Technische Universität
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Segway in public spaces

Institut für Mobilität & Verkehr
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Evaluation of the Saarland pilot trial with regard to the usage compatibility and the road traffic regulatory handling of these special transport devices

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Titelbild
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rechts unten: Fahrzeugeinweisung in Neunkirchen, Aufnahme Segway Austria, H. Radlgruber

Cover Picture
left: Test riding and braking tests in Kaiserslautern, Photo André Darmochwal
upper right: First driving instruction in Saarbrücken, Photo Segway Austria, Mr. Radlgruber
lower right: First driving instruction in Neunkirchen, Photo Segway Austria, Mr. Radlgruber

Diesem Bericht liegt das im Auftrag des Bundesministeriums für Verkehr, Bau- und Stadtentwicklung, vertreten durch die Bundesanstalt für Straßenwesen (BASt) unter FE-Nr. 82.0288/2005/ durchgeführte Forschungsprojekt zugrunde.

Die Verantwortung für den Inhalt liegt allein beim Autor.

This report is based on the research project No. FE 82.0288/2005/ in commission of the German Federal Ministry of Transport, Building and Urban Affairs (BMVBS) represented by the German Federal Highway Research Institute (BASt).

The responsibility for the content remains with the author.

Kaiserslautern
April 2006

Preface

Rarely, an innovz-project got more attention in the media than ›Segway in Public Spaces‹. The best image was drawn by the Süddeutsche Newspaper: »The erect standing locomotion bestows the driver with a self-confident, dignified, Ben Hur like feeling.« With that it was out: RTL Television garnished their Segway report with scenes from the movie ›Ben Hur‹ and the Spiegel magazine saw Saarland policemen as ›Ben Hur on the beat‹. You have to drive the Segway to feel this!

What has a university institute for mobility and transport to do with that? Segway – as a new ›motorized mobility device of its own‹ – is yet not licensed in Germany to be used in public spaces – different from some European neighbouring countries and most states of the USA. Commissioned by the German Federal Highway Research Institute – a subsidiary of the Federal Ministry of Transport, Building and Housing – we scientifically accompanied a Segway pilot project in the German State of Saarland to clarify, if and under which regulations the Segway could be licensed also in Germany. The findings from the pilot project in the Cities of Saarbrücken and Neunkirchen, as well as, from our own examinations on our university campus are representative and to be generalized. We recommend the Segway be licensed on sidewalks, in pedestrian zones and traffic calmed areas at walking speed (maximum of 7 km/h) and on bicycle facilites with up to 20 km/h, which is the maximum speed of the Segway.

We would like to thank our partners within the Segway project for their goal-oriented and friendly co-operation – to mention one for all, the leader of the pilote project, Bernhard Strube from the Ministry of the Interior, Family, Women and Sports of the State of Saarland.

Kaiserslautern, March 2006
Hartmut H. Topp

Vorwort

Selten hatte ein innovz-Projekt größere Presse als ›Segway im öffentlichen Verkehrsraum‹. Das schönste Bild zeichnete die Süddeutsche Zeitung: »Die stehende Fortbewegung verleiht dem Fahrer etwas Selbstbewusstes, Würdevolles, Ben-Hurhaftes.« Damit war es raus: RTL Fernsehen garnierte seine Segway-Reportage mit Ausschnitten aus dem Kino-Film ›Ben Hur‹, und der Spiegel sah saarländische Polizisten als ›Ben Hur auf Streife‹. Man muss Segway fahren, um das nachzufühlen!

Was hat ein Universitätsinstitut für Mobilität und Verkehr damit zu tun? Segway – als neues ›Kraftfahrzeug eigener Bauart‹ – ist in Deutschland bisher nicht für den öffentlichen Verkehrsraum zugelassen – anders als in einigen europäischen Nachbarländern und in den meisten Staaten der USA. Im Auftrag der Bundesanstalt für Straßenwesen (BASt) haben wir ein Pilotprojekt im Saarland wissenschaftlich begleitet, um zu klären, ob und mit welchen Regelungen Segway auch in Deutschland zugelassen werden kann. Die Erkenntnisse aus dem Pilotprojekt in Saarbrücken und Neunkirchen sowie aus eigenen Untersuchungen auf unserem Universitätscampus sind repräsentativ und verallgemeinerbar. Wir empfehlen die Zulassung des Segway mit Schrittgeschwindigkeit (maximal 7 km/h) auf Gehwegen, in Fußgängerzonen und verkehrsberuhigten Bereichen und mit der bauartbedingten Höchstgeschwindigkeit von 20 km/h auf Radverkehrsflächen.

Wir möchten uns bedanken bei unseren Partnern im Segway-Pilotprojekt für die zielführende und angenehme Zusammenarbeit – stellvertretend für Alle beim Projektleiter, Herrn Bernhard Strube vom Ministerium für Inneres, Familie, Frauen und Sport des Saarlandes.

Content

Summary

The device

In 2001, the inventor Dean Kamen presented the Segway, whose self-balancing technology had initially been developed for an electric wheel chair. The rider stands on a platform, which contains accumulators, steering electronics and stabilization measuring technique; the wheels, which are attached to both sides of the platform, contain electric motors. A grip pole that also incorporates the steering facility, allows holding on and balancing. The electronics are continuously measuring the centre of gravity of both the rider and the device and accordingly balance the Segway by steering the electric motors. To move forward the rider have to lean slightly forward, by leaning backward he slows down. Because of safety reasons all technical components are laid out redundantly, to ensure that the device can be stopped safely, in case any component fails.

The Segway has been designed to enlarge the pedestrian's radius of action, the user should move in a similar way and on the same places than he would do as a pedestrian. The Segway increases the pedestrian's flexibility and radius of action.

The research project

Up to now, the Segway has no traffic licensing in Germany and therefore cannot be insured. It can only be used on private ground and is not allowed on public ground. But the manufacturer aims at a legal classification as it was done in the USA and other European countries. Judgement and licensing are not immediately possible within the existing legal framework, because due to the Segway's construction it possesses special characteristics and its way of acting in traffic is unknown.

On the manufacturer's initiative the Federal Board for Road Traffic started a research project to test 6 devices. In cooperation with the Ministry of Internal Affairs and the Ministry of Commerce of the Saarland the Segways have been tested for 3 months. 3 of the devices provided by the manufacturer have been tested by the patrolling district

Kurzfassung

Das Fahrzeug

2001 stellte der Erfinder Dean Kamen den Segway vor, dessen selbstbalancierende Technologie ursprünglich für einen elektrischen Rollstuhl entwickelt wurde. Der Fahrer steht auf einer Plattform, die Akkus, Steuerelektronik und Lagemesstechnik enthält, in den seitlich angebrachten Rädern befinden sich Elektromotoren. Eine Griffstange dient zum Festhalten und besseren ausbalancieren, daran ist auch die Lenkeinrichtung befestigt. Die Elektronik misst dabei ständig den Schwerpunkt von Fahrer und Fahrzeug und gleicht durch Steuerung der Elektromotoren aus. Der Fahrer kann so durch Vorlehnen das Fahrzeug geradeaus fahren, durch zurücklehnen bremst er. Aus Sicherheitsgründen sind alle technischen Komponenten redundant ausgeführt, so dass bei Ausfall jeder Komponente das Fahrzeug sicher zum stehen gebracht werden kann.

Der Segway ist als »Erweiterung« des Fußgängers gedacht, der Benutzer soll sich an denselben Orten und ähnlich beweglich fortbewegen können, wie als Fußgänger. Er erhöht dabei nur Flexibilität und Aktionsradius.

Das Forschungsprojekt

Bislang hat der Segway keine Fahrzeugzulassung und kann dadurch nicht versichert werden. Er darf nur auf Privatgelände und nicht im öffentlichen eingesetzt werden. Eine rechtliche Einordnung wie schon in den USA und anderen europäischen Ländern wird vom Hersteller aber angestrebt. Da das Fahrzeug konstruktionsbedingt einige besondere Eigenschaften aufweist und sein Verhalten im Verkehr unbekannt ist, ist eine Beurteilung und Zulassung innerhalb des bestehenden rechtlichen Rahmens nicht direkt möglich.

Auf Initiative des Herstellers schrieb die Bundesanstalt für Straßenwesen ein Forschungsprojekt aus, bei dem in Zusammenarbeit mit dem Innenministerium des Saarlandes und dem Wirtschaftsministerium des Saarlandes sechs Fahrzeuge über

police of Saarbrücken, 3 by the Municipal Office of Neunkirchen. The devices have been used several hours daily and partly by several people subsequently.

The observation of the Segway's use in every day traffic should provide knowledge about its usage capacities, its compatibility to coexist with other road users and their safety. It has been looked at the Segway's device characteristics, its handling, its interaction in public transport as well as its legal classification. The investigation focused on the usage compatibility and should provide answers, which traffic facilities are suitable for the Segway, whether rider's licence, compulsory insurance, number plate and helmet are necessary and whether the technical equipment is sufficient.

Methods and procedure

Before empirical data had been collected a theoretical excursion was made into the licensing conditions, the experience made with the Segway in the country and abroad, a classification vis-à-vis other new types of devices and an intensive analysis with the corresponding legal basis and requirements, in Germany.

The pilot study took place between August 25 and November 30, 2005. It was accompanied by several empirical measures: in the beginning and in the end of the pilot study period comparative test-driving and braking tests took place on a defined circuit. Places in the city of Saarbrücken und Neunkirchen known for high traffic density have been video controlled all-day by a mounted camera. The videotapes have been examined using the ViVA*traffic*® system for video conflict analysis. Each of the 6 devices had its own riding recorder, which enabled the pilot study participants to report directly, and timely existing and potential conflicts, technical and handling problems as well as extraordinary situations. The most important means of data collecting were 2 rounds of interviews held with all pilot study participants, the first round after 3 weeks, the second one after termination of the practical phase of the pilot trial. Additionally there was a telephone hotline for all unforeseen eventualities, which allowed the participants to ask questions at any time during the pilot study.

einen Zeitraum von drei Monaten erprobt wurden. Drei der vom Hersteller zur Verfügung gestellten Fahrzeuge wurden bei der Kontaktpolizei in Saarbrücken getestet, drei beim Ordnungsamt Neunkirchen. Die Fahrzeuge wurden täglich mehrere Stunden bewegt, zum Teil wurden sie von mehreren Teilnehmern in Folge genutzt.

Die Beobachtung der Nutzung im verkehrlichen Alltag sollte Schlüsse über die Nutzungseigenschaften, die Verträglichkeit der Fahrzeuge im Zusammenspiel mit anderen Verkehrsteilnehmern und deren Sicherheit zulassen. Untersucht wurden Fragestellungen, die die Fahrzeugeigenschaften, die Fahrzeugbedienung, die Interaktion des Fahrzeugs im Verkehrsraum, sowie die rechtliche Einordnung betrafen. Im Mittelpunkt stand dabei die Nutzungsverträglichkeit und es sollte beantwortet werden, welche Verkehrsflächen sich für den Segway eignen, inwiefern Fahrerlaubnis, Pflichtversicherung, Kennzeichen und Helm erforderlich sind, sowie, ob die technische Ausstattung ausreichend ist.

Methodik und Vorgehensweise

Der empirischen Datenerhebung vorgeschaltet war eine theoretische Betrachtung der Zulassungssituation und Erfahrungen mit dem Segway im In- und Ausland, eine Einordnung in den Kontext anderer, neuartiger Fahrzeugtypen sowie eine intensive Auseinandersetzung mit den entsprechenden rechtlichen Grundlagen in Deutschland und deren Erfordernisse.

Der Pilotversuch fand zwischen dem 25. August und dem 30. November 2005 statt. Er wurde empirisch auf mehreren Ebenen begleitet: es fanden zu Anfang und am Ende des Pilotzeitraums vergleichende Fahrversuche auf einem definierten Parcours statt, ebenso Bremsversuche. An Standorten im Stadtraum von Saarbrücken und Neunkirche mit hohem Verkehrsaufkommen wurden ganztägige, statische Videoaufnahmen angefertigt und mit dem System ViVA*traffic*® *zur Video-Konfliktanalyse ausgewertet. Jedem der sechs Fahrzeuge war ein Fahrtenrekorder fest zugeordnet, der die Pilotteilnehmer in die Lage versetzte, konkrete und potentielle Konflikte, technische und Bedienprobleme sowie andere außergewöhnliche Situationen direkt und zeitnah zu erfassen. Als*

The results led to a recommendation for the road traffic regulatory handling and classification of the Segway in Germany.

Data collecting

Theoretical part

Especially in recent years, a lot of new types of devices were launched. Besides the Segway the spectrum comprises bicycles with electric or petrol driven auxiliary motors, motor driven pedal scooters, rolling luggage, self-propelled lawn-mowers, small motorcycles, small scooters, cross-country devices, quads, electric wheel-chairs and road-worthy cabin-scooters.

The legal classification and licensing is often difficult. In some cases the devices have been designed to take advantage of certain legal regulations: this is true for some cabin-scooters which have been licensed as electric wheel-chairs and can be used in road traffic, up to a speed of 15 km/h without rider's license. For this classification a whole bundle of regulations have to be considered: The law regulating the road traffic (Straßenverkehrsgesetz, StVG), the road traffic regulations (Straßenverkehrs-Ordnung, StVO), the road traffic licensing regulations (Straßenverkehrs-Zulassungsordnung, StVZO), the law regulating compulsory insurance (Pflichtversicherungsgesetz, PFlVG), the driver's license regulations (Fahrerlaubnisverordnung, FeV) as well as other additional regulations. The intercourse of the road users is controlled by the road traffic regulations (StVO), the conditions under which a device can take part in public transport is supervised by the road traffic licensing regulations (STVZO).

The German law determines according to the type of vehicle, where and how a certain vehicle can be used: the law regulating the road traffic (StVG) distinguishes roughly between motor vehicles, vehicles and special means of transportation. Motor vehicles (Kraftfahrzeuge) are all vehicles that move by engine force. These types of vehicles basically have to be used on roads only, whereas so called special means of transportation (besondere Fortbewegungsmittel) have to be used on footpath and sidewalks only.

wichtigstes Mittel zur Datenerhebung wurden zwei Interviewrunden mit allen Pilotteilnehmern durchgeführt, die erste fand nach drei Wochen, die zweite nach Abschluss der praktischen Pilotphase statt. Zusätzlich wurde für alle nicht vorhergesehenen Fälle eine telefonische Hotline eingerichtet, die den Teilnehmern jederzeit während des Pilotversuchs für Fragen zur Verfügung stand.

Die gewonnenen Ergebnisse mündeten schließlich in eine Empfehlung zur straßenverkehrsrechtlichen Behandlung und Einordnung des Segways in Deutschland.

Datenerhebung

Theoretischer Teil

Gerade in den letzten Jahren sind eine Reihe neuartiger Fahrzeuge auf den Markt gekommen. Das Spektrum reicht neben dem Segway von Fahrrädern mit elektrisch oder benzingetriebenem Hilfsmotor über motorisierte Tretroller, fahrende Koffer, selbstfahrende Rasenmäher, Kleinstmotorräder und –Roller bis hin zu geländegängigen Gefährten, Quads, elektrischen Rollstühlen und straßentauglichen Kabinenrollern.

Die rechtliche Einordnung und Zulassung gestaltet sich häufig schwierig. In einigen Fällen wurden die Fahrzeuge aber auch daraufhin entworfen, bestimmte gesetzliche Regelungen zu nutzen: beispielsweise bestimmte Kabinenroller, die als elektrische Rollstühle zugelassen und führerscheinfrei bis 15 km/h auf der Fahrbahn genutzt werden dürfen. Bei dieser Einordnung sind ein ganzes Bündel von Vorschriften beachtlich: das Straßenverkehrsgesetz (StVG), die Straßenverkehrs-Ordnung (StVO), die Straßenverkehrs-Zulassungsordnung (StVZO), das Pflichtversicherungsgesetz (PFlVG), die Fahrerlaubnisverordnung (FeV) und weitere ergänzende Verordnungen. Das Miteinander der Verkehrsteilnehmer regelt dabei die StVO, die Bedingungen, unter denen Fahrzeuge am Verkehr teilnehmen dürfen, regelt die StVZO.

Das deutsche Recht bestimmt dabei anhand der Fahrzeugart, wo und wie bestimmte Fahrzeuge eingesetzt werden dürfen: grob differenziert das StVG nach Kraftfahrzeugen, Fahrzeugen und besonderen Fortbewe-

Trying to classify the Segway into the existing legal categories one has to state that it had to be looked at as motor vehicle and thus would have to be used on roads. Then it would be subject to licensing, to compulsory insurance, because it is faster than 6 km/h. A rider's licence would be necessary, because the Segway is not listed in § 4 FeV (the driver's licence regulations) of the saving clause. The Segway then would have to possess an official number plate as proof of licensing and its technical equipment such as brakes, lights, wheels, horn, mirror, speedo, seats etc. had to correspond to the regulations of the StVZO (road traffic licensing regulations) – for lack of classification into other vehicle categories the Segway would have to meet the requirements of a passenger motor-car.

It is one objective of the study to find out whether the legal requirements vis-à-vis the Segway are justified with regard to traffic facilities, its compatibility to coexist with other road users, its riding and other characteristics and how the Segway can actually be licensed.

It might be helpful to recall how the Segway is classified in other countries. In the USA, where the Segway has been sold since 2002, a federal law determines that the Segway is a »electric personal assistive mobility device« and therefore can – as a matter of principle – be used on sidewalks and private grounds. But it is up to the single states and local authorities to introduce special regulations. In most states the Segway can be used unrestrictedly on sidewalks and cycle tracks, some states allow additionally its use on roads, often on those with speed limit.

Up to now, the use of the Segway in public transport is possible in 9 European countries, in Spain and the Netherlands it is tolerated if moving at walking speed, in Hungary, Portugal, Greece, France and the Czech Republic its use is possible by ministry decree, mostly for moving at walking speed and limited to sidewalks. In Italy the Segway can additionally be used on cycle tracks up to a speed of 20 km/h; in Austria it is regarded as bicycle and can only be used on the corresponding traffic facilities.

Like in Germany, in Belgium, Great Britain and Switzerland corresponding decision

gungsmitteln, wobei als Kraftfahrzeuge alle Fahrzeuge gelten, die durch Maschinenkraft fortbewegt werden. Diese dürfen grundsätzlich nur auf der Fahrbahn genutzt werden, besondere Fortbewegungsmittel nur auf Fuß- und Gehwegen.

Versucht man, den Segway in die gesetzlich vorgegebenen Kategorien einzuordnen, stellt man fest, dass er als Kraftfahrzeug zu betrachten wäre und damit die Fahrbahn benutzen müsste. Er wäre zulassungspflichtig, eine Versicherung müsste für ihn abgeschlossen werden, da er schneller als 6 km/h fahren kann. Eine Fahrerlaubnis wäre für ihn erforderlich, da er nicht im Ausnahmekatalog des §4 FeV enthalten ist. Als Nachweis der Zulassung müsste ein amtliches Kennzeichen befestigt werden und die technische Ausstattung (Bremsen, Beleuchtung, Bereifung, Hupe, Spiegel, Tachometer, Sitze, etc.) müsste den Vorschriften der StVZO genügen – mangels Einordbarkeit in andere Fahrzeugkategorien wären das für Segways die Anforderungen an Pkw.

Es ist nun im Rahmen der Studie zu prüfen, ob diese rechtlichen Anforderungen an den Segway hinsichtlich der Verkehrsflächen, Interaktion mit anderen Verkehrsteilnehmern sowie seiner Fahr- und sonstigen spezifischen Eigenschaften gerecht wird und wie er tatsächlich zugelassen werden könnte.

Hilfreich dabei ist eine Betrachtung, wie das Fahrzeug in anderen Ländern behandelt wird. In den USA, wo der Segway schon seit 2002 verkauft wird, regelt ein Bundesgesetz, dass er als »persönliche, elektrische Mobilitätshilfe« grundsätzlich auf Gehwegen und Privatgelände eingesetzt werden darf, überlässt aber spezielle Regelungen den Bundesstaaten und lokalen Behörden. In den meisten Bundesstaaten ist die Nutzung auf Fuß- oder Radwegen uneingeschränkt gestattet, einige Staaten erlauben zusätzlich die Nutzung auf Fahrbahnen, häufig auf solchen mit Geschwindigkeitsbegrenzungen.

In Europa ist die Nutzung des Fahrzeugs im öffentlichen Raum bislang in neun Staaten möglich, in Spanien und den Niederlanden wird er mit Schrittgeschwindigkeit geduldet, in Ungarn, Portugal, Griechenland, Frankreich und Tschechien ist eine Nutzung durch Ministerialerlass möglich, in der Regel mit Schrittgeschwindigkeit und auf Fußgängerflächen begrenzt. In Italien darf zusätzlich

findings are in process, and until decision is made the Segway must not be used in public transport.

Worldwide, estimated 15.000 to 20.000 devices have been sold meanwhile, mostly in the USA. A considerable number of them are used by institutions, police, safety guard, on fairs, in airports or by advertisers, but the number of private users is rising. Due to the fact that the device is on sale only recently, no reliable statements can be made concerning the device's long-term use by rider's experience. To some extent, discussions pro and contra the Segway are carried out very emotionally – often as a clash between persons who are in favour of modern technology and use the device with great enthusiasm and pragmatists who do not see an opening for the Segway in the system of transport means and reject it for being unnecessary or a mere fun device.

