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Tomorrow’s Car – for today’s people: can tilting three wheeled vehicles be a solution for the problems of today and the future?

Frank Will, James Nicholas Davidson, Paul Couchman, David Bednall
Deakin University

ABSTRACT

The current automotive industry and today’s car drivers are faced with every increasing challenges, not previously experienced. Climate Change, financial issues, rising fuel prices, increased traffic congestion and reduced parking space in cities are all leading to changes in consumer preferences and the requirements of modern passenger vehicles.

However, despite the shift in the industry dynamics, the principal layout of a car hasn’t changed since its invention. The design of a ‘conventional’ vehicle is still principally a matchbox with four wheels, one at each corner. The concept has served its purpose well for over 100 years, but such a layout is not suited to solving today’s problems.

To address the range of problems faced by the industry, a number of alternative commuting vehicles have been developed. Yet the commercialization of these ‘alternative’ vehicles has yet to be successful. This is largely due failure of these vehicles to meet the changing demands of the industry and the limited understanding of consumer behaviour, motivation and attitudes.

Deakin University’s Tomorrow’s Car concept tackles all of these problems. The vehicle is a novel three-wheeler cross over concept between a car and a motorbike that combines the best of both worlds. The vehicle combines the low cost, small size and ‘fun’ factor of a motorbike together with the safety, comfort and easy to drive features of a car produce a vehicle with a fuel efficiency better than either car or scooter.

Intensive market research has been conducted for various major potential markets of alternative vehicles including India, China and Australia. The research analysed consumer attitudes in relation to narrow tilting vehicles, and in particular towards Deakin’s Tomorrow’s Car (TC). The study revealed that a relatively large percentage of consumers find such a concept very appealing. For the other consumers, the overall appearance and perception of safety and not the actual safety performance were found to be the most impeding factors of such vehicles. By addressing these issues and marketing the vehicle accordingly the successful commercialization of Tomorrow’s Car can be ensured.

INTRODUCTION

Some of the most important challenges for the automotive industry today and even more importantly, ‘tomorrow’ are global warming, the global gridlock, and record oil prices.

As the roads become more congested, fuel prices increase and society become more environmentally conscious, consumers are looking to purchase smaller, more efficient vehicles, that are more enjoyable to drive.

In light of the change in consumer preferences and the increasing awareness of climate change, governments are also trying to reduce the impact of individual transportation on global warming. Governments, such as in the European Union, are now setting CO₂ emission limits for new vehicles in an attempt to reduce the effect the automotive industry is having on climate change.

Furthermore, the Mega cities are experiencing rapid growth, yet the parking space in the centers of these cities is decreasing with increased development. The result is an increase in traffic jams that uses precious energy, produces unnecessary emissions and delay the people involved, leading to more tension and aggression on the roads.

At the beginning of the 20th century, the situation in major cities was quite similar. Horses were the main means of transportation with their key disadvantage being the severe pollution through horse excrements. At the time, the solution to this problem was the invention of the motorized passenger vehicle.
However, over the last hundred years the basic configuration of most passenger cars has not fundamentally changed. The concept of a 'motor vehicle' is one still similar to most horse coaches. The design consists of a passenger compartment in the center of the vehicle and four wheels, one on each corner, to provide stability. The vehicles were predominately used to transport a number of passengers. Yet, today, the transport requirements in large cities are quite different than hundred years ago. The average occupancy levels have decreased as most people drive their car alone, particularly during the commute to and from work.

As was the case in the early 20th century, society and the automotive industry are looking for a potential solution to the abovementioned problems and potential improvements in transportation. Motorbikes, scooters and bicycles have all been considered as valid alternatives to the ‘conventional’ motor vehicle. These modes of transport have many advantages and are more ‘fun to drive,’ or better to ride than conventional vehicles but have had limited commercial success due to the high safety risks. The lack of crash zones, roll over protection and other typical car type safety features, like air bags and safety belts all contribute to motorbike riders being 34-times more likely to die in a crash compared to car drivers per km travelled [1]. Such safety risks together with special skill requirements and lack of creature comforts have all contributed to the limited success of the vehicles.

In light of these issues a new type of vehicle is required that will satisfy the needs of today’s people. “Tomorrow’s Car” (TC) for today’s people, from Deakin University is a new revolutionary cross-over fun vehicle with ultra-low fuel consumption and emissions. This new vehicle generation combines the best of two worlds: the, low cost, small size and ‘fun to drive’ factor of a scooter, together with the safety, comfort and easiness to operate of a car. The result is a vehicle that is more fuel efficient than most cars or even scooters. An image of how such a vehicle could look is shown in figure 1.

![Figure 1: A possible design version of “Tomorrow’s Car”, two of them sharing one bay](image)

To ensure the commercial success of TC an ordered and systematic approach was undertaken in its development. After analyzing previously developed and currently available alternative vehicle, a review of the current market trends in the automotive industry and the shift in consumer preferences was completed, and market opportunities were identified accordingly. The potential commercial viability of the concept was then tested through a series of market research experiments to validate the development of the vehicle.

This article firstly provides a summary review of other alternative vehicles before analysing the current market trends facing the industry. The article then describes the key features of Tomorrow’s Car and design choices, the results of the market research study and the most significant attractive and impeding features of the concept. The article concludes with a description of how TC addresses the major issues facing society and the industry alike and how the commercial success of TC can be guaranteed.

