 'combustion engine' and 'e-mobility' the four payoffs for the environment that ensue with and without car sharing and with and without autonomous driving, we maintain: Car sharing by itself, i.e. without autonomous driving, reduces the number of miles driven and is therefore

more environmentally friendly than no car sharing. This effect is fairly plausible with combustion engines. We will assume that it also persists within the ‘e-mobility’ plane because even zero-emissions vehicles cause some environmental harm – be it just the particulate matter from tire abrasion or the wind noise.

The situation is similar with autonomous driving, though with the sign reversed: We postulate that autonomous driving will raise the demand for transport because the barriers to mobility are reduced. The effect becomes extreme when autonomous driving meets car sharing models: Only with autonomous robot taxis will the wet dreams of all traffic visionaries become true and we all can have ourselves taken from A to B everywhere and at any time at the push of a button (or rather at the click of the mouse or the swipe of a finger) – the barriers to entry for consumers of mobility cannot be any lower. That carpooling reduces the overall traffic volume, as was the original intention, can then no longer be assumed. Perhaps the problem of parking space will be solved because we no longer need to leave our vehicles near us. The downside, however, is that all vehicles will constantly be driving to and from pick-up locations, many of the trips empty, which reduces the original rationale of carpooling to absurdity. Of course some calls for transport will complement each other, so that not every trip will necessitate an empty trip in the opposite direction. Thus, the factor by which the traffic volume will increase when all transport occurs in autonomous robot taxis is likely smaller than 2, though certainly greater than 1. This means that for the environment, this scenario is the least desirable of the four within each of the two planes ‘combustion engine’ and ‘e-mobility’.

The second perspective from which we shall contemplate the cube is that of the consumer. For him, too, we shall assume that autonomous driving is the strictly dominant strategy: Be it with combustion engines or e-mobility, be it in their own cars or with mobility services – the consumers no longer want to hold the wheel but rather enjoy the added comport and safety of autonomous transport. Yet we deem the consumer’s benefit to be relatively low because he will have to pay higher prices to cover the R&D expenditures of the new functionality. The automotive industry will skim off the consumer’s willingness to pay to such an extent that he just barely decides in favour of autonomous driving. The issue of mobility concepts is something we consider to be ultimately neutral for consumers. This may be surprising initially, for is it not precisely those mobility concepts that are supposed to make traffic all modern and fancy in the future? Well, we shall consider the payoffs that ensue for the consumer depending on whether and how his demand to be taken from A to B can be satisfied. Any preference of the consumer for carpooling due to his environmental conscience was already covered in the environmental dimension. Therefore, in the combustion engine scenario – be it human-driven or machine-driven – we assume that the consumer is ultimately indifferent between getting from A to B in his own car or by virtue of some mobility concept, however well that may work.

However, a different picture emerges with e-mobility. As already hinted above, e-mobility enables sweeping cost savings in the production stage alone. Add to this the additional savings per mile that arise thanks to the extended lifetime of electric vehicles. Whether, as a third effect, the mere operation of electric vehicles will also be sustainably cheaper than that of today’s cars is not for us to discuss because that would necessitate speculation about future power prices. Yet the first two effects shall suffice for our proposition that the transition to e-mobility will reduce

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the driver's cost per mile by several orders of magnitude, which entails a payoff that consumers should really look forward to.

Now the automotive industry enters the scene. As we are already feeling quite strongly today in the days of 'Dieselgate', the alternative of pure e-mobility is becoming a real threat to the auto industry. Not only does the technological leap require innovation and investment, but large chunks of the traditional value chain are becoming completely obsolete at the same time. A wholesale transition to e-mobility would mean an enormous bloodletting for the auto industry. Against this background, the adoption of a new self-image as a provider of mobility may be considered an act of desperation – the auto manufacturers' hope being to be able to keep the cost advantage of e-mobility in their own books: Over the course of decades, consumers have gotten used to a certain status quo regarding the cost of a mile of mobility, which is now reflected in their willingness to pay. To maintain this willingness to pay and to continue to skim it off using modern mobility concepts is what we recognise as the rationale behind the auto industry's new business models. Yet this will not work while carpooling only amounts to some environmentally conscious consumers sharing a ride. To practically implement complete coverage with robot taxis requires nothing less than the full automation of road traffic. Only when all road travel can be achieved with a robot taxi ordered specifically for the trip does the full transformation of the mobility concept from the individual vehicle owner to the business model of a pure mobility provider become viable.

For the consumer this means that his old willingness to pay will continue to be skimmed off in the modern mobility scenarios, so he does not (directly) participate in the cost savings afforded by e-mobility. While the game-theoretic analysis of the cube reveals that the scenario of 'e-mobility with autonomous driving and modern mobility concepts' appears inevitable as the Nash equilibrium, for both the consumer and the environment, the two constellations with conventional vehicle owners and e-mobility are far superior to the Nash equilibrium. This situation is indeed reminiscent of a prisoner's dilemma, even though it does not qualify as such: For that to be the case, the vertex that is located diagonally across from the Nash equilibrium would have to be preferable to the Nash equilibrium for all three players. Neither does a prisoner's dilemma occur in any of the six two-by-two planes of the cube among the two players concerned. Nevertheless, we find that the Nash equilibrium is the best outcome neither for the environment nor for the consumer – because both parties are only induced to play the Nash equilibrium as such by the automotive industry.

At least the automotive industry expects to be rescued in the Nash equilibrium, and – as direct or indirect beneficiaries of the most important industry in Germany – we should all appreciate that to be in our interest.

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