In such controversies the following arguments are often cited as disadvantage: the high weight and the limited range of action, being too slow on roads, not being able to use its main advantages sufficiently on sidewalks, namely speed and manoeuvrability. The positive arguments are: its noise- and pollution saving use, the improvement in daily life for some people handicapped in mobility. The number of known accidents with the Segways is very limited; one well-reported case in Atlanta seems to be caused primarily by a false estimation of the rider. Nevertheless in San Francisco, after intensive debates riding the Segway on sidewalks is no longer permitted.

Empirical part

In the main part of the study 11 participants use the 6 provided Segways regularly during the pilot study period, 8 test persons in Saarbrücken, 3 in Neunkirchen.

Data collecting as mentioned before comprised test driving with braking tests, video control, riding recorder and interviews and was partly done twice for comparative purposes: Test driving and braking tests were carried out before and after the pilot study. 2 interview rounds were held, 3 weeks after the beginning and at the end of the study. Accompanying videos were taken several times during the whole period of the pilot

auf Radverkehrsflächen bis 20 km/h gefahren werden; in Österreich gilt er als Fahrrad und darf nur auf den entsprechenden Verkehrsflächen eingesetzt werden. In Belgien, Großbritannien und der Schweiz sind, wie in Deutschland, entsprechende Entscheidungsprozesse im Gang, bis zu deren Abschluss der Segway im öffentlichen Raum nicht genutzt werden darf.

Mittlerweile sind weltweit 15.000-20.000 Fahrzeuge verkauft, die meisten davon in den USA. Viele davon wird bei institutionellen Nutzern, bei Polizei, Wachdiensten, auf Messen, Flughäfen oder von Werbetreibenden eingesetzt, doch der Anteil der Privatnutzer steigt. Da das Fahrzeug noch nicht lange verkauft wird, lassen sich noch keine verlässlichen Aussagen zur Langzeitnutzung des Fahrzeugs aus den Einsatzerfahrungen ermitteln. Diskussionen um das Für und Wider des Segways werden zum Teil sehr emotionalisiert geführt – es treffen oft Personen, die neuer Technologie aufgeschlossen gegenüber stehen und das Fahrzeug begeistert nutzen, auf Pragmatiker, die für ihn keine Nische im Verbund der Verkehrsmittel sehen und ihn als überflüssig oder Spaßfahrzeug ablehnen.

Als Nachteile werden in entsprechenden Diskussionen häufig das hohe Eigengewicht und die begrenzte Reichweite genannt, auf Fahrbahnen gilt er häufig als zu langsam, auf Gehwegen kann er seine Hauptvorteile, Schnelligkeit und Wendigkeit nur begrenzt nutzen. Positiv wird der lärm- und schadstoffarme Einsatz vermerkt, auch die Erleichterung, die er manchen Mobilitätsbehinderten im Alltag bringen würde. Die Zahl der bekannt gewordenen Unfälle mit Segways sind sehr begrenzt, ein Fall aus Atlanta scheint in erster Linie auf eine Fehleinschätzung des Fahrers zurückzuführen sein. Trotzdem wurde in San Francisco nach intensiver Diskussion das Fahren mit dem Segway auf Gehwegen verboten.

Empirischer Teil

Im Hauptteil der Studie nutzten elf Probanden die sechs zur Verfügung gestellten Segways regelmäßig während des Pilotzeitraums; acht Teilnehmer in Saarbrücken, drei in Neunkirchen.

Die aus den schon genannten Elementen Fahrversuche mit Bremstests, Video,

study, and riding recorders as well as the telephone hotline were always at disposition during the whole pilot study.

Test-driving

Before the pilot study one Segway handed out to the Institute for Mobility & Transport brought first information concerning road behaviour and rider's control and with these data the general conditions of a test circuit could be determined for the pilot study. This circuit integrated several elements, which were adapted to local facilities and which could be set up with few and locally available means. The test circuit should provide detailed statements concerning handling and safety while riding, concerning the importance of rider's experience and the quickness of successful learning. The following features were tested: conduct and ability of the participants to ride safely in normal situations, to react to unforeseen situations, to react safely when braking or getting out of the way, as well as the way how they deal with uneven terrain. Stations of the circuit were »driving slalom«, »going around bends on a small roadway with a notch behind obstructed view«, »obstacles/gathering of people on the roadway«, »opening door by a car«, »changing grounds«, »combination of slopes, uneven terrain or bends« and »test braking«.

After about 3 hours exercise, the riding performance of all participants proved to be unexpectedly good. Basic riding tasks have been mastered quickly and without problems. More difficult tasks, which needed greater coordination such as riding and steering at the same time or riding and simultaneously observing the surrounding, have been acquired within 1 hour. The problems arising at the slalom station and the obstacle station showed clearly the concentration requirement of inexperienced rider's in complex situations: there were problems with the steering when changing direction, and with keeping the line and not touching the pylons. It does not take long to learn the basic riding skills; the handling of the Segway seems easy and intuitive. But in complex situations inexperienced riders tend to overestimate their performance and react too late, in an overhasty or false way.

Because of the largely positive results of

Fahrtenrekorder und Interviews bestehende Datenerhebung fand teilweise zu Vergleichszwecken zweimal statt: Die Fahrversuche und Bremstests wurden vor Beginn, sowie nach Abschluss des Pilotversuchs durchgeführt. Die Interviews fanden in zwei Runden drei Wochen nach Beginn, sowie nach Abschluss statt. Die Videoaufnahmen wurden begleitend zu mehreren Zeitpunkten während des ganzen Pilotzeitraums durchgeführt, auch die Fahrtenrekorder und die Hotline standen kontinuierlich den gesamten Zeitraum über zur Verfügung.

Fahrversuche

Mit einem dem Institut Mobilität & Verkehr zur Verfügung gestellten Fahrzeug konnten im Vorfeld erste Informationen zum Fahrverhalten und zur Fahrbeherrschung gesammelt werden und daraus die Rahmenbedingungen eines Testparcours für den eigentlichen Pilotversuch festgelegt werden. Dieser Parcours bestand aus mehreren Elementen, die an die örtlichen Gegebenheiten angepasst und mit wenigen und weitgehend lokal zur Verfügung stehenden Mitteln aufgebaut werden konnten. Er sollte es erlauben, nähere Aussagen zur Handhabbarkeit und der Sicherheit beim Fahren zu treffen, sowie zur Bedeutung von Fahr-Erfahrung und der Schnelligkeit des Lernerfolges. Getestet wurde dabei das Verhalten und die Fähigkeit der Teilnehmer, in Normalsituationen sicher zu fahren, auf unvorhergesehene Situationen zu reagieren, beim Bremsen oder Ausweichen sicher zu reagieren und der Umgang mit Bodenunebenheiten. Stationen des Parcours waren »Slalom fahren«, »Kurvenfahrt in schmaler Fahrbahn mit Engstelle hinter einem Sichthindernis«, »Hindernisse/Personenansammlungen auf dem Fahrweg«, »Türöffnen vom Fahrzeug aus«, »Änderung des Bodenbelags«, »Kombination von Gefälle, unebenem Untergrund oder Kurve« sowie »Bremstests«.

Das Fahrvermögen aller Teilnehmer erwies sich schon nach der rund dreistündigen Schulung als unerwartet gut. Grundlegende Fahraufgaben wurden schnell souverän gemeistert. Anspruchsvollere Aufgaben, die größere Koordination erforderten, wie gleichzeitiges Fahren und Lenken, oder Fahren und Umgebung beobachten wurden innerhalb der ersten Stunde angeeignet. Die Probleme bei der Slalom- und der

the first training the second training consisted only in slalom driving, combination exercises and in braking tests. With a 3-months-riding experience all participants acted safely and appropriately, the devices could be steered smoothly; complicated situations were intuitively comprehended and then cautiously approached.

Braking tests

To obtain more detailed information on the process of braking, the stopping distance, the medium braking delay and the application safety during the braking process, in Kaiserslautern additional braking tests have been carried out besides the comparative braking tests. They have been documented on video and analysed using the software ViVA*traffic*®. Within 20 m the device should be speeded up to its maximum speed of 20 km/h and then on a certain braking line stopped. 6 test riders were beginners with little to no experience, 1 rider had about 10 hours riding practice.

Backward shifting of the centre of gravity behind the imaginary axis between the 2 wheels stops the Segway. The electronics try to balance the backward shifting of the centre gravity by a corresponding slowing down respectively by moving backwards. When braking too fast the following problems can arise: namely swinging, loss of control and in case of leaning backwards too much crashes.

The additional braking tests confirmed the results made in the course of the test riding: Especially inexperienced riders have problems with braking, but after few hours of testing the number of problems was strongly reduced. In comparison to slower, but controlled braking the stopping distance becomes clearly longer if the rider brakes too fast and has problems controlling the device. According to the measurements in the Kaiserslautern braking tests the medium braking delay was about 5 m/s² even for learners. However these measurements varied to some extent: in 37 % of all cases the braking delay was less than 5,0 m/s², in 14 % less than 3,5 m/s².

Hindernisstation zeigten anschaulich das Konzentrationserfordernis ungeübter Fahrer in komplexen Situationen: schwierig fielen die Lenkwechsel, ebenso wie das Halten der Fahrlinie und das Nichtberühren der Pylone. Grundlegende Fahrfähigkeiten lassen sich sehr schnell aneignen, die Bedienung des Segway erscheint einfach und intuitiv. In komplexen Situationen überschätzen sich ungeübte Fahrer aber häufig und reagieren zu spät, zu hektisch oder falsch.

Angesichts der großteils positiven Ergebnisse beim ersten Durchgang wurden in der zweiten Runde nur noch Slalom und Kombinationsübung, sowie Bremstests durchgeführt. Mit drei Monaten Fahrpraxis haben hier alle Teilnehmer sicher und angemessen agiert, die Fahrzeuge wurden sehr flüssig gesteuert, anspruchsvolle Situationen intuitiv erfasst und entsprechend vorsichtig angefahren.

Bremstests

Um nähere Informationen über den Ablauf des Bremsvorgangs, die Bremswege, die mittlere Bremsverzögerung und die Verwendungssicherheit beim Bremsvorgang zu erhalten, wurden neben den vergleichenden Bremstests zusätzliche Bremstests in Kaiserslautern durchgeführt, auf Video aufgezeichnet und mit der Software ViVA*traffic® ausgewertet. Innerhalb von 20 m sollte das Fahrzeug auf die Höchstgeschwindigkeit von 20 km/h beschleunigt werden und ab einer bestimmten Bremslinie abgebremst. Sechs Testfahrer waren Anfänger mit geringer bis keiner Fahrerfahrung, ein Fahrer hatte rund 10 Stunden Fahrerfahrung.*

Gebremst wird der Segway durch Rückverlagerung des Schwerpunktes hinter die zwischen den Rädern gedachte Achse. Die Elektronik versucht die Schwerpunktverlagerung durch entsprechende Fahrtreduzierung bzw. Rückwärtsfahrt auszugleichen. Bei Schnellbremsungen mögliche Schwierigkeiten können dabei Aufschaukeln, Kontrollverlust und Sturz bei zu starkem Zurücklehnen sein.

Die zusätzlichen Bremstests bestätigten die schon im Rahmen der Fahrversuche ermittelten Ergebnisse: Schwierigkeiten bei Bremsvorgängen treten vor allem bei uner-

Video

To find out how well the Segway fits into public traffic, especially and exemplary with regard to neuralgic places, and how strong the conflict potential is when the Segway is used in public space, video cameras have been positioned at appropriate places. These mounted cameras took pictures of the same, constant detail over a period of about 8 hours. Appropriate positions for video pictures are places with high traffic density, with different, overlapping traffic as well as places, which are often visited by the pilot study participants with the Segway. Those places were especially pedestrian precincts and crossings. Pictures have been taken in Saarbrücken and Neunkirchen on 2 days and 3 places in each city. In Neunkirchen, the »Messeplatz« during the autumn fair, the »Stummplatz«, a part of the pedestrian precinct with bus traffic and central stop, and the »Hammergraben«, another part of the pedestrian precinct, have been video documented. In Saarbrücken the crossing »Karcherstraße/Kaiserstraße« has been video observed, a junction where the traction line »Saarbahn«, bus, individual traffic and strong pedestrian traffic meet, furthermore the crossing »Bahnhofsstraße/Dudweilerstraße«, where the pedestrian precinct crosses the main traffic road, and a notch of the pedestrian precinct of the »Bahnhofstraße«.

The video tapes have been examined for interactions and conflicts between Segway riders and other road users, characterised and evaluated using the software ViVA*traffic*®.

Interactions are the adaptation of reactions to other traffic procedures such as braking and getting out of the way. Conflicts are given in case of a threatening collision, they can be avoided by the reaction of at least one of the road users or they provoke accidents.

During the approximately 48 hours of video recording 36 episodes with the Segway have been documented and after evaluation 7 interactions observed, all of which did not reveal further conflict or accident potential. The results suggest that the Segway is fitting very well into the transport system and by its capability to ride slowly, to stop easily and its manoeuvrability the conflict potential

fahrenen Fahrern auf, schon nach wenigen Stunden Praxis reduziert sich der Anteil sehr deutlich. Durch die an Schnellbremsungen gelegentlich anschließenden Kontrollprobleme erhöht sich der Bremsweg effektiv im Vergleich zu weniger schnellen, dafür kontrollierteren Bremsvorgängen. Die bei den Kaiserslauterer Bremstests gemessene mittlere Bremsverzögerung betrug schon bei Fahranfängern rund 5 m/s², allerdings wiesen die Messungen eine gewisse Schwankungsbreite auf: in 37 % aller Fälle betrug sie weniger als 5,0 m/s² in 14 % aller Fälle weniger als 3,5 m/s².

Video

Zur Beurteilung, wie gut sich der Segway in das Verkehrsgeschehen insbesondere und exemplarisch an neuralgischen Punkten einfügt und wie hoch das Konfliktpotenzial beim Betrieb im öffentlichen Raum ist, wurden an geeigneten Standorten Videokameras montiert. Diese stationären Kameras filmten über einen Zeitraum von rund acht Stunden einen gleichbleibenden Ausschnitt. Geeignete Standorte für Videoaufnahmen sind dabei Orte mit hoher Verkehrsdichte, verschiedenen, sich überlagernden Verkehrsarten und Orte, die von den Pilotteilnehmern mit dem Segway häufig frequentiert wurden. Dies sind insbesondere Fußgängerzonen und Kreuzungsbereiche. Gefilmt wurde in Saarbrücken und Neunkirchen jeweils an zwei Tagen, aufgenommen wurden dabei insgesamt drei Standorte. In Neunkirchen handelte es sich um den Messeplatz während der Herbstkirmes, den Stummplatz, einen Abschnitt der Fußgängerzone mit Busverkehr und zentraler Haltestelle sowie den Hammergraben, ein weiteres Stück Fußgängerzone. In Saarbrücken wurde die Kreuzung Karcherstraße/Kaiserstraße gefilmt, an der Saarbahn, Bus, Individualverkehr und starke Fußgängerströme verkehren, die Kreuzung Bahnhofstraße/Dudweilerstraße, wo sich die Fußgängerzone mit einer Hauptverkehrsstraße kreuzen und eine Engstelle der Bahnhofstraße, der Fußgängerzone gefilmt.

Die gewonnenen Videoaufzeichnungen wurden auf Interaktionen und Konflikte zwischen Segwayfahrern und anderen Verkehrsteilnehmern durchgesehen, indexiert und mit ViVA*traffic® ausgewertet. Interaktionen sind dabei Abstimmungen von Verhaltensweisen auf andere Verkehrsvorgänge*

is lower than that of bicycles or inline skating.

Riding recorder and hotline

Each of the 6 Segways was equipped with a dictating machine as riding recorder and a pin-on microphone for documentation. This should enable a quick, uncomplicated and timely recording of the detailed happening of all special events while riding the Segway. Written records after shift should be avoided. During riding training all participants received an instruction and a short guideline how to use the recorder. The guideline stated which events should be documented: Conflicts with other road users respectively obstacles in public transport or other events, which resulted in a loss of control or fall. The circumstances like place, traffic situation, ground conditions; weather and the reactions of all participants, the consequences and the assumed reason were of interest, too. By documentation of the events statements should be possible on the Segway's conflict potential in public transport, on potential accidents and problems in handling the Segway. It should also be possible to receive knowledge about every day difficulties.

Within the 3-months testing period 9 events were documented on the 6 riding recorders, less events than originally assumed. This might be due to the smaller number of such events in general and the interpretation of minor events as not being worth recording. 4 events were riding problems, 1 was a technical problem without any further consequences, 1 was an interaction and 2 were accidents, one of which resulted in a light damage of a device. The recorded events mostly took place in the first half of the pilot study.

To find answers to further, actual and unexpected questions, remarks and problems of all kinds, a telephone hotline was established. It had been expected that the major part of arising questions and problems being addressed to the hotline would show up in the first 3 weeks, but as it turned out, the hotline was only used once, because the few arising questions or problems could sufficiently be answered amongst the colleagues respectively the riding recorder was considered to be the appropriate medium.

(z.B. Abbremsen, Ausweichen). Konflikte liegen bei Kollisionskurs vor, sie lassen sich entweder durch Reaktion mindestens eines Verkehrsteilnehmers vermeiden oder führen zu Unfällen.

In den rund 48 Stunden Videoaufnahmen wurden 36 Passagen des Segways erfasst und nach Auswertung sieben Interaktionen beobachtet, die allesamt kein weiteres Konflikt- oder Unfallpotenzial aufwiesen. Die Ergebnisse legen nahe, dass der Segway sich sehr gut in das Verkehrsgefüge einordnet und durch die Möglichkeit der Langsamfahrt, des einfachen Stehenbleibens und seiner Wendigkeit ein Konfliktpotenzial aufweist, das unter dem von Fahrrädern oder Inlineskatern anzusiedeln ist.

Fahrtenrekorder und Hotline

Jeder der sechs Segways wurde mit einem Diktiergerät als Fahrtenrekorder und einem Ansteckmikrofon ausgestattet. So sollten bei besonderen Ereignissen aller Art während der Nutzung schnell, unkompliziert und zeitnah kurze Berichte zur konkreten Fallsituation erfasst werden können. Schriftliche Protokolle nach Schichtende sollten vermieden werden. Im Rahmen der Fahrzeugschulung erhielten die Teilnehmer eine Einweisung und einen knappen Leitfaden zum Aufsprechen. Dieser gab vor, welche Ereignisse erfasst werden sollten: Konflikte mit Verkehrsteilnehmern bzw. Gegenständen im Verkehrsraum oder sonstige Ereignisse, die zu einem Kontrollverlust oder Sturz geführt haben. Daneben waren die äußeren Umstände (z.B. Ort, Verkehrssituation, Bodenbeschaffenheit, Wetter), sowie die Reaktionen aller Beteiligten, die Folgen und die vermuteten Ursachen von Interesse. Durch die zu erfassenden Ereignisse sollten Aussagen über Konflikte des Segways im Straßenverkehr, Unfallpotenziale und Probleme in der Handhabung aufgezeigt werden, sie sollten aber auch Hinweise zu alltäglichen Schwierigkeiten liefern.

Innerhalb des dreimonatigen Testzeitraumes wurden neun Ereignisse auf die sechs Fahrtenrekorder aufgesprochen. Das waren weniger Ereignisse als ursprünglich vermutet, wohl zurückzuführen auf eine generell geringe Zahl derartiger Ereignisse, und die Einstufung von Bagatellereignissen als nicht wichtig genug zum aufsprechen.

Interviews

For comparative reasons 2 rounds of interviews took place, the first one 3 weeks after the start of the pilot study, the second one at the end. The interviews were guided ones with an appointed questionnaire to a complex of 5 topics: »handling the device«, »device characteristics«, »interactions in public transport«, »feeling of safety and endangering potential« as well as »self-assessment of the study participants«. But there was enough time for further questions. In the first round 28 questions with a median duration of 35 minutes per interview were given. The second round focused on comparability and development of riding skills and the importance of the rider's experience, therefore the questionnaire was shorter: 19 questions and about 25 minutes time for each interview.

The interviews showed that all pilot study participants could handle the Segway well right from the beginning. Handling the Segway was thought to be most difficult when riding on wet, slippery or loose grounds; concerning difficulties in handling the Segway the participants gave generally better notes in the second round – retrospectively it was considered less difficult. The statements to the Segway's use in bad weather were less positive: Because of becoming cool by lacking activity on the device, it was considered to be poorly usable as soon as the weather became cold, stormy or wet; on snowy and icy roads there were problems with the grip.

The ratings of the Segway's riding characteristics were good, in average, and very good concerning manoeuvrability, acceleration and range. The rating was lowest when it came to the Segway's capability to keep track – already a little slope in the terrain as well as a varying inflation pressure in the wheels provoke a slight cornering.

Concerning the technical equipment a signalling facility and the spring suspension, which is guarantied only by the wheels and was thought to need improvement, was missed most of all. But also the lighting installation was criticized (the provided Segways had only a backlight).

Interactions and conflicts with other road users occurred occasionally, according to

Vier Ereignisse waren Fahrprobleme, eines ein technisches Problem ohne weitere Folgen, eine Interaktion, sowie zwei Unfälle, einer davon führte zur Beschädigung eines Fahrzeugs. Die aufgesprochenen Ereignisse fanden weitgehend in der ersten Hälfte des Pilotzeitraums statt.