### ALTERNATIVE COMMUTER VEHICLES

As highlighted above, society currently faces several significant issues within the automotive industry and current transportation options available. In order to address the problems faces by consumers, several alternative vehicles have been developed, yet none have fully meet all the needs of consumers.

The requirement for a new narrow cross over vehicle was identified when one of the authors became frustrated with being stuck in traffic jams on the way to and from work, some years ago in Germany. Despite the fact that even though the travel distance was only 17km, with most of it on the Autobahn, the travel time was around 40 minutes. From the several alternatives discussed before the bicycle was selected as a potential alternative due to the lower cost and the positive effect on the physical fitness. While cycling to work the author was involved regularly in various collisions and near miss situations caused by careless car drives. These incidents highlighted the safety issue associated with such forms of transport and deterred the author from using such modes of transport. A notion shared by many car drivers.

Therefore another safer alternative mode of transport is needed to meet today’s demands. In a first step of the development of such a vehicle, several other alternative vehicles were considered. Examples of alternative small vehicles that were introduced during the last 15 years are the Ecomobile, the C1 scooter from BMW, the Smart car, the Carver and the MP3 scooter from Piaggio. The vehicles are briefly described and analysed in the following section.

The analysis describes the key features of each vehicle, why or why they were not successful and completes a benchmarking study to analyses current market trends. The analysis had two purposes, firstly to back-up the
initial individual thoughts with solid data and secondly to identify other opportunities that could be satisfied with a novel vehicle concept, so that a successful commercialization of a new vehicle could be ensured.

**Ecomobile**

The Ecomobile is a fully encapsulated motorcycle with two main wheels on each side, plus one support wheel on each side. The position of the support wheels is controlled manually through a dynamic hydraulic system. In normal stable driving conditions, these support wheels don't touch the ground. When the vehicle loses stability at low speeds from a lack of self-stabilizing coriolis forces, the driver can activate the support wheels so that they touch the ground and stabilize the vehicle. The vehicles were all handmade using aerospace technology and around 100 vehicles were built between 1987 and 2005. More recently the Econmobile has been replaced by a new model called Monotracer [2]. With a retail price above around $100,000, the Ecovehicle was very expensive and not affordable for households with an average income. However, the vehicle is still being made which is a strong proof that such a concept satisfies certain consumer needs. The pros and cons of the vehicle are as follows:

**Advantages:**

- Fun to drive by leaning sideways and counter-steering like a typical motorbike or motorcycle
- High performance with a top speed over 240kph and acceleration from 0 to 100kph in 6.3 sec, typical for expensive sports cars
- Full weather protection without the need of special clothing or safety gear
- Comfort – no helmet is required
- Safety features like a car: fully enclosed with seat belts, anti-lock brakes (ABS), air bags etc.
- Narrower than any car
- Two car type seats that can take child seats
- Very good aerodynamics
- Good fuel economy
- Luggage compartment included
- Length of 3.7m makes it more visible than a motorcycle

**Disadvantages:**

- Price – very high
- Motorcycle driver’s license required
- Safety: The support wheels are not automated, so the vehicle can tip over if the support wheels are activated too late
- Unstable over obstacles at low speeds with a very unfavourable diamond type wheel configuration. Therefore special training is required.
- Most people tip it over at least once
- Width of 1.2m, that means two of these vehicles can practically not parked independently in one standard car park
- High entrance point, means the passengers have to be physically flexible
- Uncomfortable and unusual seat position
- Design in general is very subjective but the vehicle does not look like either a car or a motorcycle, but more like a plane without the stabilising wings.

**BMW C1**

The objective of this vehicle was to make a scooter much safer, particularly during a crash situation with another vehicle for either the front or side. The vehicle is partially encapsulated with a roof and a windscreen and has a special patented safety crush zone and roll over structure. It was aimed at young people between 16 years and 18 years old that could drive such scooters in Europe with a special license before they turn 18, when they are eligible for a car driving license. Initially the vehicle sold really well, but sales dropped significantly and production was stopped after only two years. Even though the improved safety was the reason of the initial success, it also was one its major problems.

The BMW C1 has a high centre of gravity and small wheels which make it difficult to manoeuvre at low speeds or over little obstacles like a curb stone. This is of particular concern for smaller people as they were strapped with the seat belt which limited there capability to balance the vehicle with their body movement. Drivers were required to attend a special training course on how to safely drive the scooter and even during the press launch one journalist fell off at 0mph and needed medical attention to his knee [3].

Other advantages were:

- No helmet was required
- Alum space frame safety cell with superior crash performance
- Roll- and shoulder bars
- Additional car type safety features like safety belt, ABS, and windscreen wiper
- Excellent fuel economy and range
- Continuously variable automatic transmission

But the disadvantages were:

- Safety / handling
- High centre of gravity
- Only 1 seat, a second seat was an option but outside of the safety cell
- Incomplete weather protection as it was open to the sides
- Low performance with a top speed of only 112kph
- The relatively high weight made it difficult to put it on a centre stand
- Small wheels resulted in low rider comfort
- The luggage compartment was very small
- Price around $10,000 was quite high, almost comparable to a small car.