Zur Klärung weiterer, aktueller, unerwarteter Fragen, Anmerkungen und Probleme aller Art, wurde daneben eine telefonische Hotline zur Verfügung gestellt. Es wurde erwartet, dass ein Großteil der auftretenden Fragen und Probleme, für die die Hotline in Anspruch genommen werden würde in den ersten drei Wochen entstehen, verwendet wurde die Hotline allerdings nur ein einziges Mal, da die wenigen auftretenden Fragen oder Probleme hinreichend im Kollegenkreis beantwortet werden konnten bzw. der Fahrtenrekorder als das geeignete Medium angesehen wurde.

Interviews

Zu Vergleichszwecken fanden zwei Interviewrunden statt, die erste nach drei Wochen Laufzeit des Pilotversuchs, die zweite zu deren Ende. Befragt wurde in geführten Interviews mit festgelegtem Fragenkatalog zu fünf Themenkomplexen: »Fahrzeugbedienung«, »Fahrzeugeigenschaften«, »Interaktion im Verkehrsraum«, »Sicherheitsgefühl und Gefährdungspotenzial«, sowie »Selbsteinschätzung der Pilotteilnehmer«. Daneben blieb aber Raum für weitergehende und Rückfragen. In der ersten Runde wurden 28 Fragen mit einer mittleren Befragungsdauer von 35 Minuten gestellt. In der zweiten Runde stand die Vergleichbarkeit und Entwicklung der Fahrfähigkeiten, sowie die Bedeutung von Fahrerfahrung im Vordergrund, deshalb wurde der Fragebogen auf 19 Fragen (ca. 25 Minuten) verkürzt.

Die Interviews ergaben, dass alle Pilotteilnehmer mit der Fahrzeugbedienung von Anfang an gut zurecht kamen. Am schwierigsten wurde der Umgang mit dem Segway beim Fahren auf nassen, glatten oder lockeren Oberflächen empfunden, grundsätzlich wurde in der zweiten Runde zur Frage von Schwierigkeiten im Umgang mit dem Segway bessere Noten gegeben – in der Rückschau wurde er als weniger schwierig empfunden. Wenig positiv äußerten sich die Teilnehmer zur Nutzbarkeit bei schlechtem

the participants' memory about 20 times per person during the whole pilot study period, half of the incidents were said to have happened in the first 3 weeks. The majority of these incidents were the startling of other road users, probably mainly due to the unusual sight and the very silent approach of the device. Occasionally interactions occurred, rarely crashes, which also included striking objects like walls, doorframes, cupboards and railings. There were no accidents with injuries.

According to the experience and judgement of the pilot study participants tracks of main traffic roads and of roads restricted to 30 km/h were not at all suited to conditionally suited for use of the Segway; cycle tracks, pedestrian- and sidewalks, pedestrian precinct and traffic reduced areas however were very well suited. 10 of the 11 interviewed participants consider a speed limit for the Segway reasonable on pedestrian areas.

All participants felt safe while riding the Segway, on the basis of their experience they consider dangerous situations to occur rarely, the endangering potential of such situations, if they happen at all, being rather low. 60 % of the interviewed persons favoured wearing a protective helmet, 40 % however only speed dependent: when riding at walking speed no helmet was thought to be necessary.

When the Segway was used longer (more than 2 hours) some participants complained about numbness in the feet and slightly aching feet and legs caused by the long and motionless standing on the device and the lacking spring suspension.

Most participants reported that their riding skill had considerably improved between the 2 interviews, especially coordination, the perception of dangerous situations and a much better feeling of safety were mentioned.

Assessment

Handling the device

The Segway is basically and intuitively very easy to handle, nevertheless some incidents happened which probably mainly

Wetter: Wegen der Auskühlung durch mangelnde Bewegung wurde das Fahrzeug bei Kälte, Wind oder Niederschlägen als schlecht nutzbar empfunden, bei Schnee- oder Eisglätte hat es Probleme mit der Haftung (Grip).

Die Fahreigenschaften des Segway wurden im Durchschnitt mit gut bewertet, sehr gut wurde dabei die Manövrierfähigkeit, das Beschleunigungsvermögen und die Reichweite beurteilt. Die Spurtreue wurde am schlechtesten bewertet – schon eine geringe Seitenneigung des befahrenen Geländes kann, ebenso wie der schwankende Luftdruck in den Reifen zu einer leichten Kurvenfahrt führen.

An der technischen Ausstattung wurde am häufigsten das Fehlen einer Signaleinrichtung und die verbesserungswürdige Federung genannt, die ausschließlich durch die Reifen realisiert wird. Aber auch die Beleuchtungseinrichtung (die zur Verfügung gestellten Fahrzeuge waren nur mit einem Rückstrahler ausgestattet) wurde bemängelt.

Interaktionen und Konflikte mit anderen Verkehrsteilnehmern kamen gelegentlich vor, nach der Erinnerung der Teilnehmer während des gesamten Pilotzeitraums rund zwanzigmal pro Teilnehmer, wobei etwa die Hälfte davon in die ersten drei Wochen eingeordnet wurde. Beim größten Teil dieser Ereignisse handelt es sich um Erschrecken anderer Verkehrsteilnehmer, vermutlich hauptsächlich zurückzuführen auf den ungewohnten Anblick und das sehr leise Annähern des Fahrzeugs. Gelegentlich kam es zu Interaktionen und selten zu Zusammenstößen, wobei hierunter auch Berührungen mit Gegenständen (z.B. Wänden Türrahmen, Schränken, Geländern) subsummiert wurden. Unfälle mit Verletzungen fanden keine statt.

Nach der Erfahrung und Einschätzung der Pilotteilnehmer sind die Fahrbahnen von Hauptverkehrsstraßen und Tempo-30-Zonen gar nicht bis bedingt für den Segway geeignet, Radverkehrsflächen, Fuß- und Gehwege, Fußgängerzonen und verkehrsberuhigte Bereiche dagegen sehr. Eine Geschwindigkeitsbeschränkung für den Segway auf Fußgängerflächen halten zehn der elf Befragten für sinnvoll.

Alle Teilnehmer fühlten sich sicher bei der

were caused by the fact that the participants still were learning how to ride the Segway. Besides smaller riding insecurities 7 major incidents happened, which are partly documented on the recorder, partly reported via hotline and explained in the interviews.

Two of the incidents caused breaks in the handlebar of the device, in two other incidents the riders suffered from blue marks; no other injuries were seen. Basically all accidents happened because of wrong decisions or false conduct. Above all in the first weeks, the physical limits of the device were similarly unknown as the device was. Some borderline situations will never be experienced with other devices. It has been overestimated to what extent the electronics can make corrections in extreme situations and how much power the two 1.5 kW electric motors can develop.

It is often underestimated how important the grip is for a self-balancing device. In the training offered by the manufacturer to each buyer of a segway some of the problematic situations are taught and warnings are given. This is done e.g. for riding uphill, passing over curbs and surpassing the maximum slope.

Limits to the Segway's use

The use of the Segway can be limited by slight complaints, which might be caused by long and motionless standing on the platform. Cold, wind, rain, snowy or icy roads are factors, which can strongly limit the Segway's use.

Technical characteristics and equipment of the Segway

In every day use of the device potential improvements of some details became evident. Because of the low motor sound the device is hardly audible, a bell as warning signal is necessary. Furthermore a sufficient lighting facility is necessary so that the Segway can be seen in the darkness. Up to now the device is equipped with reflection surfaces only. The wheels tend to loose quickly pressure, which can lead to lateral spin while riding straight on. The display cannot record differentiated fault reports very well, possibly the acoustic and tactile warning in case of emergency switch off should be en-

Benutzung des Segways, auf Basis ihrer gemachten Erfahrungen schätzen sie das Vorkommen gefährlicher Situationen als selten ein, das Gefahrenpotenzial dieser Situationen, wenn sie denn auftreten als eher gering. Die Mehrheit der Befragten sprachen sich für einen Schutzhelm aus, teilweise allerdings abhängig von der Geschwindigkeit: bei Schritttempo sei er nicht notwendig.

Bei längerer Benutzung des Segways (mehr als zwei Stunden) traten bei einigen der Teilnehmer Taubheitsgefühle und leichte Schmerzen in Füßen und Beinen auf, bedingt durch das lange, bewegungslose Stehen auf dem Fahrzeug und die mangelnde Federung.

Ihre Fahrfähigkeiten, so gaben die meisten Befragten an, hätten sich zwischen den beiden Interviews merklich verbessert, insbesondere die Koordination und das Einschätzen gefährlicher Situationen sowie ein besseres Sicherheitsgefühl wurden hier genannt.

Bewertung

Fahrzeugbedienung

Der Segway ist grundsätzlich sehr einfach und intuitiv zu bedienen, trotzdem geschahen eine Reihe von Vorfällen, die wohl vor allem darauf zurückzuführen sind, dass die Teilnehmer noch im Lernprozess im Umgang mit dem Fahrzeug waren. Neben kleineren Fahrunsicherheiten kam es zu sieben größeren Vorfällen, die teilweise auf den Tonbändern dokumentiert, über die Hotline gemeldet und in den Interviews erläutert wurden.

Bei zweien dieser Vorfälle kam es zu Brüchen am Lenker des Fahrzeugs, bei zweien trugen die Fahrer blaue Flecken davon; es kam zu keinen weitergehenden Verletzungen. Grundsätzlich lassen sich alle Vorfälle auf Fehleinschätzungen oder Fehlverhalten zurückführen. Die physikalischen Grenzen, die für das Fahrzeug gelten, waren für die Nutzer vor allem in den ersten Wochen noch ähnlich ungewohnt, wie das Fahrzeug selbst. Manche Grenzsituationen sind mit üblichen Fahrzeugen nicht erreichbar. Es wurde überschätzt, in welchem Maß die

hanced. As the platform is positioned on the height of the shinbone and has sharp metal edges, a rebound protection seems to be advisable.

Reaction of other road users

The Segway as a new and unusual device has raised attention and curiosity amongst all road users. When the pilot study participants stopped it did not take long before many people gathered who were curious to learn about the device, its functioning, price and the reason for its use by police/ Municipal Office. Sometimes criticism was brought forward, but positive reactions were more common. With increasing duration of the pilot study and an accompanying reporting in the media people got used to the Segway and the devices became more and more familiar in the city.

Experiences for the utilization by police and Municipal Office

The experiences in utilizing the Segway for office purposes were described very positively. The high flexibility and range have positively been mentioned being 2.5 to 3 times higher in comparison to the patrol duty on foot. The officials could patrol certain areas more often and were faster with the devices. The higher standing on the platform brought more view and presence. The acceptance of the device in the pedestrian precinct was reported to be very good in contrast to police car or bicycle.

Transferability of the pilot study results

By the use in the daily traffic and by the intensive utilization over many hours a day the results of the pilot study are exemplary transferable to everyday transport and deliver an idea how the Segway fits into the traffic system when used appropriately and suitably.

Questions

With respect to licensing, safety and the importance of the Segway the questions put forward during the study could be sufficiently answered by the obtained results.

Elektronik in Extremsituationen korrigierend eingreifen kann und welche Kraft die beiden, je 1,5 kW starken Elektromotoren entwickeln können. Die Bedeutung der Haftung für ein selbstbalancierendes Fahrzeug wird häufig unterschätzt. In den Schulungen des Herstellers wird auf einige der aufgetretenen Situationen, wie auf das Fahren am Hang, das Überwinden von Bordsteinen und das Überschreiten der Maximalneigung eingegangen und vor Gefahren gewarnt.

Beeinträchtigungen der Nutzbarkeit

Die Nutzbarkeit des Segways kann durch leichte Beschwerden eingeschränkt werden, die durch langes, bewegungsloses Stehen auf der Plattform entstehen können. Auch Kälte, Wind, Regen, Schnee- oder Eisglätte können sie Nutzbarkeit des Segways stark beschränken.

Technische Fahrzeugeigenschaften und Fahrzeugausstattung

Aufgrund des leisen Motorgeräusches ist das Fahrzeug kaum zu hören, eine Klingel als Gefahrensignal ist notwendig. Ebenso eine ausreichende Beleuchtungseinrichtung, damit der Segway bei Dunkelheit gesehen werden kann; bislang ist das Fahrzeug nur mit Reflektionsflächen ausgestattet. Die Reifen verlieren teilweise schnell Druck, was zu Seitendrall bei Geradeausfahrt führen kann. Das Anzeigedisplay kann differenzierte Fehlermeldungen nur schlecht darstellen, möglicherweise sollte die akustische und taktile Warnmeldung bei der Notabschaltung verstärkt werden. Da sich die Standplattform auf Schienbeinhöhe befindet und recht harte, metallene Kanten hat, wäre ein Anprallschutz sinnvoll.

Reaktion anderer Verkehrsteilnehmer

Der Segway hat als neuartiges und ungewohntes Fahrzeug Aufmerksamkeit und Neugier bei allen Verkehrsteilnehmern verursacht. Blieben die Pilotteilnehmer stehen, sammelten sich innerhalb kürzester Zeit Passanten, die neugierig waren auf das Fahrzeug, Funktionsweise, Preis und den Grund für den Einsatz bei Polizei/Ordnungsamt. Gelegentlich wurde Kritik geäußert, positive Resonanz überwog aber. Mit zunehmender Dauer des Versuchs und begleitender Berichterstattung trat ein Gewöhnungseffekt

Recommendation for admission

For licensing the Segway in Germany an important basis for the decision is whether and how well the Segway fits into the existing transport system with regard to traffic flow and the Segway's conflict potential. For that purpose the road performance, the device's equipment as well as the handling and the acquirement of the handling have to be taken into consideration.

Potential ways of admission

Based on these considerations which possibilities offers the German law to license the Segway?

There are more alternatives to be considered, all of which require either legal alterations or modifications of the Segway or both. Beside the above mentioned possibility to classify the Segway as passenger motorcar the Segway could also be classified as motor-assisted bicycle, wheel-chair, bicycle with motor support (light moped), but in any case the Segway has to correspond to the specific technical requirements of each type of device. The Segway can only be characterized as light moped if the weight requirements of the light moped saving clauses are altered.

As the Segway differs from other motorcars a characterization as special transport mean (besonderes Fortbewegungsmittel) could be considered, however this would require a corresponding decision by the ministry, court or a modification of § 16 (2) StVZO (the road traffic licensing regulations). Such a characterization would allow an unrestricted use of the Segway without need for admission, riding licence, compulsory insurance and helmet, but would restrict the use of the Segway to pedestrian traffic areas with a correspondingly adapted speed.

A technical reduction of the construction based maximum speed to 6 km/h would have the same effect – the need for rider's licence, helmet and compulsory insurance would be abolished, the use of the device would be restricted to pedestrian traffic areas and could hardly make use of its specific advantages.

ein, die Fahrzeuge gehörten zunehmend selbstverständlich zum Stadtbild.

Erfahrungen für die Nutzung bei Polizei und Ordnungsamt

Im dienstlichen Einsatz wurde die Schnelligkeit, hohe Flexibilität und Reichweite hervorgehoben, die im Vergleich zum Streifendienst zu Fuß um den Faktor zweieinhalb bis drei höher war. Bestimmte Bereiche konnten häufiger bestreift werden. Der erhöhte Standort auf der Plattform verschaffte mehr Überblick und mehr Präsenz. Die Akzeptanz des Fahrzeugs in Fußgängerbereichen wurde als sehr gut geschildert, im Gegensatz zu Streifenwagen oder Fahrrad.

Übertragbarkeit der Ergebnisse des Pilotversuchs

Durch den intensiven Einsatz über viele Stunden täglich sind die Ergebnisse des Pilotversuchs modellhaft auf den Verkehrsalltag übertragbar und zeigen, wie sich das Fahrzeug bei angemessenem und angepassten Gebrauch in das Verkehrsgeschehen einfügt.

Fragestellungen

Die im Rahmen der Studie aufgeworfenen Fragen hinsichtlich der Zulassung, der Sicherheit und der Bedeutung des Segways konnten aufgrund der vorliegenden Ergebnisse hinreichend beantwortet werden.

Empfehlung für die Zulassung

Wichtige Grundlage bei der Entscheidung über die Zulassung des Segways in Deutschland ist, ob und wie sich der Segway hinsichtlich des Verkehrsflusses und seines Konfliktpotenzials gut in die bestehende Verkehrsstruktur einfügt. Berücksichtigt werden müssen dabei auch die Fahreigenschaften und die Fahrzeugausstattung, sowie die Bedienbarkeit und die Erlernbarkeit der Bedienung des Segways.

Möglichkeiten der Zulassung

Welche Möglichkeiten bietet das deutsche Recht zur Zulassung des Segway vor dem Hintergrund diesen Erwägungen?

If the Segway was characterized as motor-car of special type (e.g. as »electric personal assistive mobility device«) the requirements of admission, rider's licence, insurance, obligatory helmet and technical equipment could be shaped according to need and with respect to the specialities of the device. For this the StVZO (the road traffic licensing regulations) would have to be changed correspondingly.

Recommendation for admission

The German road traffic regulations define requirements and prerequisites for devices, their assigned traffic areas and their road behaviour in public transport according to type of device and not according to application. All attempts to define the Segway within existing categories will therefore lead to the fact, that requirements for the device are to be met, which technically are difficult to fulfil or which are unreasonable with respect to the Segway's use. It could happen that the Segway will be classified to a traffic area in which it does not fit properly and in which the conflict - and danger potential is very high for the rider as well as for other road users. In some cases the Segway cannot use its specific advantages.

To fulfil all these requirements and to reflect the results of the pilot study we recommend integrating the Segway as a »electric assistive mobility device«, as motorized vehicle of special type, into the Straßenverkehrs-Zulassungsordnung StVZO (the road traffic licensing regulations).

The use of the Segway should be allowed on cycle lanes, in traffic-calmed areas, in pedestrian zones, in the last two with a limitation to walking speed. Like for motor-assisted bicycles a compulsory insurance seems advisable, an adjustment of the regulations for insurance does not seem to be necessary. Correspondingly the Segways should only be required to carry a small insurance plate. According to the Fahrerlaubnisverordnung (the driver's licence regulation) a rider's licence is not necessary in this case, the training is sufficient because the manufacturer links the sell of a Segway to obligatory riding tests and as the pilot study has shown that mainly the riding experience and the riding skills improve the safe handling of the Segway. There is a lower risk

Dazu kommen mehrere Varianten in Betracht, die aber alle entweder rechtliche Änderungen oder Modifikationen am Fahrzeug, oder beides erfordern. Neben der schon dargestellten Möglichkeit einer Einordnung als Pkw könnte der Segway als Mofa, Krankenfahrstuhl, Fahrrad mit Hilfsmotor (Leichtmofa) eingeordnet werden, müsste dabei aber immer die spezifischen, technischen Anforderungen dieses Fahrzeugtyps erfüllen. Als Leichtmofa kann er nur bei einer Änderung der Gewichtserfordernis der Leichtmofa-Ausnahmeverordnung eingeordnet werden.

Da er sich sehr von anderen Kraftfahrzeugen unterscheidet, wäre eine Einordnung als besonderes Fortbewegungsmittel denkbar, die allerdings durch eine entsprechende ministerielle, richterliche Entscheidung oder eine Modifikation des § 16 (2) StVZO untermauert werden müsste. Dies würde eine freizügige Nutzung des Segways ohne Erfordernis von Zulassung, Fahrerlaubnis, Pflichtversicherung und Helm ermöglichen, allerdings beschränkt auf Fußverkehrsflächen mit entsprechend angepasster Geschwindigkeit.

Ähnlich würde sich eine technische Reduzierung der bauartbedingten Höchstgeschwindigkeit auf maximal 6 km/h auswirken – so fielen Fahrerlaubnis-, Helm- wie Versicherungspflicht weg, das Fahrzeug wäre auf eine Nutzung auf Fußverkehrsflächen beschränkt und könnte seine spezifischen Vorteile kaum ausspielen.

Würde der Segway als Kraftfahrzeug eigener Art eingeordnet, (z.B. »elektronische Mobilitätshilfe«), ließen sich die Anforderungen an Zulassung, Fahrerlaubnis, Versicherung, Helmpflicht, sowie die technische Ausstattung entsprechend den Erfordernissen und unter Würdigung der Besonderheiten des Fahrzeugs gestalten. Dabei müsste die StVZO entsprechend geändert werden.

Empfehlung für die Zulassung

Das deutsche Straßenverkehrrecht legt Anforderungen und Vorgaben an Fahrzeuge, deren zugewiesene Verkehrsflächen und Verhalten im öffentlichen Raum fahrzeugtypbezogen und nicht anwendungsbezogen fest. So führen alle Versuche, den Segway in bestehende Kategorien einzuordnen

of accidents and less danger of falls connected with the Segway in comparison to a bicycle. An analogous regulation of recommending the use of a protective helmet without the obligation to wear a helmet seems to be sufficient.

The technical equipment of the Segway is not yet sufficient for using it in public spaces. The Segway should be equipped with a lighting facility as standard, like it is required for bicycles, as standard it also should have a bell. According to the results of the pilot study the provided brake technology seems to be sufficient for the recommended use, the equipment of the device with rear-view mirror and speedo does not seem absolutely necessary.

dazu, dass zum einen an das Fahrzeug Anforderungen gestellt werden, die technisch schwer zu erfüllen, oder angesichts der Nutzung unverhältnismäßig sind. Unter Umständen wird der Segway so einer Verkehrsfläche zugeordnet, in die er sich nur schlecht einfügt und auf der das Konflikt- und Gefahrenpotenzial für Fahrer wie andere Verkehrsteilnehmer sehr hoch ist. In einigen Fällen kann der Segway seine spezifischen Vorteile nicht ausspielen.

Um all diesen Ansprüchen gerecht zu werden und unter Berücksichtigung der Ergebnisse des Pilotversuchs empfehlen wir, den Segway als elektronische Mobilitätshilfe, als Kraftfahrzeug eigener Art mit in die Straßenverkehrs-Zulassungsordnung aufzunehmen.

Dabei sollte er sowohl auf Radverkehrsflächen, als auch in verkehrsberuhigten Bereichen und auf Fußverkehrsflächen, auf letzteren Beiden mit einer Beschränkung auf Schrittgeschwindigkeit, genutzt werden dürfen. Eine Pflichtversicherung wie für Mofas erscheint sinnvoll, eine Anpassung der Vorschriften zur Versicherungspflicht nicht notwendig. Entsprechend sollen die Segways nur mit einem kleinen Versicherungskennzeichen ausgestattet werden. Eine Fahrerlaubnis ist unter diesen Umständen nach der Fahrerlaubnisverordnung nicht notwendig, die im Zusammenhang mit dem Erwerb eines Segways vom Hersteller vorgegebenen, obligatorischen Schulungsmaßnahmen sind ausreichend, darüber hinaus steigert, so zeigt der Pilotversuch, vor allem Fahrpraxis und Fahrerfahrung die Sicherheit im Umgang mit dem Segway. Das Unfallrisiko und die Gefährlichkeit von Stürzen erscheinen beim Segway im Vergleich etwa zum Fahrrad geringer. Eine analoge Regelung bezüglich einer Empfehlung zur Nutzung von Schutzhelmen ohne explizite Helmpflicht scheint ausreichend.

Die technische Ausstattung des Segways für den Einsatz im öffentlichen Raum ist noch unzureichend. Der Segway sollte serienmäßig mit einer Beleuchtungseinrichtung, vergleichbar zu der für Fahrräder vorgeschriebenen; ausgerüstet werden, ebenso mit einer Glocke. Nach den Ergebnissen des Pilotversuchs scheint die vorhandene Bremstechnik für die empfohlene Nutzung ausreichend, die Ausstattung des Fahrzeugs mit Rückspiegel und Tachometer erscheint als nicht zwingend notwendig.

Background

1 Pilot study

1.1 Device

In 2001 Dean Kamen presented his invention, the Segway Human Transporter (HT) in the USA. The device had already attracted attention under its code name »ginger«, although it was only known, that it would revolutionize mobility.

The Segway HT is based on technology, which was originally developed for the electric wheel chair »iBot«. This chair possesses six wheels and can automatically climb steps and enable the driver, to reach higher placed objects for example in a cupboard, by getting on its back wheels. The same components, which guarantee the iBots balance, are integrated into the Segway and allow the device to balance on just two wheels.

The Segway consists of a platform with a grip pole on which the steering rod is attached. On both sides of the platform the two wheels – about 45 cm in diameter – are mounted in single wheel suspension with an electric motor in each wheel hub. The platform contains accumulators, steering electronics, tilt sensors and gyroscopes. They are continuously measuring the centre of gravity of both the rider and the device and according to the behaviour of the upright pendulum they provide for the stabilization of the device. They thereby steer the electric motors in such way that the centre of gravity is always vertical to the imaginary axis between the two wheels. Leaning forward or backward induces acceleration or slowing down of the Segway, operating the rotary switch on the grip pole steers the device. By steering the two wheels against each other the Segway can turn on the spot. Backward riding is basically not necessary because of the Segways ability to turn on the spot.

According to the manufacturers statement, the device weighing 38 kg (Segway HT i170) has a carrying capacity for useful load up to 118 kg and a maximum speed of 20 km/h. The Segways range of action depends on the type of accumulator, on the weight and the terrain and can extend to 25 km.

The Segway can be used in three riding stages, which are steered by three electric »keys« of different colours; the electric chip incorporated in each keys directly influences the computer embodied in the Segway. According to the key maximum speed and rotating speed differ.

The black key is meant for beginners, because it only allows a slow rotating speed and a riding speed in the range of a walking speed up to 9.6 km/h. More experienced riders can reach a maximum speed of about 12.9 km/h with the yellow key. The red key is meant for experienced riders; it allows quick turnings and the riding of the Segway at a speed of up to 20 km/h. This graduation guarantees an effective speed limit of the devices.

The Segway has been designed to enlarge the pedestrians radius of action: With the Segway the rider should move on the same places, as he would do as a pedestrian. The Segway should increase the pedestrians flexibility and radius of action and by doing so form a link between short tracks within walking distance and medium and long tracks usually reached by car.

Figure 1: a representative of the Municipal Office of Neunkirchen
Source: Segway Austria

1.2 Pilot project

Four years after launch the Segway is well established in its home-country USA and is spreading around the world. In 2005, between 15.000 and 20.000 Segways *[unofficial estimate, based on internet research]* are used worldwide. In European countries, too, one can see growing numbers of the Segway, above all at fairs, airports or industrial plants. In France, Italy and Austria, the Segway has been registered meanwhile and is used for sight seeing, in device rental to supplement the travel chain and to some extent for private use.

In the Federal Republic of Germany, one of the potentially greatest European markets, demand increases with the growing familiarization of the Segway. Because of the lacking registration and the resulting lack of insurance cover the Segway can only be used on private grounds, up to now. Therefore it is rather rarely that the device can demonstrate its advantages, namely a quick manoeuvrability on short and medium distances.

In 2002, in cooperation with the manufacturer Segway Llc., the Deutsche Post AG (German Postal Service) wanted to test a slightly modified version of the Segway HT for the mail delivery in the frame of a field study in Dresden. In order to get an exemption permit, the Deutsche Post AG approached the expert committee at the Federal and district level »Technical Motoring« (Bund-Länder-Fachausschuss »Technisches Kraftfahrwesen«), which however did not grant such an exemption permit due to technical safety reasons in traffic.

In 2005 again, Segway approached the Federal Ministry of Transport, Building and Urban Affairs (Bundesministerium für Verkehr, Bau und Stadtentwicklung, BMVBS) and asked for permission to carry out a pilot study. In the Federal State Saarland an interesting partner had been found.

Since September 2005, a trading company for Segways, a subsidiary of Segway Austria, has started business in Germany and concentrates because of the lacking registration on commercial clients and the marketing in airports and fairs.

1.3 Project partners

The Segway-standard types have been field-tested in the frame of the pilot study by the patrolling District Police in Saarbrücken and by the Municipal Office of Neunkirchen; the study is carried out in the responsibility of the Saarlands Ministry for Interior, Family, Women's Affairs and Sport (Ministerium für Inneres, Familie, Frauen und Sport) and the Ministry for Economic Affairs and Labour (Ministerium für Wirtschaft und Arbeit). Segway Austria provided the necessary devices. On behalf of the Federal Ministry of Transport, Building and Urban Affairs (Bundesministerium für Verkehr, Bau und Wohnungswesen) the Federal Highway Research Institute (Bundesanstalt für Straßenwesen BASt) looks after and finances the research and development project, which scientifically accompanies the pilot study. The Insitute for Mobility and Transport imove of the Technical University of Kaiserslautern carries out the project.

1.4 Definition of problems

In Germany, the Segway has not yet been registered to road traffic, i.e. it can only be used on private grounds. To use the Segway on public traffic grounds therefore is a summary offence according to § 24 StVG i.V.m. (law regulating the road traffic), § 69a (2) No. 3 StVZO (road traffic registration regulations) and is punished by a fine of 50 Euro (No. 178 BKatV, regulation for catalogue of fines). However, the aim is a registration within the law regulation road traffic and a corresponding registration of the Segway.

The existing legal frame supports the specific device characteristics, the electronic stabilization and steering in a very limited way. And the Segways usage compatibility in road traffic and the interaction with other traffic participants is still not exactly known. This leads to a number of questions, which still have to be answered.

Concerning the general use, focus is laid on the registration for use, respectively the licensing, on the utilization in appropriate traffic areas such as roads, cycle tracks, pedestrian precincts and sidewalks. Furthermore other questions have to be considered concerning riders licence, insurance,

number plates and even the possible obligation to wear a helmet.

The large city Saarbrücken (approx. 179,000 citizens) and the medium-sized town of Neunkirchen (approx. 49.800 citizens) with their different traffic structures, traffic areas, pavements and topograhy are a good starting point for these considerations.

1.5 Aim

In the frame of a three-months-pilot study with two comparative groups, from September 25 to November 30, 2005, the research project aimed at gathering more detailed information on the performance of Segway riders, on the utilization and compatibility of the Segway in public spaces and at evaluating the data. These data should provide answers to a number of open questions and form the basis for the recommendation vis-à-vis the registration and legal traffic classification of the Segways. These data should be the decisive basis for a possible registration of the devices.

Within the trial the following questions are relevant, e.g.:

Concerning registration:

- Does the Segway meet the requirements of the road traffic registration regulations (StVZO) with regard to its wheels, steering facility and braking system?
- How should the lack of a riders seat be handled?
- What kind of signalling and lighting facilities are needed?
- In which form can the Segway be registered, how should it be handled vis-à-vis an obligation to number plates, riders licence, insurance or helmet?
- Can the Segway be registered in the frame of the existing legal rules or are changes or supplements to the rules necessary?

Concerning safety:

- How long does it take to ride the Segway safely, what kind of knowledge of the device, its road performance and use in public spaces is necessary?
- How much conflict potential has the Segway when interacting with other road users and objects in the traffic area?
- Where can the Segway be conducted in the safest way for all traffic participants with respect to its conflict with other traffic participants and its road behaviour?
- Should there be a minimum age limiting the riding of the Segway and is it at all necessary?

Concerning utility value:

- For which use and user groups is the Segway interesting to ride?
- Which aspects regarding city and traffic politics could come up when the Segway is used widely?

1.6 Methods and procedures

The scientific analysis of the Segway in public spaces is divided into three work units: the theoretical and empirical data collection for the Segway with regard to the existing questions, interpretation of the obtained results and finally based on this analysis an expert recommendation how the Segway can be registered in Germany.

Data collecting

In the theoretical part of the data collecting a literature inquiry examines the registration situation for Segways inside the country and abroad. Available reports on the use of the Segway and experience made up to now are reviewed. A survey of similar and comparable novel devices such as goped, power board or light mofa and their actual legal classification in Germany offers the frame for the corresponding classification of the Segway. This and a survey of the relevant legal basis in Germany should answer the questions aiming specifically at the registration.

The empirical part of the data collecting is the most extensive one; it consists of the pilot study, which took place for three months between September 25 and November 30, 2005. The framework has been agreed on before in close cooperation with the project partners.

To provide a wider spectrum of ways and activities for which the Segways have been

used and places that have been visited by the devices, the pilot study has been carried out with two comparative groups: In Saarbrücken, seven participants of the patrolling District Police regularly and alternatively used three devices (all together up to nine), in Neunkirchen originally six participants of the Municipal Office used the three devices, on a regular basis there were only three persons to use the Segways. All participants normally carried out their routine duty and wore uniforms, while using the Segways. Within the limits of the exemption permit, the devices have also been used wearing civilian clothes

After consultations with the officials of the Police and the Municipal Office, the manufacturer equipped the devices with bags, locks, pinned battery driven headlights and rear lights, as they are normally used for bicycles.

Observing the use of the Segways in routine traffic should provide results on the usage capacities, compatibility of the devices in the interaction with other traffic participants and their safety. The aim was to obtain results concerning the registration potential of the Segways especially by an intensive inspection of technical characteristics relevant for registration as well as of possible problems in routine practise.

Interpretation of results and consequences

Results should be achieved on several levels:

- With the participants the comparative test riding took place on a circuit with defined tasks at the beginning and after the end of the pilot study. This should give an impression of the riders progress to control the device, of aspects concerning the riding safety and of the most important challenges.
- Selected places with a high traffic density have been video controlled from a stable camera position and the video pictures have been reviewed by the system ViVA*traffic*® for video conflict analysis.
- With six riding recorders for the test devices the participants of the pilot study were able to document directly and timely all practical conflicts, conflict potentials, handling problems as well as other exceptional situations. The protocols of the riding recorders have been evaluated and gave information on frequency and seriousness of exceptional situations while using the Segway in normal traffic.
- The more general impressions, experiences and problems of the participants in handling the devices have been recorded in two interview rounds, the first of which took place three weeks after the start of the project, the second one after the end of the pilot study. The two interview rounds should enable a comparison and draw conclusions of the learning progress in handling the Segway.
- A special telephone hotline was established to deal with and register problems and incidents, which otherwise had not been covered by the mentioned instruments. This hotline was available at any time during the pilot study in case the participants had any question.

Recommendation for registration

Recommendations for the legal road traffic characterization and classification were made on the basis of the interpretation and

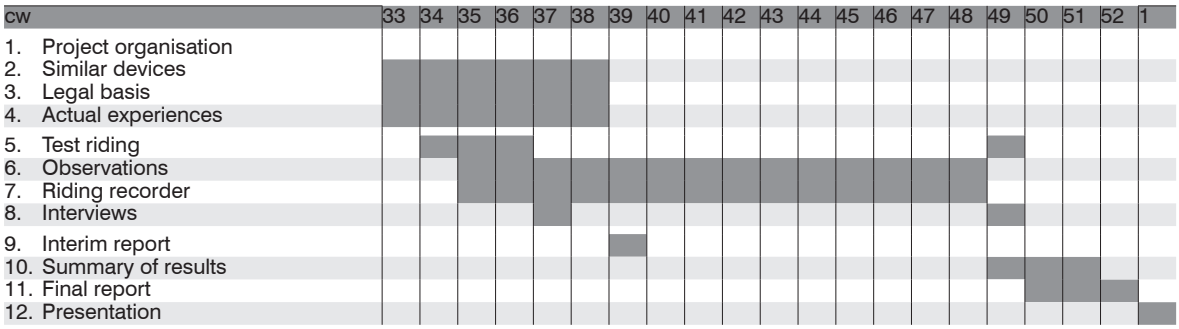


Figure 2: time-table for the project »Segway in public spaces«

summary of the empirical results and by considering the theoretical part.

Time-table

The overall duration of the project was originally planned to last four months, starting on July 15, 2005 and ending on November 30, 2005. Because of need of further co-ordination amongst the project partners the granting of an exemption permit and the beginning of the pilot study have been delayed until September 25. The pilot study run over three months up to November 30, 2005. The running period of the project was prolonged without any further expense to Januar 31, 2006. and the time-table accordingly adapted. The final meeting of the project participents took place on January 11, 2006 and the results of this report has been presented then.

The activities have been divided into work packages; the theoretical part comprises the following work packages

1. »Survey of similar devices«
2. »Presentation of the legal basis« and
3. »Actual handling experience and spread of the Segway inside the country and abroad«
4. The empirical part consists of the work packages
5. »Realization and evaluation of riding tests«
6. »Realization and evaluation of video observations«
7. »Evaluation of the riding recorders« and
8. »Realization and evaluation of the user interviews«

1.7 Activities

- July 20, 2005: Kick-off-meeting with representatives of all project participants; during the meeting the participants could come to know each other and on the basis of the imove offer discuss the procedure and open questions.
- August 16 and 17, 2005: In Saarbrücken and Neunkirchen representatives of Segway Llc. and Segway Austria taught the participants of the pilot study how to ride the device. Briefing of the participants about the measures (No. 6 – 8) planned for scientific supervision by representatives of imove. After the instruction the participants had to pass a training circuit (compare No. 5).
- August 25, 2005: Start press conference in the District Police administration (Landespolizeidirektion) with representatives of all project partners in Saarbrücken.
- August 25, 2005: Start of a three-monthly pilot phase, which went until November 30, 2005.
- August 29, 2005: Video recordings in Neunkirchen.
- September 5, 2005: Video recordings in Neunkirchen.
- September 13, 2005: First round of interviews with the participants of the pilot study in Neunkirchen.
- September 14, 2005: First round of interviews with the participants of the pilot study in Saarbrücken.
- September 23, 2005: Braking tests in Kaiserslautern.
- September 30, 2005: Delivery of the interim report.
- October 13, 2005: Video recordings in Saarbrücken.
- October 27, 2005: Interim meeting of all participants in Saarbrücken, short review on the actual state of the scheme, outlook on and coordination of further proceeding.
- November 24, 2005: Video recordings in Saarbrücken.
- December 5, 2005: Second round of the circuit and second round of interviews with the participants of the pilot study.
- December 31, 2005: Delivery of the final report (draft)
- January 11, 2006 (scheduled): Final meeting with presentation of the results.
- January 31, 2006: Delivery of the final report at the latest.

I. Data collecting

2 Classification of the Segway

2.1 Survey of similar devices

In the last years, like the Segway many other unconventional, novel small devices have appeared and are very popular thanks to different reasons. The devices being produced in many small- and smallest production series come from Asian areas and make the market quite difficult to survey.

The spectrum of these small devices covers conventional bicycles with electrical- or petrol motors up to quads. The number of wheels varies between two and four. The number of persons who can be transported on these devices differs, too, but the greatest part of the devices is designed to carry one person.

The classification of many of these devices is difficult and some of them cannot easily be categorized within the existing legal categories of known vehicle groups. A classification according to target groups, which would make the categorisation easier, is difficult, because the market is still too small, difficult to survey and there is not enough experience. The prices vary as much as the utility value. Some of the devices are full substitutes for conventional means of transport, whereas others belong rather to the category »fun mobile« or »sports kit«. The registration status is therefore correspondingly difficult. Some of the devices have alternatively been registered as small motor cycle; many others do not have the registration for use in public road spaces.

In spite of the above-mentioned difficulties in categorizing these devices, they are summarized roughly according to similar characteristics and utility values. The vehicles can be classified into the following groups:

- Motor-assisted bicycles
- Scooters
- Small motor cycles
- Quads
- Cabin scooters

The survey of unusual motor devices does not pretend to be complete; the categorized devices should demonstrate the manifold of such devices in first line, show exemplarily typical characteristics and the difficulties of assessment and registration.

2.1.1 Motor-assisted bicycles

Besides the classic electrical or combustion engine powered bicycles there are some novel bicycle-like devices. They all have in common, that they dispose of a me-

Name	ScootX	ELB-201Z	ELB-85Z	Saxonette Classic
Picture				
Maximum speed	20 km/h	25 km/h	25 km/h	20 km/h
Power	electric	electric	Electric	petrol
Number of persons	1	1	1	1
General road registration	no	yes	yes	yes
Licence obligation	/	no	no	yes
Registration obligation	/	no	no	no
Insurance obligation	/	yes	yes	yes
Prices	about 370 Euro	about 1.300 Euro	about 800 Euro	n.n.
Info	www.escooter.de	www.elektron-bikes.de	www.bavaria-bike.de	www.elobike.de

Figure 3: selected bicycles with auxiliary motors and comparable devices

Name	MZ Charly	goped-GSR 40	EZ-Rider	Power-board
Picture				
Maximum speed	20 km/h	30 km/h	20 km/h	45 km/h
Power	electric	petrol	Electric	electric
Number of persons	1	1	1	1
General road registration	yes	no	yes	no
Licence obligation	yes (when born after 1965)	/	yes (when born after 1965)	/
Registration obligation	no	/	no	/
Insurance obligation	yes	/	yes	/
Prices	about 1.000 Euro	about 900 Euro	about 800 Euro	about 1.200 Euro
Info	www.muz.de	www.go-ped.de	www.escooter.de	www.escooter.de

Figure 4: selected motor scooters and comparable devices

chanical device for power transmission on at least one of the two wheels, of a seat for one rider as well as of an auxiliary motor.

2.1.2 Motor scooters

This categorization implies for all devices, which have a platform for at least one foot and an auxiliary motor. As a rule they are designed for use by only one person. The most prominent representative of this group is the so-called goped, a further development of the classic scooter with an additional electric motor.

As a rule these devices have no general road traffic registration because of the often low traffic safety.

Name	PBR 90	Di Blasi R7E	Pocket-bike	Rocket-bike
Picture				
Maximum speed	80 km/h	45 km/h	65 km/h	100 km/h
Power	Petrol	petrol	petrol	petrol
Number of persons	1	1	1	1
General road registration	yes	yes	no	no
Licence obligation	yes	yes	/	/
Registration obligation	no	no	/	/
Insurance obligation	yes	yes	/	/
Prices	about 1.900 Euro	n.n.	from 200 Euro on	from 500 Euro on
Info	www.Honda-dax.de	www.escooter.de	www.pocketbike-shop.biz	www.pocketbike-shop.biz

Figure 5: selected small motor cycles and similar vehicles

Name	MZ ATV50	Loncin LX110ST-A	Honda TRX 250	Mini-Quad ATV
Picture				
Maximum speed	45 km/h	50 km/h	70 km/h	25 km/h
power	petrol	petrol	petrol	petrol
Number of persons	1	1	2	1
General road registration	Light motor vehicle	yes	yes	no
Licence obligation	yes	yes	yes	/
Registration obligation	no	yes	yes	/
Insurance obligation	yes	yes	yes	/
Prices	about 1.990 Euro	about 2.290 Euro	about 7.750 Euro	n.n..
Info	www.muz.de	www.fun-buggy.de	www.quad-oase.de	www.escooter.de

Figure 6: selected quads

2.1.3 Small motor cycles

Small motor cycles of different kind are relatively wide spread in Germany and partly have been present in the market since decades. General characteristics usually are: they have two wheels, they are fully motor powered, and have seats for one or two persons. As a rule, the novel devices are smaller, lighter than the classical motor cycles, but have similar road behaviour.