**Carver**

The Carver is a narrow encapsulated three wheeler, where the front wheel and the main body are tilting controlled by a specially developed patented active hydraulic system. The powertrain is placed between the two rear wheels, which is not tilting and consequently has similar dynamic requirements to that of a normal car. This means the rear non tilting part has to be relatively wide with a low centre of gravity so that it doesn’t tip over.

Due to its special tilting control system, the Carver drives like a normal car with direct steering instead of counter-steering. It’s the most fun to drive vehicle the author operated on a public road and it is so much fun to drive when it tilts that one is even inclined to continuously zigzag along the road, which can be risky and also make it tip over. Unfortunately the sales were much lower than predicted with only around 200 vehicles being sold so the production ceased in 2009 [4].

**Advantages were:**

- Fun to drive with active tilt control
- Full weather protection without the need of special clothing or safety gear
- Comfort – no helmet is required
- Safety features like a car: fully enclosed with seat belts, anti-lock brakes (ABS), air bags etc.
- Narrower than any car
- Can be driven with car license
- Two car type seats that can take child seats
- Good fuel economy
- Luggage compartment included
- Length of 3.4m makes it more visible than a motorcycle

**Disadvantages were:**

- High price of around $80,000 due to its complex active tilt control system including 2 oil pumps, 2 reservoirs and even rear wheel steering
- Safety: Too much fun as there is no natural feedback when it becomes unstable
- Width of 1.4m, that means two of these vehicles cannot be parked independently in one standard car park
- Only moderate performance compared to the price with a top speed of 185km/h
- High entrance point, means the passengers have to be physically flexible
- Uncomfortable and unusual seat position

**Smart Car**

The smart car concept is designed to address the needs of urban commuting, mainly a smaller footprint for parking [5]. The approach was to reduce the car length instead of the width. The advantage of that approach is that conventional car technologies could be used for the chassis and suspension and no tilting control is required.

Disadvantages are that the space advantage can only be used in some dedicated car parks. The advantage of the small footprint can’t be utilised in standard car parks as a second car would lock the first car in the same car park. The aero dynamical drag factor also suffers due to the reduced length. The driving dynamic at higher speeds and over uneven ground also feels very uncomfortable. Due to its short length some unusual yaw oscillations can be felt, therefore the top speed has been restricted to 135km/h.

The launch of the vehicle was very rocky with reports of vehicle tipping over backwards due to the short length and failing the elk-test. This was immediately corrected with the introduction of electronic stability control. The vehicles sales are were lower than expected and often it was reported that the company would stop production. However, the vehicle is also important to meet Daimler's corporate average CO2 emission target, so the business case probably is not related only to the success of the vehicle itself. The vehicle also takes away sales from other competitors that make small cars, strengthening Daimler’s market position.

**Advantages of the smart car are:**

- Short length allows several vehicles in some parking bays
- Good fuel economy
- All typical car safety features
- No special training or license required
- 2 standard car seats
- Child seats are possible
- Luggage space available

**Disadvantages are:**

- Low performance and a top speed of only 135kph
- Relatively high price compared to other small cars with 5 seats
- Space advantages can only be used in a small percentage of car parks
- Uncomfortable ride and vehicle dynamics at higher speeds
- Unfavourable aerodynamics.

**Piaggio MP3**

The MP3 is a scooter with two front wheels and one rear wheel with a semi-automatic tilting lock function. Compared to a normal scooter, the advantages of the two front wheels are better braking performance and
higher stability on slippery ground, particularly when one front wheel loses traction [6]. The vehicle has been one of the best-selling scooters in some markets like Germany where it is very expensive to get a special motorbike driver’s license and the vehicle can be driven with a normal car license.

Advantages are:

- With a size equivalent to that of a scooter, more than one vehicle to be parked in one car park
- Can be driven with car license in some markets
- Parking is much easier than with scooters of similar size and weight due to the patented tilt lock system
- Better safety compared to a normal scooter or motorbike
- Moderate price compared to cars
- 2 seats
- Good fuel economy.

Disadvantages are:

- Safety:
  - No roll over protection
  - No tilt control during braking
  - Can tip over when tilt brake is locked
- Sensitive to side wind
- Difficult to push when parking
- Helmet is required
- Relatively expensive compared to a scooter with similar performance due to complex tilting system and tilt lock mechanism
- No weather protection
- Low performance with a top speed of only 110kph
- Handling is very "stiff" and requires unusual high steering forces in corners
- Unfavourable aerodynamics.

So in summary, all vehicles showed more or less significant safety issues. An interesting observation is that the C1, with its superior safety in a serious crash scenario compared to the MP3 sold well initially, which means that the safety performance is obviously a very important characteristic for a successful alternative vehicles. However, after disadvantages of the vehicles in more frequent day to day operation became evident, like starting, stopping and parking manoeuvres, the MP3 performed much better, which proves that a novel vehicle can be a market success.

In the long term, the safety performance in situations that are experienced on a very frequent basis, but with a relatively small impact (related to the severity of potential injuries or damages), seem to be much more important than the safety performance in very rare situations, but with a serious impact.

However, on occasion it has also been shown that high costs and/or some safety risks are accepted if the performance of the vehicle is high enough to compensate, as demonstrated by the Ecomobile.