2.1.4 Quads

Quads have become very popular in Germany the last five years. Above all DIY-stores have promoted the fun vehicle to a great number of clients.

A quad has four wheels, as a rule, is designed for cross-country driving, normally has a combustion engine and offers place for one or two persons. In most cases they have general road registration.

Name	Cityel	TWIKE	Charly Classic	Albizia
Picture				
Maximum speed	45 km/h	85 km/h	15 km/h	45 km/h
Power	Electric	Electric	Petrol/ Electric	Diesel
Number of persons	2	2	1	2
General road registration	small motor cycle	No	wheel chair for handi-capped	light motor vehicle
Licence obligation	yes, class M o. S	/	no, if electric powered	yes, class S
Registration obligation	No	/	no	no
Insurance obligation	yes	/	yes	yes
Prices	about 6.800 Euro	n.n.	about 13.300 Euro	about 11.500 Euro
Info	www.cityel.de	www.twike.de	www.twike.de	www.twike.de

Figure 7: selected cabin scooters and similar devices

2.1.5 Cabin scooters

Cabin scooters are no new invention; already in the 60s of the last century there were first models like the BMW Isetta or the Messerschmitt-cabin scooter. Their small overall dimension, which was unusual for a motor vehicle, was the most prominent characteristic. The offered seats for one or two persons and the storage capacity were correspondingly low. Cabin scooters use combustion engines or electric motors. They usually have four, in some cases three wheels. From the legal registration point of view many of them are classified as wheel chairs for handicapped people and therefore no driving licence is required.

Sometimes, elderly people use them, 16 to 18-years old persons or those who have been deprived of their driving licence. They all make use of the cabin scooters legal registration characteristics and stay mobile with a motor vehicle.

According to this survey one can easily realize how different these devices can be and how difficult the exact classification might be. Because of its technical characteristics, the Segway does not exactly belong to any of the mentioned categories.

2.2 Survey of the legal basis

When discussing the classification of the Segway in road traffic one has to consider some prescriptions, which

- Classify the Segway being a device: the road traffic act (StVG), the road traffic regulations (StVO),
- Manage the way and the conditions for registration: road traffic registration regulations (StVZO)
- Define the necessary technical characteristics and equipment for use on public roads according to registration: road traffic registration regulations (StVZO), the exemption permit for light motor cycles
- Regulate the requirements of an compulsory insurance of the device: law regulating compulsory insurance (PflVG)
- Define the requirement of licensing for the device: drivers licence regulation (FeV)
- Establish the requirements of a number plate for the device: road traffic registration regulations (StVZO), law regulating compulsory insurance (PflVG)
- Define the requirements of wearing a helmet: road traffic regulations (StVO)

2.2.1 Device characteristic

The German road traffic law classifies vehicles into motor vehicles, vehicles and special means of transportation. Motor vehicles are according to §1 (2) StVG vehicles that move by engine force and are not bound to tracks. According to §24 StVO and §16 (2) StVZO the following vehicles belong to the special means of transportation: push-wheel chairs and grip-wheel chairs, luges, prams, scooters, bicycles for children and similar means of transportation. According to a judgement of the German federal court (Bundesgerichtshof) of 2003 (file number: VI ZR 333/00) inline skating is classified as special means of transport, too.

The road traffic regulations are obliging for all three different types of traffic participants, whereas the rules of the road traffic registration regulations are only obliging for devices, including motor vehicles.

2.2.2 Registration

According to §16 road traffic registration regulations (StVZO), only the devices are registered to traffic on public roads, which correspond to the regulations of the road traffic regulations (StVO) and the road traffic registration regulations (StVZO). According to §18 (1) road traffic registration regulations (StVZO), motor vehicles additionally need an operating licence or an EU-type-authorization, and they have to carry an official number plate as prove of the registration. According to §18 (2) road traffic registration regulations the following vehicles are exempted from the regulations of registration procedure: small motor cycles, light motor cycles, 4-wheel-light-motor vehicles and motor powered wheel chairs (see figure 8).

2.2.3 Insurance

Motor vehicles, which are stationed regularly in the country, must have a third party liability insurance, if used on public roads

and places, according to §2 law regulating the compulsory insurance (PflVG). An exemption of this obligation is only possible, when the construction of the device does not permit to go faster than 6 km/h.

2.2.4 Riders licence

Basically according to §1 drivers licence regulations (FeV) everybody is registered to public road traffic, but there are some limitations in such cases where persons cannot move safely in public road traffic because of physical or mental handicaps (§2 drivers licence regulations, FeV). Driving a motor vehicle requires according to §4 (1) drivers licence regulations a drivers licence as capability documentation; this is not the case for single-tracked, single-seated motor-assisted bicycles (mofas) or for motorized, single-seated wheel chairs. No drivers licence is necessary for riding a mofa or a light mofa, but according to §5 drivers licence regulations (FeV) a test certificate.

2.2.5 Number plates

As mentioned in »2.2.2 Registration«, page 13, the allowance of an official number plate by the vehicle registration authority represents a confirmation that the motor vehicle is registered to public transport, according to §18 road traffic registration regulations (StVZO). Therefore every motor vehicle has to carry an official number plate, with the exception of vehicles classified in the exemption permit of §18 (2) road traffic registration regulations (StVZO). In this case they need no registration. 2-wheel or 3-wheel small motor cycles, bicycles with an auxiliary motor, motorized wheel chairs and 4-wheel small motor cycles belong to the exemption permit and dont have to carry an official number plate, according to §29e road traffic registration regulations (StVZO), but have to be equipped with an insurance indicator.

Devices with a construction based maximum speed of 6 km/h at most, do not need registration and insurance and therefore do not have to carry a number plate at all.

2.2.6 Technical equipment

According to §16 road traffic registration regulations (StVZO) all vehicles registered to public road traffic have to correspond to the rules of the road traffic registration regulations (StVZO) with regard to characteristics and technical equipment. The following rules are of special interest for the Segway: the ones concerning the braking and lighting facilities such as headlight, rear light, stop light, reflector, blinker, alarm device, rear-view mirror, speedometer, seats, steering facility, tyre equipment as well as first-aid-equipment.

Braking facilities

According to §41 (1) road traffic registration regulations (StVZO) motor vehicles must possess two independent brake devices or one brake device with two different and independent operating facilities. Motor vehicles with the exception of motor cycles have to reach a medium full delay of at least 5.0 m/s^2. If the motor vehicle had a construction based maximum speed of 25 km/h, at most, a medium full delay of 3.5 m/s^2 is sufficient. According to §65 road traffic registration regulations (StVZO) all other vehicles have to be equipped with an enough powerful brake, which is easy to handle and does not damage the roadway. Bicycles have to possess two independently operating brakes.

Technical lighting facilities

According to §50 road traffic registration regulations (StVZO) motor vehicles have to be equipped with two white headlights, which illuminate the roadway. For motor cycles, motor vehicles up to 1 m width and motorized wheel chairs one headlight is sufficient. If the motor vehicles reached a construction based maximum speed of 8 km/h, at most, a white reflector is sufficient instead of the illuminating headlight. When the full beam is switched on, the low beam must continue to burn and in a distance of 100 m the full beam must still possess a luminous power of 1 lux. For motor cycles the luminous power is 0.5 lux, if they have not more than 100 cm^3 swept volume it is 0.25 lux.

According to §50 (6a) road traffic registration regulations (StVZO) mofas, small motor cycles and motor-assisted bicycles have to possess only one headlight for permanent low beam, which reaches a luminous pow-

er of 1 lux in a distance of 25 m. The rated power of the incandescent lamp must be 15 watt. According to §67 road traffic registration regulations (StVZO) bicycles must be equipped with a white headlight and a white rear light. The dynamo of bicycles must have a rated power of 3 watt with a rated voltage of 6 volt; a battery can support the dynamo.

According to §39 road traffic registration regulations (StVZO) motor vehicles with the exception of motor cycles must have a reverse gear, according to §52a road traffic registration regulations (StVZO) a white rear light must illuminate the backward roadway, if the reverse gear is operating. Rear lights are not required for motor cycles and motorized wheel chairs, too.

According to §53 road traffic registration regulations (StVZO) motor cycles have to be equipped with two sufficiently light, red rear lights as well as with two stoplights, which have to irradiate the rear lights. Motor cycles without sidecar need only one rear light; and only one stop light is registered. Stoplights are also not necessary for wheel chairs and motor cycles with a construction based maximum speed of 50 km/h, at most. Furthermore according to §53 (4) road traffic registration regulations (StVZO) two rear lights are necessary on the back side of motor vehicles, motor cycles without side-car need only one rear light. According to §67 (4) road traffic registration regulations (StVZO) bicycles need one red rear light at the back side and at least one red rear reflector, all other vehicles need one red rear light and two rear reflectors according to §66a road traffic registration regulations (StVZO).

According to §54 road traffic registration regulations (StVZO) motor vehicles have to be equipped with in pairs attached blinkers of yellow, 1.5 hertz (+/-0.5 hertz) pulsating light. This is not necessary for open wheel chairs, light motor cycles, small motor cycles and motor-assisted bicycles. Other vehicles, too, need no blinkers.

Alarm device

According to §55 road traffic registration regulations (StVZO) motor vehicles must have one alarm device at least, to signal other traffic participants – without frightening them – the approaching vehicle. This can be hooters or horns, which do not produce a melody. According to clause 6 mofas need at least one bell with a clear sound. §64a road traffic registration regulations (StVZO) prescribes a bell with a clear sound for bicycles and sledges.

Rear-view mirror

According to §56 road traffic registration regulations (StVZO) motor vehicles must be equipped with mirrors, which help the driver to observe the backward and sideward traffic. According to clause 4 mirrors are not necessary for open electric carts and multi lane motor vehicles with a construction based maximum speed of 25 km/h, at most, and according to §66 road traffic registration regulations (StVZO) for all other vehicles, which are no heavy transport vehicles.

Speedometer

According to §57 road traffic registration regulations (StVZO) motor vehicles have to be equipped with a speedometer, which is fixed in the drivers direct field of vision. The speedo is not necessary for motor vehicles with a construction based maximum speed of 30 km/h at most, or if a calibrated tachograph is built in.

Seats

From a construction based maximum speed of 25 km/h onwards all passenger motor cars, busses and motor vehicles used for the transport of goods have to be equipped with seats, seat anchoring and safety belts.

Steering facility

According to §38 road traffic registration regulations (StVZO) the steering facility must guarantee an easy and safe steering of the vehicle.

Tyre equipment

§36 road traffic registration regulations (StVZO) demands that all motor vehicles must generally be equipped with pneumatic tyres and that over the whole width the tread

	Passenger motor car	Light motor vehicle	Wheel chair	Motor cycle	Light motor cycle	Small motor cycle	Mofa	Light mofa, bibycle with auxiliary motor	Bicycle
Wheels	4	4	4	2	2	2-3	2	2	2
Swept volume	–	up to 50 ccm	–	more than 50 ccm	more than 50 ccm up to 125 ccm	up to 50 ccm	–	up to 30 ccm	–
Rated power	–	up to 4 kW	–	–	less than 11 kW	–	–	up to 0,5 kW	–
Maximum speed	–	up to 45 km/h	up to 15 km/h	more than 45 km/h	–	up to 45 km/h	up to 25 km/h	up to 20 km/h	–
Motorization	electric or combustion motor	electric or combustion motor	electric motor	electric or combustion motor	electric or combustion motor	electric or combustion motor	electric or combustion motor	electric or combustion motor	not motorized
Others	up to 3.500 kg width up to 250 cm	less than 350 kg	up to 300 kg, one seatwidth up to 110 cm	width up to 200 cm	width up to 200 cm	width up to 100 cm	width up to 100 cm	width up to 100 cm up to 30 kg	–
Motor vehicle acc. to StVG	✓	✓	✓	✓	✓	✓	✓	✓	×
Compulsory registration	✓ for v_{max} > 6 km/h	× acc.to §18 (2) StVZO	× acc.to §18 (2) StVZO	✓ for v_{max} > 6 km/h	× acc.to §18 (2) StVZO	× acc.to §18 (2) StVZO	× acc.to §18 (2) StVZO	× acc.to §18 (2) StVZO	×
Compulsory drivers licence (dl)	✓ dl class B	✓ dl class S	×	✓ dl class A	✓ dl class A1	✓ dl classes M, S	× Mofa-test certificate.	× Mofa-test certificate	×
Compulsory insurance	✓ for v_{max} > 6 km/h	✓ for v_{max} > 6 km/h	✓ for v_{max} > 6 km/h	✓ for v_{max} > 6 km/h	✓ for v_{max} > 6 km/h	✓ for v_{max} > 6 km/h	✓ for v_{max} > 6 km/h	✓ for v_{max} > 6 km/h	×
Compulsory number plate	✓ official number plate	✓ insurance indicator	✓ insurance indicator	✓ official number plate	✓ official number plate	✓ insurance indicator	✓ insurance indicator	✓ insurance indicator	×
Compulsory wearing of helmet	×	×	×	✓	✓	✓	✓	×	×
Brakes	2 independent brakes	2 independent brakes	2 independent brakes	2 independent brakes	2 independent brakes	2 independent brakes	2 independent brakes	2 independent brakes	2 independent brakes
Full delay	at least 5,0 [3,5] m/s^2[vmax <= 25 km/h]	at least 5,0 [3,5] m/s^2[vmax <= 25 km/h]	at least 3,5 m/s^2	–	–	–	–	–	–
Parking brake	1 brake device	1 brake device	1 brake device	×	×	×	×	×	×
Head light	2 white head lightsvmax up to 8 km/h:2 white lights	2 white head lights.vmax up to 8 km/h:2 white lights	1 white head lightvmax uo to 8 km/h:1 white light	1 white head lightvmax up to 8 km/h:1 white light	1 white head lightvmax up to 8 km/h:1 white light	1 head light for permanent low beam, 1 lx in 25 m	1 head light for permanent low beam, 1 lx in 25 m	1 white head lightvmax up to 8 km/h:1 white light	1 white head light, at least 3 W, 6 V
Luminous power full beam in 100 m	1,00 lx	1,00 lx	no full beam necessary	0,25 lxfrom 100 ccm 0,5 lx	0,25 lxfrom 100 ccm 0,5 lx	no full beam necessary	no full beam necessary	no full beam necessary	no full beam necessary
Rear light	✓	✓	×	×	×	×	×	×	×
Tail light	2 red lights	2 red lights	2 red lights	1 red light	1 red light	1 red light	1 red light	1 red light	1 red light
Stop lights	2 red lights	2 red lights	×	1 red light	1 red light	×	×	×	×
Rear reflector	2 red reflectors	2 red reflectors	2 red reflectors	2 red reflectors	2 red reflectors	2 red reflectors	2 red reflectors	2 red reflectors	1 red reflector
Blinker	✓	✓	not if open	✓	×	×	×	×	×
Alarm device	✓	✓	✓	✓	✓	✓	at least bell	at least bell	bell
Reverse mirror	✓ for v_{max} > 25 km/h	✓ for v_{max} > 25 km/h	✓	✓	✓	✓	✓	✓	×
Speedometer	✓ for v_{max} > 30 km/h	✓ for v_{max} > 30 km/h	×	✓	✓	✓	✓	✓	×

Figure 8: survey of possible legal classifications for motor vehicles

must have profiles or notches with profile depth of at least 1.6 mm on ¾ of the tread. For motor-assisted bicycles, small motor cycles and light motor cycles a profile depth of at least 1 mm is sufficient. Up to a speed of 25 km/h rubber tyres are permitted, too.

First-aid equipment

According to § 35h (2) road traffic registration regulations (StVZO) all motor vehicles have to be equipped with first-aid-material according to DIN 13 164 standard. However motor vehicles with a maximum speed of 6 km/h, wheel chairs or motor cycles do not need the first-aid-equipment.

2.2.7 Compulsory wearing of helmet

§ 21a (2) road traffic registration regulations (StVO) requires that the riders of a motor cycle and the co-riders have to wear helmets while riding. As an exemption riders of light mofas do not need to wear a helmet while riding. Riders of other devices, too, such as bicycles or of other means of transportation, do not need to wear a helmet in Germany.

2.3 Spread of the Segway all over the world and experience of its use

In 2001, the Segway has been presented as a device that should revolutionize the culture of mobility. In November 2002, the sale of the device began, in the start the Segway had only been sold in the USA and exclusively by amazon.com. Meanwhile the Segway is sold into many countries worldwide. In some countries however a classification of the Segway into the local road traffic regulations and road traffic registration regulations is not easily possible, that is the reason why the registration procedures usually need a certain amount of effort and time. Now, four years after the launch the Segway is registered in many countries, partly its specific characteristics are taken into consideration very differently.

The Segway was designed as an »enrichment« of the pedestrian; Kamen speaks of the »empowered pedestrian«. Therefore it had been tried to design the Segway in such manner that it is almost as broad as the shoulders of a normal man, that it is as manoeuvrable as a man and that it can move approximately in the same areas. According to design and construction the device has therefore been built for use in pedestrian areas, the manufacturer did not intend an interaction with motor cars on traffic roads.

Because of the grading of the maximum speed with the different keys (see chapter 1.1. »Device«, page 3), an adapted speed limit of the vehicles is generally possible.

2.3.1 Spread and licensing situation

USA

In June 2002, before the sale of the Segway started widely, the US-Senate passed a federal law that made a difference between the Segway and other devices and defines the Segway as EPAMD »Electric Personal Assistive Mobility Device«. This law allows the general use of Segways on sidewalks and private grounds, but leaves the decision on further regulations, including prohibition, up to the single states and local authorities.

In almost all federal states there are meanwhile more detailed regulations concerning the use of the Segway (in the map blue). In 12 of the 51 federal states the use of the Segway is unrestrictedly permitted to sidewalks, cycle tracks and streets. In 43 federal

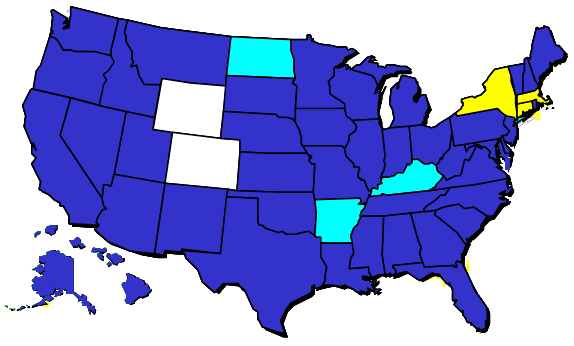


Figure 9: regulations for the Segway in US-federal states

(Dark blue: use of the Segway regulated and allowed, light blue: usage tolerated, no regulations or no mandatory regulations, yellow: ongoing legal process, white: law to be passed in 2006)

State: October 2005
Source: Segway Llc.

states the Segway is permitted to sidewalks with three of them limiting the maximum speed and in 30 federal states to cycle tracks. 18 federal states allow the unrestricted use on traffic roads, nine federal states allow the use only on roads with speed limit (20-45 mph, which is about 32-72 km/h) and ten federal states grant an exceptional use in such cases where no sidewalk or cycle track exist or pedestrians and bicyclists are permitted to traffic roads. An obligation to wear a helmet is valid in nine federal states, in eight of them only for persons under age. In 13 federal states the minimum age for riding a Segway is 16 years. In Connecticut, Rhode Island, Massachusetts and New York regulations should be passed in 2006.

Europe

After the launch in the USA Segway Llc. is preparing the registration process for using the Segway in public spaces, in other countries, above all in Europe. France, Greece, Italy, Austria, Portugal, the Czech Republic and Hungary have set the general conditions for using the Segway in public spaces, in Europe.

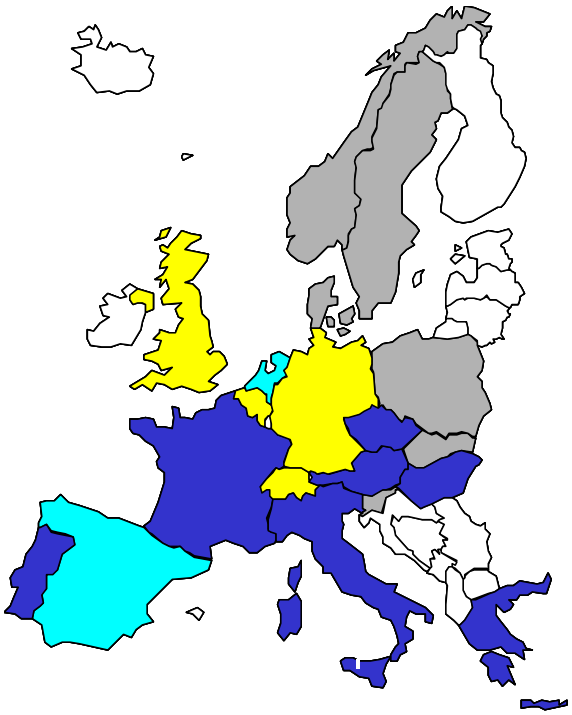


Figure 10: regulations for the Segway in Europe

(Dark blue: use of the Segway regulated and allowed, light blue: usage tolerated, no regulations or no mandatory regulations, yellow: ongoing legal process, grey: legal process in view

State October 2005
Source: Segway Llc., with alterations

The kinds of registration are as manifold as in the USA:

- In Austria, according to § 2 (1) Z. 22 of the road traffic regulations (Straßenverkehrs-Ordnung) and § 1 (2a) of the motor car traffic regulations (Kraftfahrgesetzes) the Segway is regarded as electric driven bicycle without any further restrictions and therefore its use is limited to cycle tracks.
- In the Czech Republic, the use of the Segway is permitted by ministry decree to sidewalks with a maximum speed of 5 km/h and to all other traffic areas with a maximum speed of 30 km/h.
- In Greece, the Segway is according to ministry decree no vehicle and can therefore correspondingly be used on sidewalks.
- In Portugal as well, the Segway is according to ministry decree no vehicle and can therefore correspondingly be used on sidewalks.
- In Hungary, the Segway is according to ministry decree no vehicle and can therefore be used on sidewalks at walking speed.
- In Italy, during a not further defined test phase, the use of the Segway is permitted to sidewalks at walking speed, to cycle tracks at maximum speed of 20 km/h.
- In France, during a not further defined test phase, the use of the Segway is permitted to sidewalks at walking speed.
- In Spain, the legal basis is unclear; the now applied interpretation tolerates the use of the Segway on sidewalks at ‘walking speed.
- In the Netherlands, the legal basis is unclear, the police tolerates the use of the Segway with speed of 6 km/h only on cycle tracks, if the rider was at least 16 years of age, possessed a riders licence for mopeds and a corresponding insurance.

In Belgium, Great Britain and Switzerland like in Germany the classification of the Segway is being discussed by the appropriate authorities, until the end of this norm finding procedure the Segways use is not permitted to public spaces. In Belgium, it was publicly announced that the government will pass enabling legislation in 2006.

Federal state	Permitted to			Compulsory helmet	Age restriction	Pedestrian laws	In community responsibility
	Sidewalks	Cycle tracks	Roads				
Alabama	✓	✓	✓	–	–	–	–
Alaska	✓	✓	✓	–	–	–	✓
Arizona	✓	–	if no sidewalks exist.	–	16	✓	–
Arkansas	–	–	–	–	–	–	–
California	✓	✓	✓	–	–	✓	✓
Colorado	–	–	–	–	–	–	–
Connecticut	–	–	–	–	–	–	–
Delaware	✓	✓	on roads with max. 30 mph	if under 16	–	–	✓
District of Columbia	✓ not in business area	–	–	–	16	–	–
Florida	✓	✓	on roads with max. 25 mph	if under16	–	–	✓
Georgia	✓	–	on roads with max. 35 mph	if under16	16, if using roads	✓	✓
Hawaii	✓ max. 8 mph	✓	✓	–	16	–	✓
Idaho	✓	✓	✓	–	–	✓	✓
Illinois	✓ max. 8 mph	✓	if pedestrians are permitted	–	–	✓	✓
Indiana	✓	✓	✓	–	–	–	✓
Iowa	✓	✓	–	–	16	–	✓
Kansas	✓	–	✓	–	–	✓	–
Kentucky	–	–	–	–	–	–	–
Louisiana	✓	✓	on roads with max. 25 mph	–	–	–	✓
Maine	✓ max. 5 mph	✓	on roads with max. 35 mph if no side-walks or cycle tracks exist.	–	–	–	✓
Maryland	✓	–	on roads with max. 30 mph if no side-walks or cycle tracks exist.	if under 16	–	–	✓
Massachusetts	–	–	–	–	–	–	–
Michigan	✓	–	on roads with max. 25 mph	–	–	–	✓
Minnesota	✓	✓	on roads with max. 35 mph if no side-walks exist..	–	–	✓	–
Mississippi	✓	✓	where bicycles are permitted	–	–	–	–
Missouri	✓	✓	on roads with max. 45 mph	–	16	✓	✓
Montana	✓	✓	✓	–	–	–	✓
Nebraska	✓	✓	without main roads and highways	–	–	–	–
Nevada	✓	✓	–	–	–	✓	✓
New Hampshire	✓	–	✓	–	–	✓	✓
New Jersey	✓	✓	✓	✓	16	–	✓
New Mexico	✓	✓	✓	–	–	✓	–
New York	–	–	–	–	–	–	–
North Carolina	✓	✓	on roads with max. 25 mph	–	–	✓	✓
North Dakota	–	–	–	–	–	–	–
Ohio	✓	✓	✓	if under18	14	–	✓
Oklahoma	✓	✓	✓	–	16	✓	✓
Oregon	✓	✓	✓	–	–	–	✓
Pennsylvania	✓	–	✓	if under 12	–	–	✓
Rhode Island	✓	✓	where bicycles are permitted	–	16	–	✓
South Carolina	✓	–	if no sidewalks exist.	–	–	–	✓
South Dakota	✓	–	–	–	–	✓	✓
Tennessee	✓	✓	✓	–	–	–	–
Texas	✓	✓	on roads with max. 30 mph if no sidewalks exist.	–	–	–	–
Utah	✓ if bikes are permitted	✓	on roads with max. 35 mph	if under 18	16	–	✓
Vermont	✓	✓	–	–	16	✓	✓
Virginia	✓	–	on roads with max. 25 mph if no sidewalks exist.	if under 15	14	–	✓
Washington	✓	✓	✓	–	–	–	✓
West Virginia	✓	–	✓	–	–	✓	–
Wisconsin	✓	–	on roads with max. 25 mph	–	–	–	✓
Wyoming	–	–	–	–	–	–	–

Figure 11: survey of the individual regulations in the US-federal states, state October 2005
Source: Segway Llc.

2.3.2 Experience in using the Segway

After launch companies and institutions formed the main target group of the Segway. It was expected that mail distribution-, security- and police services as well as companies with extended works premises and - halls were much interested, because for them, due to higher number of pieces, the still high price would not be so important as for single buyers. A lot of reasons may explain, why the sales figures did not meet the ambitious expectations, one of them being the unclear situation of registration to public spaces in many countries.

Today, the marketing strategy aims more at private clients. Due to the use of the Segway on fairs and sight seeing tours, the Segway-rental service on central places of cities and airports and the clever presentation in the media, the novel device experiences a greater presence in public consciousness.

Meanwhile it is unofficially estimated that 15.000 to 20.000 devices have been sold; the majority of them are used in the USA. Thats why most user statements and experience to the Segways every day use come from the USA. Reliable information on long-term use of the Segway cannot yet be made, because the devices presence on the market is still too short.

The use of the Segway

Experiences are reported on different private websites and platforms like the »Segway Chat« *[see http://www.segwaychat.com/ from November 1, 2005]* and tips and advices for the handling are communicated. In discussions the pro and contrapositions often collide: persons who are in favour and curious of modern technology use the device with great enthousiasm *[see http://www.segamerica.org/ from November 1, 2005]*, and pragmatists, who do not see an opening for the Segway in the transport system and therefore reject it for being unnecessary or a mere fun device *[see http://www.segwaychat.com/topics/667-segway.htm and http://www.walksof.org/segways/howTo.htm from November 1, 2005]*.

Often cited disadvantages of the Segway are: high weight and the small range because of the limited capacity of the accumulators. Some questions concerning the handling are difficult, too: For use on traffic roads the Segway is often thought to be too slow, for use on sidewalks too fast, respectively its main advantages such as manoeuvrability, speed cannot be sufficiently used. It is often criticized that the parking stand breaks too easily and that only with troubles the Segway can be fixed at bicycle stands. Although the Segway could show its capability to close travel chains, the situation of its transport in the public means of transport is often legally unclear. It is discussed intensively, whether for short distances the Segway could replace a car (as is intended by the US-American manufacturer) or whether it competes with bicycling and walking. The Segway allows being fast en route, almost without waiting periods and without problems to find a parking place - in comparison to the car this is considerably time saving.

The Segways advantages are its manifold potential for use beside public spaces and its environmental protective use due to low-emission. The Segway could be of assistance for people who cannot walk properly or for persons suffering from multiple sclerosis in every-day-life and give back some of their former mobility and quality of life. It has often been positively mentioned that riding the Segway causes almost no noise and that the noise and emission pollution are very low.

With regard to the technical equipment the lack of a speedo is occasionally mentioned, also the lack of signalling facilities as well as the unfavourable position of the warning light for battery load. Meanwhile accessories shops of the manufacturer offer lighting and locks.

In 2003 there was a recall action of Segways sold in the USA, because the software run falsely and the safety of the Segways could not longer be guaranteed. This problem is solved for the new generation of Segways.

Accidents

The number of known accidents with the Segway is small. No accident with lethal ending occurred; generally there were mild injuries or fractures. The media reported re-

peatedly about one policeman from Atlanta, USA, having »the first known Segway accident«. The officer fell, as he wanted to pass the curb, separating the sidewalk from the road. He injured his knee. This like other known accidents seem to be caused either by the riders false estimation of the situation or terrain or by overestimation of the devices technical potential or the riders skill. In no case the accident happened because of an unexpected conflict with other road users or of the devices technical failure. Nevertheless in some states of the USA this led to a prohibition to use the Segway on sidewalks because of the potential risk for accidents with uninvolved passers-by and because of the relative speed difference. Most prominent example is San Francisco, where different interest groups have intensively discussed the question and the use of the Segway on sidewalks has meanwhile been prohibited *[http://www.walksf.org/segways/ from November 1, 2005]*; nevertheless the Segway is allowed to use on cycling facilities and on roads.

3 Empirical data

As already presented in chapter 1.6 »Methods and procedures«, page 5, during the three-months-pilot scheme data have been collected on multiple levels to review the main conditions, under which a use of the Segway in public can be regulated:

- Comparative test riding an a circuit with braking tests
- Video control with video conflict analysis
- Riding recorders
- Interviews with the participants of the pilot study
- Telephone hotline

3.1 Participants

The participants are employees of the Saarbrücken patrolling District Police and of Neunkirchen Municipal Public Affairs Office. All of them participated voluntarily in the pilot trial.

No		Age	Gen-derl.	Left-handed	wears glasses	Health problems	Used means of transportation	Sports	Frequency of sports	Segway was known
1	SB	40	male	no	yes	-	own car, bicycle, walking, motor cycle, - scooter	bicycle, inline skating	sev. times per week	-
2	SB	43	male	no	no	-	own car, bicycle, walk-ing, public means o. transportation	bicycle, skiing, foot ball	sev. times per week	heard/read about it
3	SB	41	male	no	no	-	own car, bicycle, motor cycle, - scooter	bicycle, skiing	sev. times per week	-
4	SB	40	male	no	no	-	own car, bicycle, walking	bicycle,tennis	sev. times per week	heard/read about it
5	SB	37	male	no	no	-	own car, bicycle, walking, motor cycle, - scooter	bicycle, skiing, inline skating	sev. times per week	-
6	SB	33	male	no	no	-	own car	bicycle	less/not regularly	-
7	SB	53	male	no	no	back problems, high-shy	own car, bicycle	bicycle, ten-nis, hand-ball, endur-ance	sev. times per week	-
8	SB	45	male	no	no	back problems	own car, bicycle, walking, motor cycle, - scooter	bicycle, walking, inline skating	sev. times per week	-
9	SB	52	male	no	no	-	own car, bicycle, walking	bicycle	sev. times per week	heard/read about it
10	NK	48	male	no	no	-	own car, bicycle, walking	dog sports	daily	heard/read about it
11	NK	45	male	no	no	-	own car	inline skating, body-building, boxing	daily	heard/read about it
12	NK	46	male	no	no	back problems	own car, walking, motor cycle, - scooter	n.n.	sev. times per week	heard/read about it
13	NK	55	male	no	yes	-	own car, walk-ing, motor cycle, - scooter	n.n.	less/not regularly	-
14	NK	50	male	yes	yes	-	own car	skiing	once a week	-
15	NK	44	male	yes	yes	Back problems	own car, bi-cycle, walk-ing	bicycle	once a week	already seen a Segway

Figure 12: survey of test persons

Neunkirchen

Six persons took part in the introduction meeting, but only three test persons regularly rode the Segway during the whole pilot period. For the non-participation the following reasons were forwarded: They did not feel well in their prominent position on the Segway and in gaining attention by using the Segway. Therefore only three persons participated in the circuit and have been questioned in the two interview rounds.

Saarbrücken

In Saarbrücken, seven persons participated in the introduction meeting, two officers were on holiday at that time, and therefore were trained later how to use the Segway. These nine test persons took part in the first interview round. Due to discomforts one officer could ride the Segway only in the first two weeks, eight officers rode the device almost regularly during the whole pilot period. Six of the eight test persons participated in the second circuit- and interview round.

In Saarbrücken, too, especially in the beginning, there was criticism amongst passers-by and colleagues. Among other things it was mentioned that the Segway was not consistent with the authority and dignity of the official function. Nevertheless all test persons continued to participate in the pilot trial.

Statistics

All eleven test persons regularly using the device were men between 30 and 55 years of age, the medium age being 44.8 years. In the beginning of the pilot project all persons were healthy and in good physical shape. In the beginning four participants indicated to suffer from back problems, no other physical discomforts were mentioned.

3.2 Test riding

Special test riding was carried out besides riding in daily practice to gain detailed statements concerning handling and safety while using the Segway in more ambitious riding situations, concerning the importance of the rider experience and the speed of successful learning.

Already in August, a couple of days before the start of the pilot study, the Segway Company handed out one Segway to the Institute for Mobility & Transport imove. Test riding on the terrain of the technical University Kaiserslautern brought important information concerning road behaviour and riders skill and with these data the general conditions of a test circuit could be determined.

It did not take long until the analysis of the legal basis for registration and the first experiences in the pilot study made it obvious that concerning the braking characteristics of the Segway more detailed information might be necessary for a legal view. This led to the decision to carry out several braking tests beside the originally planned test riding. By this more detailed information could be obtained.

On a small scale, first braking tests were carried out during the first round in the circuit for comparative reasons. On a larger scale, braking test took place in September in Kaiserslautern, and were analysed by ViVA*traffic*®. During the second circuit round braking tests were carried out in a far greater number compared with the first circuit.

3.2.1 Introduction into the use of the Segway

In August 16, 2005 in Saarbrücken and in August 17, 2005 in Neunkirchen, the Segway Company introduced the device to all participants of the pilot study and carried out introductory trainings. In a theoretical part of about 1 hour, the company presented the functioning and technical basis of the device, its physical limitations and the official safety video. Afterwards the participants could use the devices for the first time. The practical introduction followed the scheme, which had been tested by the Segway Company over several years, and in which according to the riders device control the first tests are accompanied by a person who could intervene and stabilize the device at any time:

1. In the beginning the participants should only stand on the device and learn the function of balance compensation
2. Afterwards the safe mounting and dismounting was exercised, whereby the

device should be positioned on the same place, as far as possible

3. Then the riders exercised going straight on over a short distance and on the endpoints of the track they had to turn the device by 180o and go back
4. While cornering slowly on a simple slalom track the sensation of the functioning and handling of the steering was experienced
5. By riding up and down gradients several times the safe riding of slopes was trained and turning on a slope was exercised as well
6. The participants learned how to get over small, fixed obstacles such as curbs and they were once again reminded of potential risks
7. The ways of rapid braking were demonstrated, a feature not included in the normal training, but specially designed for the requirements of police officers, and again a warning of potential risks was given.

3.2.2 Comparative tests in the circuit

A circuit with a sequence of different elements was built up for the introductory training of all pilot study participants. The participants had to ride through this circuit after the training, that is to say a moment where they were no longer familiar with the device than two or three hours.

Because the special features of both training areas were not known before and the local facilities and the existing means were very different, the single stations of the circuit were designed in such way that the circuit could be built up easily and in many places. By this information were provided, which are independent of the special place. In the existing form of the circuit not all planned stations could be realized. Furthermore the motivation of the participants differed widely when it came to ride through the circuit after two or three hours riding instructions.

It was the aim of the circuit, to allow statements on:

- The riding capacities
- Handling and safety while riding the Segway
- Additionally in difficult or more ambitious traffic situations
- The speed of successful learning
- The importance of riding skill
- The road behaviour of the device in every day traffic

Behaviour and ability of the participants were tested with regard to:

- Safely riding in normal situations
- Adequate reaction to incidents in road traffic
- Reaction to unforeseen situations
- Safely reacting if braking was suddenly necessary or getting out of the way because of an altered situation
- Dealing with uneven terrain

The evaluation was done directly on the spot according to inspection and later on according to the taken video recordings.

Stations

1. Riding slalom

When riding slalom one has to combine several skills: the riders have to ride with determination, to adapt the speed continuously and to change the steering direction continuously.

Of interest was:

- Has the Segway been conducted safely?
- Was there any danger for the participants or the environment?

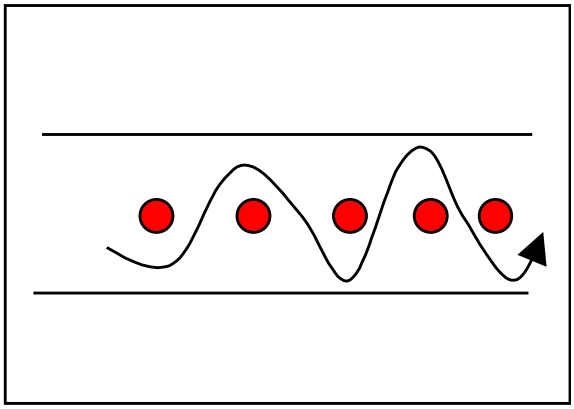


Figure 13: circuit station 1, riding slalom

2. *Going around bends on a small roadway with a notch behind obstructed view*

The participants should remain within the small, marked roadway while going around a bend. Behind a view obstruction placed in the bend a notch was created that only then became visible when the rider went around the bend. It was important to find out how the riders reacted on the obstacle and if they could keep the track.

Questions:

- Were the reactions in time?
- Were the reactions adequate?
- Was the Segway steered safely?
- Was there any danger for the riders or the environment?

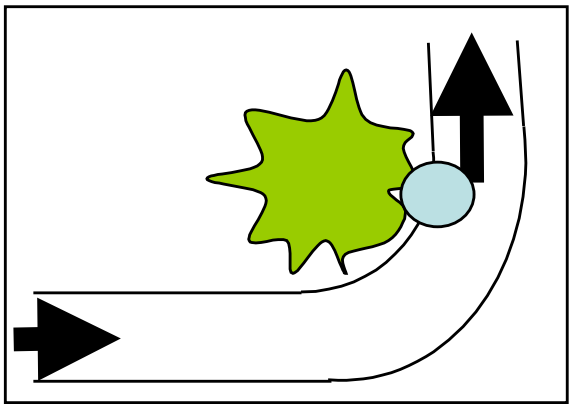


Figure 14: circuit station 2, going around bends with a notch behind obstructed view

3. *Obstacles on the roadway, gathering of people*

The rider had to pass stable and mobile obstacles (gathering of people) that were placed on the marked roadway. It was closely looked at whether and how the rider could make his way around the obstacles, with which speed he was riding, how coordinated was his sequence of action as well as to what extend there were dangers for the rider and others.

Questions:

- Was the Segway steered safely?
- Were the reactions adequate?
- Was there any danger for the passers-by?

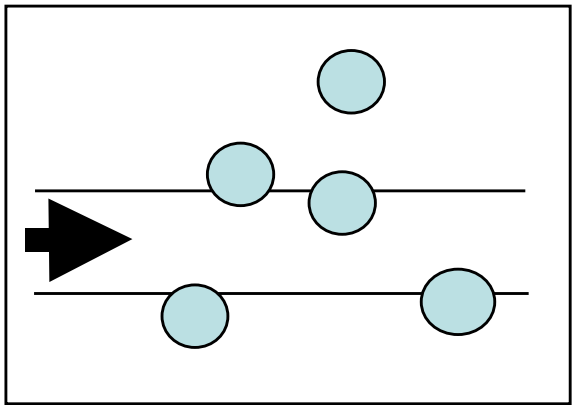


Figure 15: circuit station 3, obstacles on the roadway, gathering of people

4. *Practice test – opening of doors from the Segway*

The opening of a door while riding the device should provide insights whether and how the rider is able to carry out further activities apart from steering the Segway, which already requires physical efforts, how much these activities could adversely affect the steering and to what extent they could bear risks for the rider and other people. This station was of special interest for riding in narrow areas such as buildings or sidewalks.

Questions:

- Could the Segway adequately and safely bee steered?
- Was there an adequate reaction towards the obstacle?
- Could the door be opened without problems?

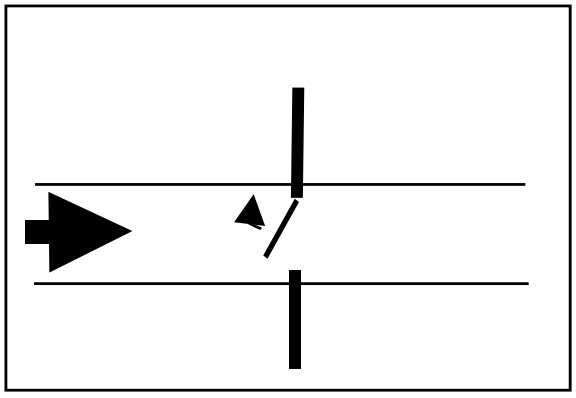


Figure 16: circuit station 4: opening of doors

5. *Changing grounds – different surface coverings*

When riding smoothly on planks or uneven terrain it was interesting to know how and to

what extent the rider could safely keep the track and the balance, how extensive was the effort for corrections and to what extent there was any danger for the rider or other persons.