There is also not one vehicle concept available that combines the safety of a car with the small space requirement of a scooter or motorcycle.

The availability of only two seats seems to be acceptable in some instances like for the smart car and the MP3.

Being able to drive an alternative vehicle with a car driver’s license also seems to be an important success factor.

MARKET TRENDS

To support the previous conclusions some further analysis and literature research has been conducted reviewing current market trends within the automotive industry. This analysis was completed to ensure that a new narrow vehicle meets all the relevant industry requirements and consumer trends.

SAFETY

Over the last couple of years safety has been considered the third most important car consumer purchasing criteria after quality and fuel economy [7]. This corresponds well with Maslow’s hierarchy of needs [8], where safety is actually the second important layer after physiological needs like breathing, food, water, etc. Additional to health security this second layer also includes resources and one can argue that vehicle quality and fuel economy are also securing resources and therefore are part of the same layer of need. Consequently the development of new safety features has constantly been a priority in the automotive industry, which has helped to reduce fatality rates over time. Examples of such safety features include safety belts, head rests, anti-lock brake systems, air bags, electronic stability systems, tyre pressure monitoring systems, etc. Often these features have been made part of safety regulations so that their fitment became mandatory. Enhanced safety standards and test procedures like the NCAP test support the drive to develop new safety features for cars.

After World War 2 motorbikes were considered as a cheap alternative means of transportation. The associated higher safety risks compared to cars were of second priority due to the limited financial resources available. That has changed since then and nowadays most motorbikes, at least in the western world, are considered to satisfy needs only the top layers of Maslow’s pyramid of needs: self-actualisation and esteem. Motorbikes are considered to be more a piece of sport equipment, similar as horses, than a transport vehicle.

Compared to new vehicles themselves, the development of new safety features for motorbikes seems to be a
smaller priority. Even though some new safety features have been introduced like anti-lock brakes and electronic stability control systems there are no standardised crash tests to evaluate and compare the safety of a motorcycle in a similar way as they are for cars. This is quite surprising because motorcyclists are about 34-times more likely to die in a crash compared to car occupants per km travelled [1]. This trend is increasing with the fatality rate for motorbikes rising between 1997 and 2004 “making up 9.4% of all motor vehicle traffic fatalities” in 2004 [1].

As a result, there is a strong need to improve the safety of motorcycles. The introduction of standardised safety tests like NCAP, together with the continuous independent testing and publication of results has been a big driver in improving car safety. The introduction of similar tests for motorcycles may produce the same results.

There could be several reasons why these programs have previously not been developed. Firstly the number of motorcycle riders is much smaller in the markets where these safety standards have been developed, with motorcycles making up only around 10% of the market, depending on the country. Secondly the layout of most motorcycles, with no roof and no back rest, makes it very difficult to install typical car like safety features like crush zones, roll over protection and air bags. Thirdly, the motivation to ride a motorcycle often is more driven though higher layers of the Maslow pyramid (self-actualisation and esteem) instead of safety, which is similar to the motivation of participants in trendy fun sports, such as skateboarding, snowboarding or roller blades. So in some instance, the motorcyclists actually enjoy the additional risk factor.

FUEL ECONOMY

There are several underlying reasons why motor vehicles are required to become more efficient in the future. The first one is a simple business case to reduce the overall costs for the consumer. The business case is illustrated in figure 2. Savings for fuel costs are displayed for different fuel prices as a function of the mileage for the example of an average fuel consumption reduction of 1 l/100km.

The second requirement for more fuel efficient vehicles is a due to global warming, and the resulting CO₂ emission regulations. This has enhanced the previous business case dramatically. For vehicles that won’t meet the new targets, tax penalties of up to Euro 95 for each gram CO₂ per km exceeding the required limit will have to be paid by the car manufacturers. For a vehicle with a gasoline engine that exceeds the limit by the equivalent of one litre/100km that could result in a tax penalty of Euro 2,280. As a result, when these regulations are introduced, the business case for more efficient vehicles will be more than ten times as strong when compared to the current environment. Under the new regulations, a fuel saving technology that reduces the fuel consumption by just one litre/100km can cost more than Euro 2,000 and still deliver return on investment after just one year!

PURCHASING PRICE

According to KPMG [7], affordability is the fourth most important consumer purchase criteria since 2005, after quality, fuel economy and safety. In 2008 it was even rated the third most important consumer purchasing criteria in the 2009 KPMG Global Auto Executive Survey [9] which probably reflected the beginning of the global financial crisis. That means that even if a product offers certain advantages the price premium needs to stay within a certain limit, otherwise it won’t be attractive to consumers or make a successful business case.

CONGESTION – GLOBAL GRIDLOCK

Parking in major cities is becoming more and more difficult and the prices to park a car is also continually growing. These factors are in influencing customer’s preference to smaller cars, which are also easier to manoeuvre in parking garages. Increased traffic congestion is a direct consequence of the growing vehicle fleet and the increased distance travelled per vehicle. “In 2003 - 2004 alone, the passenger vehicle fleet on Australia’s roads increased by three percent or around 260,000 extra vehicles nationally” [10]. This is in...
line with the OECD who “have prepared projections which indicate that, between 1990 and 2030, there will be an increase of 79 per cent in kilometres travelled by all vehicles within the OECD countries, and a rise of 312 per cent for countries outside the OECD (OECD 1996)” [11]. This indicates that this is a trend that will prevail for a longer time and the traffic congestion problem likely to continue to grow.