Questions:

- Was there an adequate reaction towards the danger?
- Could the Segway be ridden safely?

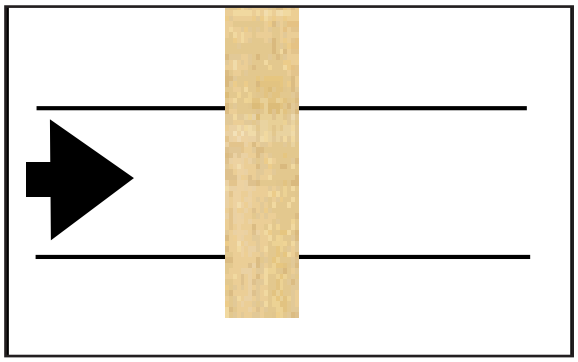


Figure 17: circuit station 5: changing grounds

6. *Combination tests: slopes, uneven terrain and bends*

Two difficult situations should be combined: for example riding downhill, on uneven terrain, in a narrow bend or with an obstacle/notch. It was closely looked at how safely the device was steered, if the track was kept and how the riders reacted when confronted with a number of requirements; it was also looked at whether there was any danger for the rider or other people.

Questions:

- Was the Segway steered safely?
- Could the track guide be followed?
- Was there any danger for the rider or the environment?

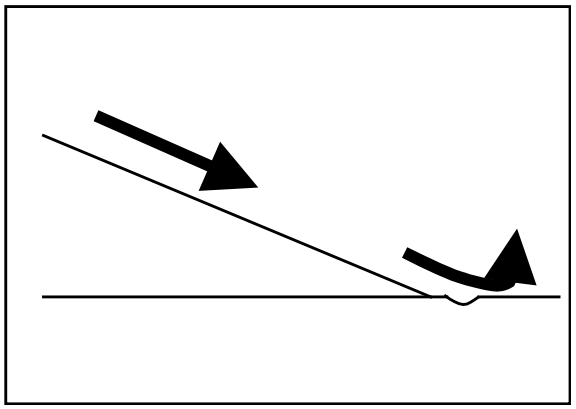


Figure 18: circuit station 6: combination test

First circuit round

The first circuit round took place after the introduction into the handling of the units, in August 16, 2005 in the Saarbrücken Police School, and in August 17, 2005 in Neunkirchen at the fairground. In Saarbrücken, seven test persons had to go twice through the stations 1 to 6 and to do braking tests; in Neunkirchen six persons passed twice the stations 1, 2, 5 and 6 and did braking tests, too.

In beforehand, the participants had been told what the circuit was made for and that no «competition" was held who is riding best through the circuit. The tracks were marked and the participants had to ride between the marks, the single stations were

Figure 19: braking test

Figure 20: demonstration of the process of braking

video documented. Each participant went through each station twice or three times.

Second circuit round

The second circuit round took place with all participants from Neunkirchen and Saarbrücken, in the Saarbrücken Police School, in December 5, 2005.

All participants went through many of the stations they had done in the first round satisfactorily well after a two or three hours practice. Due to a three months riding practice these stations were not built up in the second circuit, however those stations were built up, which led to considerable problems during the first circuit. This should allow insights into the learning process, the gaining of riding experience and the importance of riding exercise on specific difficult tasks.

The stations 1 and 6 had to be passed and braking tests were carried out. Six participants from Saarbrücken and three from Neunkirchen went through the circuit three times. The braking tests played a much greater role in the second round than originally assumed (see above).

Meanwhile it had been considered to carry out the second circuit round and the corresponding braking tests on the ADAC-test ground near Saarbrücken. There, different ground conditions were existent as well as a watering and speed-measuring device. This possibility could not be realized because of time problems – the earliest time at which the terrain was accessible was December 14, 2005.

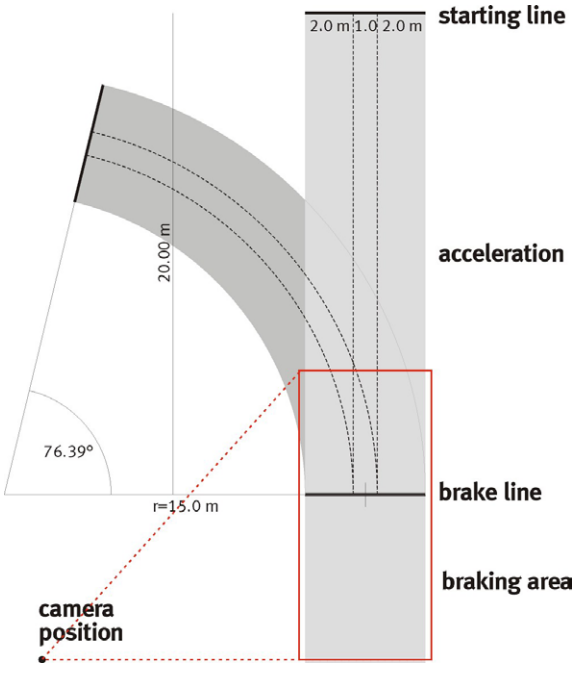


Figure 21: test set up of the braking tests

3.2.3 Additional braking tests

In August 23 and 24, 2005 on the parking place of the Technical University of Kaiserslautern, additionally to the circuit braking tests were carried out under defined conditions and with suitable camera positioning. Here the unit used was the one given to the Technical University for accompanying and evaluating the pilot project. This should lead to more detailed information on the process of braking, the stopping distance, the medium braking delay and application safety during the stopping process, especially when stopping very suddenly. The tests were video controlled and evaluated by a special software. The program allows an exact determination of the speed at the stop line, of the braking delay and the stopping distance by the video pictures.

The Segways process of braking

Backward shifting of the centre of gravity behind the imaginary axis between the two wheels stops the Segway. Gyroscopes measure the extent of shifting and the steering electronics influence the electric motors in such way that the platform for standing comes again under the gravity. If the Segway rider continues to lean backwards the ride is delayed by the gravity balancing of the Segway until it reaches zero. After that the Segway starts to move backwards.

Because of safety reasons accumulators, tilt sensors, steering electronics and motors are laid out redundantly, to guaranty that the device does not fail suddenly but can be safely stopped even if components do not work.

Because of the special character of the braking device, in which the rider does not only handle the braking device but is in a way part of it, it is hardly possible to examine the braking behaviour only technically. The riding skill of the Segway rider influences the braking behaviour largely.

Basically there are three ways to brake:

1. Leaning backwards with shifting the gravity backwards
2. »Sitting down« a strong backwards shift of the gravity by stretching the buttocks
3. Putting down of one foot to the ground behind the device and pulling near the steering grip so that the unit quickly speeds up into the opposite riding direction.

The resulting braking delay increases from version 1 to 3, as a rule, and version 3 above all needs a much greater skill in handing the device. By three parts resting upon the surface (one foot, two wheels) this version is statically more stable. Braking risks are:

1. By leaning back too fast and too strong the system man-Segway tilts too fast backwards behind the gravity so that the steering electronics and the negative impulse of the electric motors cannot correct this manoeuvre fast enough. With the consequence that the rider comes to fall backwards.
2. Too strong backwards shifting of the gravity and the resulting strong compensation movement of the Segway can provoke a counteracting correction and build up an oscillation, which hardly can be controlled.
3. A higher potential loss of control than in version 1. The speeding up backwards has to be very short, otherwise the forward ride disappears and the Segway is moving backwards very fast. Thereby the Segway can strongly hit the riders legs. Greater risk of losing grip by fewer weight of the unit device/rider.

Decisive factors for braking are therefore:

- Good performance of the eddy-current-brakes (electric motors) in combination with the dynamic balancing system of the Segway (technical factors)
- Controlled handling of the Segway by the rider in this extreme situation (human factors)

Only with a good interplay of both factors a short and safe stopping is possible.

Test set up

From the starting line the acceleration track up to the maximum speed was 20 m. The maximum speed was reached if the speed limiter interfered perceptibly while using the Segway with the red key. The maximum speed should be kept as far as to the stopping line. The surface was made of such paving stones as are common on sidewalks and pedestrian precincts. The surface was relatively even and mostly free of grit, sand, leafs or other loose substratum. The test set up comprised also a bend approach to a stopping line with a radius of 15 m and an acceleration track of again 20 m.

Seven persons of the imove –team took part in the braking tests. These persons had different skills in handling the Segway. Six persons were almost inexperienced, they had used the Segway less than one hour, and two of them had only gone through a 10-minutes-short-introduction. These six persons are called beginners from now on. One participant had an experience in riding the Segway of about ten hours; he will be called an advanced rider.

The spot-check comprised 194 braking manoeuvres for the beginners and 40 for the advanced rider. The tests were carried out on dry tracks and by about 20 °C.

3.2.4 Comparative braking tests

The test set ups were similar in Kaiserslautern and in Saarbrücken and Neunkirchen. In August 16 and 17, 2005, during the introductory training braking tests were carried out in Saarbrücken and Neunkirchen, and at the end of the pilot study, in December 5, 2005 for all participants from Saarbrücken and Neunkirchen in Saarbrücken. In December however cornering did not take place and because of the wet ground the starting-, riding- and stopping line could not be marked by adhesive tapes but by oil crayon and was additionally equipped with course markers.

In August, during the first round of the braking tests the seven participants from Saarbrücken and the six of Neunkirchen went through the circuit twice, in December, during the second round six participants

from Saarbrücken and three of Neunkirchen rode through the test set up 15 times.

The video camera was positioned on a stand behind the stopping line because there was no suitable mast for a higher positioning of the camera.

3.3 Videorecording

At different times and on different places with a high traffic density video pictures were taken during the pilot study. The recordings were looked through, labelled with an index and whenever needed evaluated with the system ViVA*traffic*® for video conflict analysis. In the end one has information on the interaction and the conflict potential with other traffic participants.

In Saarbrücken and Neunkirchen, according to the suitability of the potential recording positions video recordings should be made on different places and at different times. The recordings should cover the whole pilot period. The exact place and the time for the recording were always directly coordinated with the leaders of both groups, Mr. Janes in Neunkirchen and Mr. Siegwart in Saarbrücken.

In the end, video recordings were made in Neunkirchen at two times and on three places and in Saarbrücken at two times and on three places.

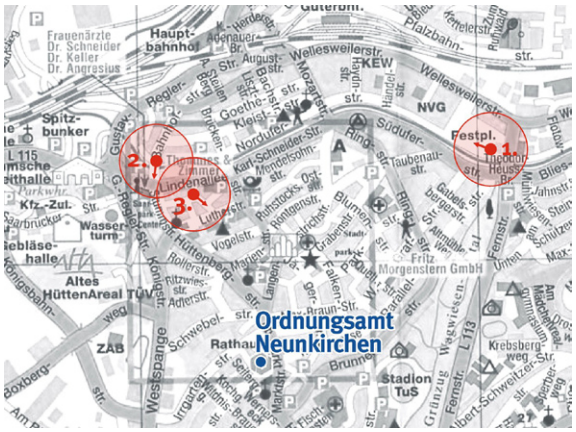


Figure 22: camera positions in Neunkirchen

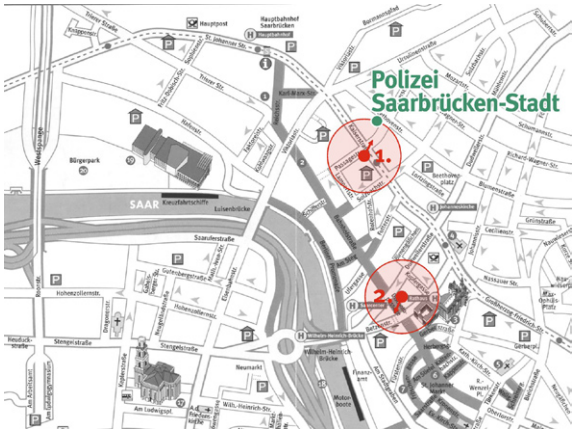


Figure 23: camera positions in Saarbrücken

3.3.1 Places

Suitable for video recording and evaluation by ViVA*traffic*® were especially places that the participants of the pilot study passed frequently with the Segway, as well as places with a high density of other traffic participants and with several, overlapping traffic flows. Based on the limitation of the exemption permit to pedestrian and bicycle traffic areas other traffic participants are above all pedestrians and bicyclists. But especially on crossing areas we find an increasing interaction with other motor cars and vehicles of the public transport systems, in Saarbrücken these were beside busses the trains of the city-tram Saarbahn. Crossings are therefore especially suited for video recording. Similar suitable are special events where a great number of visitors and actions are present on a limited area.

According to these criteria especially suitable places were:

in Saarbrücken:

- Karcherstraße/Kaiserstraße – in the Karcherstraße the Police Department Saarbrücken-City is located, all Segway riders pass this crossing (individual traffic and city tram) when going to or coming from mission
- Crossing areas along the pedestrian precinct, the Bahnhofstraße, for example the crossing Bahnhofstraße/Dudweilerstraße, Bahnhofstraße/Ufergasse, Bahnhofstraße/Viktoriastraße
- The square in front of the railway station (public transport)

All places along Bahnhofstraße and Kaiserstraße had in common that there were no suitable high masts for positioning the video camera, the cameras therefore had to be placed onto surrounding buildings.

in Neunkirchen:

- Stummplatz, in front of the Saarpark-centre,
- Stummstraße (pedestrian precinct)
- Pasteurstraße (pedestrian precinct)
- Kurt-Schumacher-Brücke, crossing area of pedestrian precinct with Linden-avenue (individual traffic and central bus stop)

The very wide mission areas of the employees of the Neunkirchen Municipal Public Affairs Office put some problems, the mission areas covering regularly not only the city but also the less crowded districts in the periphery and in parks.

Besides that certain events seemed to be especially suited, because they concentrated a great number of visitors and other traffic participants on a narrow place and they made patrolling and official presence necessary. Such events were for example the summer festival in the German-French garden, the fair in Neunkirchen or the skaters parade.

In the frame of interviews, discussions with the pilot study participants and viewing on the spot the positioning of the video cameras was agreed on.

3.3.2 Recording times

Neunkirchen

During the training program in August 17, already, Mr. Janes directed the attention to the Neunkirchen fair, which took place between August 26 and August 30, 2005. At the relatively limited area of the festival ground the Municipal Public Affairs office should care for the market stalls and patrol the place with several officers. On Monday of August 29, 2005 between 10.45 am and 3.00 pm two video cameras took pictures of two sidewalk crossings (see plan, position 1) from the roof of a low pavilion. During the whole time one Segway was used, which patrolled the festival ground.

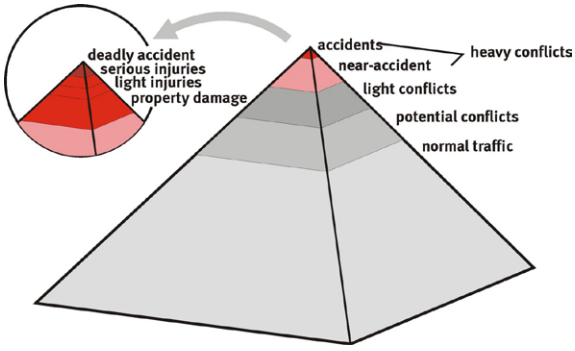


Figure 24: conflict pyramid: link between conflict frequency and conflict seriousness, own presentation according to Hydén

A second date for video recording was September 5, 2005; here also two video cameras were installed at a time. One was positioned at the Kurt-Schumacher-Brücke with view towards the Stumm-square, where the pedestrian precinct ends and a central bus stop is located (see plan, position 2). The second camera was positioned at the junction of Hammergraben-street into Pasteurstraße, also located within a pedestrian precinct. During the recording time from 10.00 am to 5.00 pm two Segways were used.

Saarbrücken

Based on the experience made with the video recording and positions in Saarbrücken as they have been demonstrated in the first interview round two crossings have been selected for video recording. A final commitment could only be made after inhabitants consented to the positioning of the cameras for one day.

The first day of video recording in Saarbrücken was October 13, 2005; pictures were taken at two positions at a time between 9.30 am and 5.30 pm. In cooperation with two local companies we could position the cameras in such way that the crossing area Karcherstraße/Kaiserstraße with part of the Saarbahn tram stop could be overlooked as well as a notch in the pedestrian precinct, the Bahnhofstraße between Dudweiler- and Betzen-street.

On the second recording day, November 24, 2005, one camera was positioned this time with view towards the crossing Bahnhofstraße/Dudweilerstraße, which had not been possible on the first recording day because of strong dazzling light.

3.3.3 ViVA*traffic*®

ViVA*traffic*® was developed because up to now sufficiently exact data could not always

be collected with regard to traffic procedures like braking, speeding up, adapting speed. Aspects of traffic safety, too, were evaluated above all by accident figures, which mostly are not up-to-date and of different quality as well as not always reflecting all relevant details of traffic behaviour.

The system ViVA*traffic*® makes it possible to measure from video pictures road distances, speed and acceleration and thereby gaining direct insights into the behaviour of traffic participants and their interaction.

ViVA*traffic*® requires inclined recording from an elevated position. It can take into consideration the resulting perspective distortion by the way of calculation, in case of ankles beneath 15° towards plane the distortion becomes so strong, that an evaluation is no longer possible. Evaluations from crossing areas are therefore well possible, evaluations of traffic incidents in long street blocks not.

In the context of this project the evaluation by ViVA*traffic*® is made in first line to measure distance, speed and speed variations in the interaction of other traffic participants with the Segway.

3.3.4 Interaction and conflict

Interaction

Interactions are adaptations of the own ways of behaviour to other traffic procedures for example in form of braking or getting out of the way. Interactions can be used as criterion for the estimation of traffic flow (comfort criterion); they also can present the first step of a conflict (safety criterion).

Conflict

A situation is then characterized as conflict, if a collision course arises between two or more traffic participants, so that the reaction of at least one traffic participant is necessary, to avoid the threatening collision. The arising of conflicts is an important criterion for the estimation of traffic safety *[see Hupfer, Christoph: Computergestütze Videobildverarbeitung in der Verkehrssicherheitsarbeit, Universität Kaiserslautern, Fachgebiet Verkehrswesen, Grüne Reihe Nr. 40, Kaiserslautern 1997]*.

3.4 Riding recorder

All Segways have been equipped with six identical voice recorders and each with a clip-on-microphone, to serve as riding recorders. This should enable the pilot study participants to give a quick, uncomplicated and timely record of the actual situation in case any special incidents occurred, while riding the Segway. The use should be very simple for the pilot study participants, written records after shift should be avoided by the employment of the technical devices.

Certain, actual incidents should be documented with the riding recorder. Among them conflicts with other traffic participants or with obstacles in the public spaces or other incidents, which led to a general loss of control over the Segway or even a fall.

How to use the riding recorder

At the beginning of the pilot study each participant received all necessary documents, among them a guideline how to use the riding recorder. The guideline contained a survey of cases in which the riding recorder should be used and a survey of the necessary information that had to be reported in such cases.

In August 16 respectively 17, 2005, after the introduction all participants were informed on the pilot study, the purpose of the riding recorders, their handling and in which situations they should be used.

For easier handling the survey of using the riding recorder was attached in weatherproof way to the backside of the voice recorder in catchwords – the this enabled the participants to go through the required information point by point while recording.

The participants of the pilot study should give a short report of:

- General information
- Kind of incident
- Reaction of the Segway rider
- Consequences
- Causes
- Others

Eventual subjective impressions should be objectified by the given, standardised points which were meant to be orientation for the protocols of the riding recorder; although all participants of the pilot study were thought to be rather objective because of their professional practice.

Even if the shift passed without problems or further incidents, the pilot study participants were asked to record name, date and a short resume after the end of the shift. For uncertainties, problems or questions the participants had the opportunity to use a telephone hotline at any time.

3.5 Hotline

As supplement and additional level to the riding recorder and the interviews provision was made right from the beginning to be addressable with a hotline via telephone or email. The hotline was established to solve actual, unexpected questions, remarks and problems of all kinds, especially to help with things, which could not be expected in beforehand. If needed the hotline should furthermore play a mediator role in case of technical or other problems with a third party.

It was expected that the majority of arising questions and problems, for which the hotline was made for, should come up in the first three weeks.

3.6 User interviews

Beside the riding recorders, which aimed at actual incidents, interviews with the participants of the pilot study were carried out in which general impressions of the devices handling and characteristics were of interest. The results of the interviews give a frame for better evaluation and understanding of the other study elements such as test riding, video recording and riding recording.

The questioning of the Segway users was effected in guided interviews, for the interviewing person there was an interview guideline. As already was the case with the test circuit, two interview rounds should provide comparisons and insights of the learning performance in handling the Segway, the first interview round being held in the first two or three weeks and the second one after the end of the pilot study. The interviews were voice recorded with the consent of the interviewed persons.

3.6.1 Times of interviews

First interview round

As planned the first round of questioning took place three weeks after the beginning of the pilot study, in September 13, 2005 in Neunkirchen and in September 15, 2005 in Saarbrücken.