However, the average car occupancy for journeys to work is only 1.2 according to Public Transport User Organisation (PTUO) [12], and in the US it is the same even considering all times usage [13]. Bearing in mind that most families have two cars where one at least is only used for commuting, a vehicle with only two seats would be sufficient to solve the needs of at least of 50% of passenger car drivers. This means that most of the existing passenger cars are absolutely oversized compared to the needs of their users.

What is even more concerning is that most of that traffic growth is actually predicted for cities. Today “urban areas already account for 50% of the world’s population, but 80% of the world’s wealth” (9). “By 2030, urban areas are projected to account for 60% of the population and greater than 80% of the wealth ”[14]. This is going to paralyse many mega cities so that the advantages of individual transportation with motor vehicles will diminish rapidly. The average speed in the Greater Tokyo Area is already down to 15km/h reported in 2008 [15].

**FUN**

New trendy fun sports are emerging every year. Whether it be surfing during the 1960’s, windsurfing and skateboarding in the 1970’s, mountain biking and snowboarding in the 1980’s, rollerblading in the 1990’s, kite-surfing, rip-sticks and so on. There are several similarities between all these trend sports (compared with normal transportation methods of walking or driving a car):

- They provide additional fun and thrill while the body is leaning sideways into the third dimension and experiencing additional centrifugal force added to the force of gravity
- They are outdoor activities, mostly performed in free nature
- They involve a significant element of risk and it takes a while to learn them
- New pieces of sports equipment are required with costs of up to several thousand dollars involved which often create new sport industries.

So the biggest question is what is coming next?

Engine performance of passenger cars on the other hand is continuously increasing. The physical ACAE fleet characteristics showed a 22% higher power of vehicles 2002 when compared to the baseline vehicles of 1995 [16]. This is very interesting as more powerful engines normally use more fuel to operate which is not helping to achieve the commitments to reduce CO2 reductions. This may be due to the fact that consumers may think they can make up lost time in traffic congestions with more powerful engines or that they just want to be able to have more fun while accelerating hard during the limited occasions when there is no other car in front of them. This trend to increased engine performance was even stronger in the US where the average engine performance almost doubled between 1985 and 2004 [17].

**DRIVER’S LICENSE**

The proportion of people with driving licenses is increasing throughout the world. In Germany, for example 84 percent of adults possess a driving licence and the proportion of female driving licence holders has grown to 76 percent [18]. The numbers of motorcycle licence holders is only around 14% compared to the numbers of car licence holders [19] and the share of female riders is again only around 14% [20]. One of the reasons is obviously the increased safety risk, although another contributing factor is the high associated cost, which could be double that of a car license [20].

From the above analysis, the important trends and requirements for a new generation of vehicles can be summarized into the following: There is a strong business case for ultra-efficient environmental friendly vehicles that offer a new dimension of fun compared to motorbikes. They should be as small as possible so that lanes and car park space can be shared and they should have at least 2 seats and offer a safety comparable to that of a car. The vehicle should still be reasonably powerful and only a car driver’s license should be required.

**TOMORROW’S CAR**

In order to address the deficiencies within the automotive industry and transportation options, Tomorrow’s Car has been developed.

A step by step approach has been taken to define the concept of TC and the targets for several features and dimensions are as follows:

- Width below 0.8m
- Length 2.5m
- 2 seats
- Weight 450kg
- Tyre size 17"
- Fuel Consumption below 2.5l/100km
- Top speed over 140kph
- Acceleration 0-100kph below 10 sec
- Price below $15,000
The first important decision was about the width of the vehicle. To be able to park two of the vehicles in parallel in one parking bay, the width needs to be below one meter, a width slightly below 80 cm has the advantage that the vehicle could also be driven through a door and parked in the hall way. The vehicle also had to be fully enclosed, a key requirement for car like safety and comfort.

Such a small width did not leave many options for the wheel configurations. Three points of contact is the minimum requirement to define a plane and to enable a stable configuration when standing. So 3 wheels were selected because they are cheaper than 4 wheels with 4 suspensions. Two front wheels are more stable in unexpected critical situations like emergency breaking in corners. They also offer some potential to accommodate extra crush zone in that the feet and legs could slide through the two wheels in case of a frontal crash. Another advantage relates to the aerodynamics; with 2 wheels in the front and one rear wheel a configuration very close to the most efficient tear drop shape can be realised.

The next question addressed was related to the mechanical part of the tilting system. One option was to have the front wheels in a non-tilting configuration similar as the Carver and another option was for all 3 wheels to tilt as the MP3. Non tilting front wheels would require a very low centre of gravity for the non-tilting sub-system otherwise it would need a relatively wide track to avoid roll over during fast cornering. Such a system would make it very difficult to achieve the required targets for the small width in combination with the high performance. Potential patent protection due to the similarity with the Carver’s technology could be another issue.

The key enabler for such a vehicle is a simple but dynamic fast response automatic tilting control system which is named SafeRide™ This a trapezoidal linkage system is similar to the one invented by Wolfgang Trautwein in 1976 [21], [22] that was already tested on a Piaggio Scooter in 1984 and is now also used in the MP3. The tilting system will deliver the extra fun similar to that of a normal motorcycle.

Some of the next decisions of the vehicle were very easy to make, such as the requirements for 2 seats in a tandem configuration. This arrangement would satisfy the need to transport more than one person which covers more than 90% of all journeys in cities. It also gives extra secure luggage compartment for shopping with the flexibility to fold down the rear seat. The seats needed backrests and headrests similar to the C1, as these features are essential components of other important safety features like seat belts and air bags.

The vehicle height and length are not critical aspects of the design. A higher vehicle would result in a reduction of fuel economy but it is better for good visibility. A short length is only important if parking on walk ways is considered, like for normal scooters. For parallel parking in one standard bay of typically 5.5m, the vehicle length just needs to be within that limit, like for normal cars. If the vehicle is longer a better aero dynamical drag could be achieved which is better for good fuel economy if the weight remains constant. Therefore the wheels can have a much larger diameter similar to typical motorbikes instead of the typical small wheels of scooters. Larger wheel diameters enable lower rolling resistance, better performance and comfort and they help to make the vehicle more stable and safe.

The question about the controls was much more difficult to answer: motorcycle controls like a handlebar with throttle grip and brake lever versus steering wheel with throttle pedal and brake pedals? To ensure the vehicle can be driven with a car license the controls had to be as close to a typical car. Therefore brake and throttle are operated through foot pedals and steering is controlled with a “hybrid handlebar”, a mixture between a steering wheel and a handlebar in a rectangular shape. A round steering wheel can’t be used as the riding characteristic of a typical motorcycle requires a precise feedback about the actual steering angle. The vehicle has at least 2 side doors so that the passenger could get out and into the vehicle on both sides. If a vehicle is parked parallel to the road it is preferred to enter the vehicle from the side close to the walk way to avoid potential dangerous interaction with the traffic on the main road. With two doors, one vehicle covers the requirements for both left- and right-hand driving markets. Table 1 shows a summary of how different key features of Tomorrow’s Car address the most important consumer and industry trends.

Finally, the vehicle configuration described above is an ideal platform for an electric vehicle. It is much better suited to electric power than a normal car because less energy needs to be stored on such a vehicle. Superior aerodynamics, low vehicle mass, low range requirement, and low payload requirement all result in lower power demand of the vehicle. Compared to a normal car the aero dynamical drag is much lower due to the 50% reduction in width which halves the effective frontal area.
The vehicle mass and payload is also much smaller, only around half of the weight of a normal small car due to the vehicle’s smaller size. As the vehicle’s main usage area will be cities, the reduced range due to battery costs and weight are not a problem, and be comparable to a normal scooter which typically only has a range of around 200km.

MARKET RESEARCH

FOCUS GROUP INTERVIEWS

Several methods were considered to complete market research and investigate if there were any potential impeding factors that could prevent the successful commercialization of Tomorrow’s Car. The first idea was to conduct one on one interviews with relevant key motoring journalists in the initial target market of Europe. However, that was not feasible due to budget constraints so it was decided to conduct conventional focus group interviews.

The key objectives of the focus group studies were to identify

- Potential impeding features of Tomorrow’s Car
- The most- and least attractive features
- Relevant open minded demographics and target markets.
The main target markets of the study were Australia, China and India. Australia has been selected as worst case “western” market, due to its relative conservative car consumers which typically follows European trends with a significant delay of between 5 and 10 years. Typical examples are the popularity of large sedans compared to smaller hatchbacks, the delayed increase of Diesel market share and introductions of more stringent emission standards. China and India were selected as the other extreme markets because they have world’s largest megacities that are suffering most from traffic congestion, which is set to increase in line with their impressive growth rates. There was also a very pragmatic reason as Deakin University has a large base of Indian and Chinese students. A total number of seven focus groups were conducted including:

- Australian Females (mixed age, pilot study)
- Australian Males (mixed age)
- Australian Females (mixed age)
- Indian Male Deakin Students
- Indian Female Deakin Students
- Chinese Male Deakin Students
- Chinese Female Deakin Students

The focus groups typically had between 6 and 10 participants. After a short introduction the video animation was shown followed by a structured question and answer session. The pilot group with Australian Females was an exception, it was conducted ad-hoc during the development of the video animation, so uncoloured sketches were used instead of the video clip and the session was conducted by a different moderator before the structured questionnaire was used.

The other two Australian groups were recruited by an external recruitment company and the remaining groups were volunteers that responded to a university internal promotion.

Within the studies, design sketches and movie animations were used to allow participants to visualize the benefits of TC in day to day usage situations. Due to budget and time constraints these sketches were made by a team member that was not formally trained as a designer with the result that the proportions of the sketches were sometimes a little unrealistic for the experienced. Examples of the screenshots from the video animation that was used in the focus groups are shown in figure 1, 3, 4, 5, 6 and 7.

RESULTS

PILOT STUDY

The pilot group with the Australian Females responded very positive to the first sketches. Regarding potential impeding factors the following questions were raised:

- if the vehicle would have cup-holders or an option to connect an i-pod
- if the vehicle would look similar to a car
- if the vehicle had a door on each side, as this would be a safety advantage when parking parallel along the road where one could enter and exit the vehicle towards the pedestrian side instead of the road side where there is the risk of getting run over by other cars.
- if the vehicle would be narrow enough to drive it through an entry door and park it in the hall way

The results indicated that the parking, fuel economy and safety benefits were clearly understood. They even expanded on these benefits and visualised further advantages. All group members agreed that they would consider buying such a vehicle, obviously dependent on the price. When asked about they preferred one or two seats all answered that one seat should be sufficient for their requirements but the bonus of having an extra second seat at the disadvantage of some extra length was seen as a positive.

The detailed analysis of the following more structured focus groups interviews was the subject of a final year project at Deakin University [23]. The results of the remaining parts of this section are a summary of the key findings from that report. The first phase of that analysis was the identification of different themes in the
responses. The following themes were identified and were fairly consistent across all demographics:

- Appearance
- Safety
- Status
- Fuel economy and the environment
- Performance
- Design and features
- Uses, drivers and associated benefits
- Costs
- Vehicle layout
- Size and storage
- Parking
- Congestion
- Overall statements

**IMPEDING FEATURES**

The most significant impeding features of TC were the overall appearance, associated safety performance of the vehicle and the size and storage capabilities. When considering appearance, the majority of participants did not see the vehicle as being visually appealing, and this directly affected their attitude toward the vehicle. Participants often considered the vehicle as 'too futuristic' and 'not what we're used to.'

However, the impact of the appearance may be attributable to the quality of the produced video. The video shown to participants only contained a basic visual representation of the vehicle and was not a polished or as professional as typical vehicle advertisements. Participants seemed to forget the fact that the images were only about a concept vehicle to visualize the benefits in daily usage situations and instead they were expecting the vehicle to be presented in a comparable way to other car advertisements, such as for 'Mercedes' as one said.

That was in clear contrast to the pilot group, probably because for them, it was much more evident that the sketches were only design concepts and therefore didn’t comment on such details. Also the difference of the colour scheme seemed to have significant effect.

The appearance of TC even affected the participant's perception of the raw concept and key features of the vehicle. Participants throughout the research expressed doubts over performance, acceleration and even safety of the vehicle. The majority of these doubts were all based on the look of the vehicle and the content of the video. For example, in one instance of the video TC is shown being overtaken by other cars and not keeping up with traffic. This visual image fostered participant’s doubts about the acceleration capabilities.

Furthermore, it is interesting to note that some consumers disliked the fact that TC was a new design and 'not something where used to.' Despite being comfortable with having something new and different such as an 'I-Pad', some participants expressed that they would not like to be 'the first to drive one.'

In addition, the safety concerns associated with the vehicle made up another significant impeding feature of the concept. It was determined that it was not in fact the actual safety performance of the vehicle, but participant’s perception of the safety of the car that fuelled participant’s safety concerns. Participants believed that because TC was small, it was not as safe as a larger car.

Despite being told that TC had an equivalent safety performance to that of other small cars on the market, participants believed that TC was not safe. These concerns were based on the assumption that because TC was smaller, had three wheels and ‘tilting control,’ which was different to that of ‘normal cars’, it must be ‘unsafe.’ Participants also based their assumptions on the appearance of the vehicle and the fact that it 'did not look safe' these concerns can again also be attributed to the visual representation of the car in the video.

**MOST ATTRACTIVE FEATURES**

Although the fuel economy did not correlate with the considerations of price, it was cited as a 'great' feature of TC. Participants were impressed by the low fuel economy and the impact the vehicle would have on the environment. With fuel prices expected to increase in the future, this finding places TC in a good position to capitalize on this attribute.

Furthermore, the manoeuvrability and ‘fun’ aspect were also cited as potential attractive features of this car. This is a significant finding in relation to TC, as it highlights a potential distinguishing feature on which the vehicle could be marketed. The fact that the vehicle is ‘fun to drive’ means that the vehicle could also be marketed against motor bikes and scooters, in which riders enjoy the associated ‘freedom' these vehicles bring.

**LEAST ATTRACTIVE FEATURES**

As outlined above, the least attractive features of the concept were the appearance and the perception of safety. However, the seating capabilities and limited storage space was also cited as a negative feature of the concept.

Throughout the research, participants expressed a dislike for the limited storage and seating capabilities. Participant’s believed that the size limited the use and capabilities of the car.

However, most of the participants expressing the dislike towards the storage space and seating capabilities, were
considering the vehicle in terms of being a ‘sole family car’, to transport the ‘whole’ family, which was never intended to be the target market of this car.

That was in contrast to the results of the pilot group possibly because in the pilot group the vehicle was not presented as TC but as an alternative commuting vehicle.

The other least attractive feature was the seating arrangement of TC. Participants expressed a dislike toward the ‘fighter jet’ seating arrangement. Several participants believed they would feel like a taxi driver and be unable to communicate with passengers.

**POTENTIAL TARGET MARKETS AND DEMOGRAPHICS**

The market analysis suggested that China and India represent significant potential markets for TC. The market analysis highlighted that both these countries have higher population growths and are experiencing increased congestion and vehicle ownership rates in line with their population. These countries are also more accustomed to two-wheeled vehicles, such as motorbikes which already make up a large percentage of the market.

However, within the focus groups, it was found that the majority the Chinese and Indian participants were the least receptive to TC. This negativity may be due to fact that the participants within the Indian and Chinese groups were primarily International Students from relative wealthy backgrounds, who were not looking to purchase small vehicles. The associated status and ‘prestige’ associated with driving smaller cars was also more evident within these groups adding to the dissatisfaction with the design.

In contrast, the most appropriate demographic appears to be singles and in particular females, or people with a low number of family members. Throughout the research, several participants were extremely receptive to the vehicle and ‘would drive one.’ These participants were all single or had small families. As they were single, they were not influenced by the limited seating capacity of storage space as they mostly ‘drove on their own.’ The potential of this target market was further enhanced by other participants who believed that TC would be most suitable for females as it is ‘easy to drive,’ small and has a ‘girlie ‘ appearance. This demographic forms the primary target market in which the vehicle should be promoted.

Similarly it was also raised by several participants that this type of car could be suited to the elderly or students. However, these target markets were only suggested by participants, and the completed research did not contain enough participants from these demographics to determine if these markets would be viable.

**SAFETY CONSIDERATIONS**

The outcome of the study highlighted the importance consumers place on the appearance and perceived safety of alternative vehicles. The appearance of Tomorrow’s Car can be relatively be easily adjusted to suit consumers preferences, however the safety performance is not as easily modified. The result of the study triggered some further thoughts about the actual safety performance of such vehicles and how they compared to normal cars and how consumer’s safety perception could be improved. By promoting the safety advantages of TC, the change of successful commercialisation of TC will be greatly improved.

Different typical safety issues are discussed as follows:

**FRONTAL OFFSET CRASH**

Due to the reduced width of Tomorrow’s Car, the vehicle should be less likely to be involved in a frontal offset crash. The likelihood to be involved in a frontal crash should reduce proportional with the percentage of width reduction. It would be interesting to analyse crash statistics to find out if there are some relevant correlation.

Another consideration is that the dynamics of such a frontal offset crash with a narrow tilting encapsulated vehicle are quite different to a normal car. A normal car doesn’t move sideways a lot in case of such a crash as the tyres provide a significant lateral grip and a car doesn’t have the freedom to avoid the another car. In case of TC, the vehicle could actually tilt sideways to partially go around the opposite car. The positive effect would be that less deformation energy need to be absorbed. The disadvantage would be that it would result in a roll-over scenario which historically is not a preferred option of consumers.

However, because of the reduced widths of TC the roll-over would be relatively smooth without the sudden lateral accelerations experienced by a wider vehicle when it suddenly flips over when the critical tilt angle is exceeded. The risk of such a ‘smooth roll-over’ in TC is further reduced as TC body structure can be stiffer with less material compared to a normal car. This is a result of the round egg-like cross section compared to less stiff rectangular cross sections of normal cars.

**SIDE IMPACT CRASH**

In line frontal offset crashes, the same advantages can be experienced in side crash scenarios. The crash energy required to be absorbed by TC in the side of the
impact can be significantly reduced by a factor of around 75%. Firstly some crash energy is absorbed when transferred into kinetic roll movement. In a second step the vehicle hits the ground so that further energy can be transferred into the opposite side. The vehicle will then start sliding on the side which absorbs further energy.

VISIBILITY

A disadvantage of TC could be the reduced visibility, both in a side crash and in a frontal crash. The question is if an increase in length and/or height would improve the visibility that would lead to measurable improvements of safety performance. That can be subject of further literature research.

FRONTAL CRASH INTO A WALL

During impact into a wall, a lighter vehicle typically performs better than a heavier vehicle as less kinetic energy needs to be absorbed. Also TC can have a stiffer egg-type body structure (as discussed before) which increases safety further.

CONCLUSION

At present there is a not a vehicle available that meets the demands of modern society. Increasing awareness of global warming, the global gridlock, and record oil prices mean society is after a mode of transport that is economical, environmentally friendly, and ‘fun’ to drive.

To address the range of problems faced by the industry, a number of alternative commuting vehicles have been developed. Yet the commercialization of these ‘alternative’ commuting vehicles has yet to be successful. This is largely due failure of these vehicles to meet the changing demands of the industry and the limited understanding of consumer behaviour, motivation and attitudes.

Deakin University’s Tomorrow’s Car has been developed to address these issues. It is also a concept that overcomes the short comings in design present in previous unsuccessful alternative vehicles.

The market analysis suggested that China and India represent significant potential markets for TC with both these countries experiencing higher population growth, increased congestion and vehicle ownership rates. These countries are also more accustomed to two-wheeled vehicles, such as motorbikes which already make up a large percentage of the market.

However, the research highlighted that the most important factors for consumers was the appearance and perception of safety of the vehicle. In order for such new vehicles to be commercially successful, further research into which factors actually influence the safety perception of vehicles needs to be completed. Whether it is simply the size of the vehicle or risk during a side impact crash, the findings need to be considered by the designers and improvements and marketing adjustments made accordingly. Only then will the commercial viability of Tomorrow’s Car be ensured.

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CONTACT

For questions regarding this study or further details about “Tomorrow’s Car” or the SafeRide™ tilting control system, or in case of interest in a collaborative research project to investigate the new system the author can be contacted at:

frank.will@deakin.edu.au

ABBREVIATIONS

ABS Anti lock brakes

TC Tomorrow’s Car