In Neunkirchen, three of the originally mentioned six participants of the pilot study could be questioned, in Saarbrücken eight of the nine participants. In Neunkirchen, the other three participants of the pilot study then had not yet or almost not used the Segway, according to the team leader. In Saarbrücken, the one participant could not take part in the interview because of a whole day appointment.

Second interview round

On December 5, 2005, after the end of the pilot phase, the second interview round took place. It was carried out together with the second round of circuit in Saarbrücken and the participants of Neunkirchen also participated in the meeting.

Three pilot study participants of Neunkirchen were questioned who rode the Segway during the whole pilot period on a regular basis. Three further participants of Neunkirchen who participated in the introductory training practically did not use the devices during the pilot period. From the Saarbrücken team seven pilot study participants could be questioned, six of them having used the Segways regularly during the whole pilot study period.

3.6.2 Interview guideline

In beforehand a complex of five topics had been set up which was questioned in the interviews: handling the device, device characteristics, interactions in public spaces, feeling of safety and endangering potential as well as self-assessment of the study participants. For uniform and comparative reasons the questions in the guideline were given as multiple choice questions, as far as possible, which however in the form of the guided interview left room for further questions or comprehension questions in case of unusual or unexpected answers.

For the first interview round a question-

naire with 28 questions had been elaborated, which in several pre-tests had been examined for redundancy, logic and completeness. In these pre-tests a median duration of 35 minutes per interview was reached.

The questionnaire for the second interview derived from the first questionnaire. The focus was put on the idea that by comparing the results some information could be found on the development of the riding skills of the participants and on the importance of the riders experience. Therefore not all questions of the first round were asked again, two further questions were added. The questionnaire of the second round contained 19 questions all together, in pre-tests the median duration was approximately 25 minutes.

In practice it became clear that the planned time per interview was too short, because especially in the second interview round – there were further questions and discussions, beside the questions of the guideline. The special topics were

- The reactions of passers-by towards the devices and the participants consorting with it
- The (non)-usage of the riding recorder and the reasons for it
- Special incidents which could be of interest for the study, but were judged by the participants as not being important – touching of curbstones, short dragging along a wall, along a hall or similar incidents.

II. Interpretation of findings and results

4 Results of the empirical data

4.1 Test riding

4.1.1 Comparative circuit tests

Observation during the introduction

Contrary to the first expectations the riding skill of all participants was relatively good already after the three hour-training. The participants understood the functioning of the device already in the first three minutes and basically internalised it within the first half hour. They very quickly mastered easy riding tasks such as starting, stopping and going straight ahead. Tasks that required more complicated coordinative capacities such as riding and steering or riding and observing the environment needed more practice, but were acquired within the first hour, as a rule. The approach of the participants was partly very different and according to individual reservation and character reached from quite bold and risky to very reserved and cautious.

The first circuit round

Riding through the first circuit round with the stations

1. Slalom,
2. Going around bends on a small roadway with a notch behind obstructed view,
3. (Mobile) obstacles on the roadway,
4. Opening doors from the device
5. Changing grounds
6. Combination exercise

showed quite clearly that the riders had very quickly internalised the basic riding tasks and that complex riding situations still required a high concentration effort. At station 2 most riders reacted to the unforeseeable incident with hectic manoeuvres in order to get out of the way. Several times they falsely used the steering lever and the device went out of the way in the wrong direction. In the second round the number of riding faults was considerably smaller.

At the slalom station the riders had to continuously concentrate on the cornering and keeping track; riding slalom showed clearly the concentration requirement of inexperienced riders in complex situations: Practically all riders constantly speeded up and stopped, cornering still was jerky, and most of the riders had problems with steering changes and keeping track: several times pylons were omitted and almost every rider touched or went over one of the pylons, one or several times.

The combination exercise showed as well that inexperienced riders tend to underestimate riding situations and overestimate themselves.

Already in the first circuit round the riders had no problems with the mobile obstacles in the roadway or with the changing ground, even the opening of a door from the Segway (only carried out in Saarbrücken) was mastered, although this was a new and not an easy activity for the riders. Only in one of the 14 tests the device slightly hit the door.

It became clear that after a short riding practice the handling of the Segway in standard situations was no problem at all, reactions to unforeseeable incidents however needed a longer exercising, if the riders were not to react falsely.

Second circuit round

In comparison to the first round slalom riding had been made more difficult, the distance between the pylons was diminished from 2.50 m to 1.00 m in 30 cm-steps and the ground was a little bit wet due to the weather conditions. In comparison to the first round the riding behaviour had become obviously safer, the participants rode in an controlled but bold manner and in most cases kept the track accurately. There were no riding faults. According to the requirements of the riding situation the speed was fluently adjusted. During 27 tests the pylons were slightly touched twice.

In comparison to the first round the combination exercise had been made more difficult by a combination of bends after the slope, but all participants showed a high riding safety and the few coordination problems of the first round had completely disappeared.

The comparison of the two circuit rounds showed that after three months of riding practice the participants had a high riding competence and were able to judge well even complex riding tasks and master them. The steering of the Segway meanwhile happens unconsciously; therefore the riders could completely concentrate on their surrounding, the traffic and their duties. In case of problems all riders have adequately and systematically reduced speed.

4.1.2 Comparative braking tests

The comparative braking test are of special interest for looking at the stopping procedure, the participants handling of the task »quick stop«. A calculator evaluation is possible only at a very small extent, because the speed at the stopping line cannot be determined. The video evaluation does not present reliable values, either, because due to the low recording ankle the evaluation with ViVA*traffic*® had too high tolerances.

All participants rode quite slowly, in the first round this was due to the lack of riding skill with the Segway and in the second round because the participants felt safer when considerably reducing the speed already before the stopping line. At the stopping line the median speed was about 16 to 18 km/h. The participants even started the quick-stop test before the stopping line, thus making it necessary to add 1.0 to 1.5 m to the measured stopping distance, practically in all cases.

	First round													
	Saarbrücken					Neunkirchen								avg.
1	3,0	4,5	4,1	3,7	2,3	7,0	2,8	6,1	3,6	6,4	3,4	5,4	6,5	
2	4,9	3,8	3,9	2,4	2,2	3,4	4,1	5,5	4,5	4,1	3,8	4,2	4,3	
	4,0	4,2	4,0	3,1	2,3	5,2	3,5	5,8	4,0	5,3	3,6	4,8	5,4	4,2

	Second round													
	Saarbrücken					Neunkirchen								avg.
1	1,6	2,2	2,1	1,4	1,9	1,9		2,4	2,8	2,7				
2	2,3	2,5	1,9	1,2	1,8	1,0		3,4		2,7				
3	2,5	1,7	1,9	1,2	1,9	1,2		2,9	2,4	3,2				
4	2,5	2,1	1,9	1,3	2,1	1,4		3,2	3,4	3,3				
5	2,7	1,8	1,7	1,0	1,6	1,4		2,7	2,7	2,3				
6	2,6	1,8	2,1	0,9	1,4	1,2		3,4	3,3	2,2				
7	2,9	1,9	1,6	0,6		1,4		3,3	2,4	2,2				
8	2,5	2,0	2,0		1,6	2,0		3,6	2,3	1,8				
9	3,0	2,0	1,9	1,5	2,2	2,0		4,6	2,3	1,5				
10	3,0	1,8	2,5	1,1	1,9	2,1		3,3	2,6	1,8				
11	2,5	1,9	2,1	1,0	1,2	1,4		3,8		2,4				
12	3,4	2,0	3,3	1,5	1,5	1,4		2,6	2,5	1,4				
13	2,8	2,0	2,1	1,4	1,5			3,2	2,5	1,7				
14	2,5	2,2	3,0	2,5	1,1	1,7		3,0		1,6				
15	2,2	2,2	2,8	1,1	1,6	1,3		3,4	2,6	1,6				
	2,6	2,0	2,2	1,2	1,6	1,5		3,3	2,6	2,2				2,1

Figure 25: results of the comparative braking tests

In four of 26 cases (15.4 %) there were difficulties while stopping (oscillating, loss of control, fall) in the first round, and in the second, longer round after three months pilot study there were difficulties in 1 of 150 cases (0.7 %).

The measured median stopping distances of all participants allowed only limited conclusion when comparing round one with round two. But as a rule one can state that the stopping safety increased and the median stopping distance decreased after three months of riding practice. The braking delay therefore improved.

The three cited stopping methods (see chapter 3.2.3 »Additional braking tests - The Segways process of braking«, page 26) often merge according to the amount of experience in using the Segway. The riders often shift the gravity backwards, then after a short moment they stretch out one foot and with rising experience this moment is shortened.

4.1.3 Additional braking tests

The braking tests carried out in Kaiserslautern have been evaluated by the software ViVA*traffic*®. The video pictures brought the following data:

- *Speed at the stopping line*
  the riding speed was measured at the stopping line (start of the stopping process). To minimize the inaccuracy of the measurement the distance of 1.5 m before the stopping line was also evaluated.
- *Delay after passing over the stopping line till standstill*
  According to the formula $s = v^2/2a$ the full delay up to standstill is determined by the speed at the stopping line and the stopping distance.
- *Time till standstill of the device*
  Here the time was measured in seconds from the beginning of the stopping process to the standstill of the device.
- *Stopping distance*

Here the distance was measured in metres from the beginning of the stopping process to the standstill.

According to the above mentioned definition the measured data were related to the two groups of test riders and evaluated separately. The parameters speed, delay, stopping time, stopping distance was broken down into classes. All together in the beginners group 198 tests were carried out and 40 tests in the advanced group.

Speed

To guarantee constant preconditions for the tests the riders had to try to ride with maximum speed towards the stopping line. With regard to the height of the reached speed beginners and advanced riders did not differ much. The median value of the rides was 21.6 km/h resp. 21.8 km/h. Only the deviation of speed was a bit larger for the beginners, the experienced rider approached the stopping line with a smaller range of speed. But this was in a size that did not influence the other measurements.

Delay after passing over the stopping line

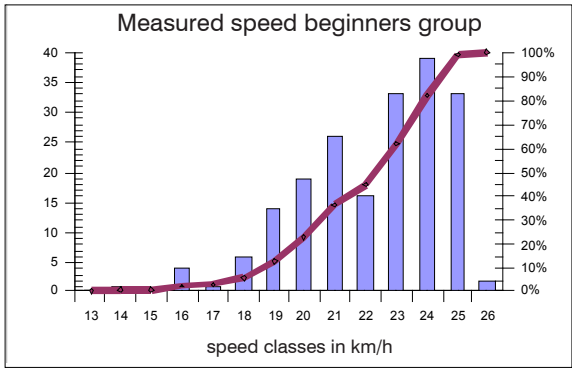
The median delay between the beginning of the stopping process at the stopping line and the full standstill had been determined by the speed at the stopping line measured by video evaluation and the stopping distance.

It is interesting to note that for the advanced riders the delay values are about 1.5 to 2 m/s² higher: the measured median delay was 5.4 m/s² for the beginners, 7.2 m/s² for the advanced rider, if one fugitive value of 16.9 m/s² for one test is not counted.

Amongst the beginners, in 14 % of all cases the minimum value of 3.5 m/s² for the braking of motor cycles was not reached, in 37 % of all cases the value of 5.0 m/s² demanded for motor cars. For the advanced riders the corresponding values were 3 % resp. 5 % of all braking tests.

Time till standstill of the device

For the advanced rider the stopping process has a duration of up to 0.5 s concern-



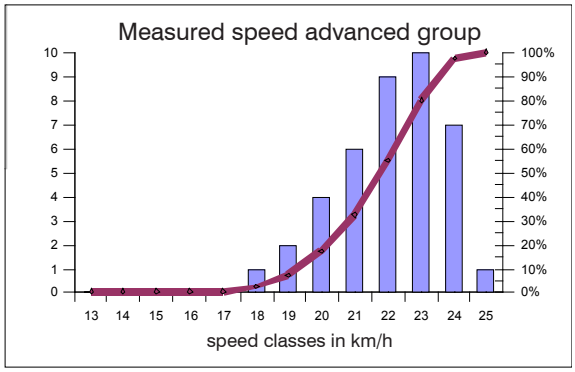
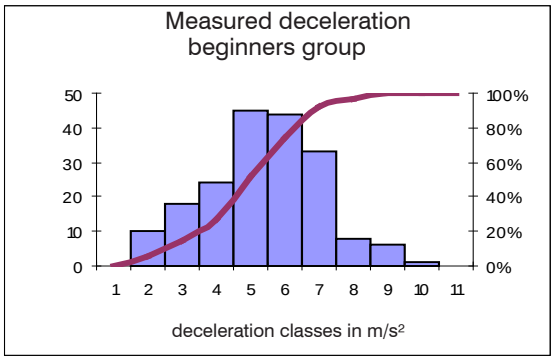


Figure 26: braking tests: measured speeds

	Beginner	Advanced rider
Braking tests	198	39
Median delay	5,4 m/s²	7,2 m/s²
Minimum delay	1,7 m/s²	4,1 m/s²
Maximum delay	9,3 m/s²	10,7 m/s²
Standard deviation	1,6	1,5

Figure 27: results of the braking tests



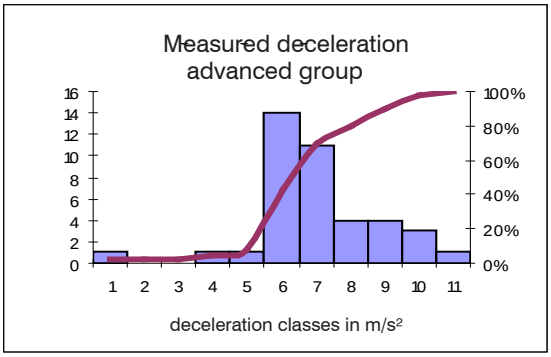


Figure 28: braking tests: measured braking delays

ing the 20 %-value, for the beginners up to 0.75 s. Concerning the 50 %-value the duration is up to 1.25 s for both groups and concerning the 80 %-value up to 1.75 s. The braking period is almost identical for both groups. Is has to be noted that for beginners very short values up to 0.5 s and for the advanced rider very long values above 2.5 s did not occur.

Stopping distance

When comparing the 20, 50 and 80 %-values here, too, the advanced rider achieved a stopping distance that was 1 m shorter than the one of the beginners. The same results are found if one compared the medium values of the measurements (advanced rider 2.55 m, beginner 3.66 m).

Problems and discussion

During the braking tests we could observe that beginners, too, were well able to achieve delays that are comparable to those of the advanced rider and are in the frame of the legal requirements for motor cycles and passenger motor cars. But often, shortly after the riders began to stop and reached the maximum delay, a sudden loss of control over the device happened. At that point the dynamic balancing system of the Segway tries to compensate the backward shift of the stopping. This leads to a oscillating of the Segway. Then the delay cannot be kept stable for the whole stopping process and has to be diminished and by that the stopping distance increases. This reaction is less vehement during the stopping process of an advanced rider.

It seems that with growing experience in handling the Segway high delays in the beginning can be transferred more easily into short stopping distances.

Result and assessment

The braking tests showed that when stopping the Segway the achieved delay performance lead to good values in average but depended clearly on the riding experience and riding skill of the rider. The braking delay values showed also a certain range of deviation, which meant that the beginners did not meet the legal requirements of 5.0 m/s² for motor cars in one third of the cases. This legal value refers exclusively to the technical set up of the brakes, but in the case of the Segway due to its special construction design the study of the technical braking performance cannot be separated

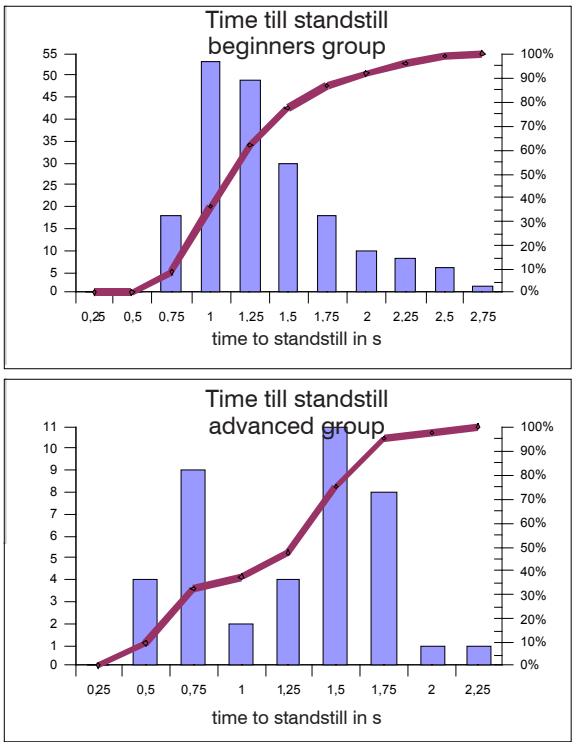


Figure 29: braking tests: time to standstill

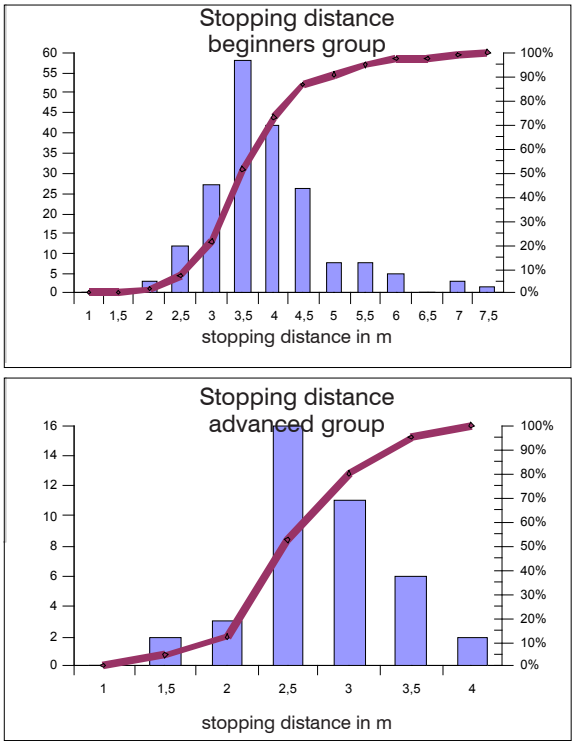


Figure 30: braking tests: stopping distance

from the riding skill of the user.

As could be seen clearly already few hours riding exercise (advanced rider) positively influence the decrease of the stopping distance (measurements) and the safety (video observations) during the stopping process. The advanced rider could stop the device safely in most cases, while the beginners obviously had considerable problems with the control of the device. The comparative braking tests with the pilot study participants further proved this fact.

During the braking test one fall happened, more information under chapter 4.6.1 »Incidents and accidents – fall during a braking test in Kaiserslautern«, page 46.

Picture 1: the pedestrian and the Segways approach the conflict area between them

Picture 2: pedestrian and Segways stop and adjust their reaction

Picture 3: the Segways give precedence to the pedestrian

Picture 4: the pedestrian crosses the conflict area in front of the Segways

Picture 5: The pedestrian leaves the conflict area and the Segways continue their ride

Picture 6: the Segways cross the conflict area

Figure 33: Example of an interaction sequence

4.2 Videorecording

We searched the video pictures of the three positions in Neunkirchen and the three positions in Saarbrücken for the passing of the Segway and indexed them. We looked through these parts of the video recording for visible interactions with other traffic participants or for obstacles in the traffic space. We then digitalized the corresponding sections for further evaluation. After that with the help of motion lines these sequences were analysed for conflict potential by the software ViVA*traffic*®.

All together seven interactions were observed, which after evaluation did not represent conflicts in the sense of definition.

The number of seven recorded interactions, of no conflict and no accident is less than expected. All together the results of the video analysis do not give rise to speculations that the Segway had conflict potential. On the contrary they support the theory backed by the evaluation of the voice recorders and the interviews that the Segway suits very well into the traffic system and that its conflict potential on bicycle tracks is comparable to the conflict potential of bicycles. On traffic areas reserved for pedestrians the Segways conflict potential is only slightly higher than that of the pedestrians due to the pilot study participants thoughtful way of riding.

4.3 Riding recorder

There were manifold expectations vis-à-vis the results gained from the riding recorder. Incidents should be documented as timely, exactly and completely as possible by a very simple way of recording. Many different incidents even if they seemed to be of less importance should be recorded, because they nevertheless could be of high importance. With other recording modalities the seemingly less important incidents would not have been recorded.

The incidents to be recorded were all exceptional situations in the normal traffic, which should provide more detailed informations on

- Interactions of the Segway with other traffic participants

Date	Time	Position	Description of the situation
5.9.05	11:39	Pasteurstraße	Start of video recording
5.9.05	13:58	Pasteurstraße	2 Segways pass the square coming up from the bottom, left, without any visible interaction with other road participants
5.9.05	14:54	Pasteurstraße	2 Segways pass the pedestrian precinct coming from the upper side in the picture. Observed interaction with a pedestrian (the Segways get out of the way)
5.9.05	15:39	Pasteurstraße	2 Segways pass the pedestrian precinct coming from the upper side in the picture. No interactions with other traffic participants observed
5.9.05	16:28	Pasteurstraße	End of video recording
5.9.05		Pasteurstraße	1 interaction observed
5.9.05	10:42	Kurt-Schumacher-Brücke	Start of video recording
5.9.05	13:50	Kurt-Schumacher-bridge	2 Segways pass the square several times coming from the right side without perceptible interactions with other traffic participants
5.9.05	13:55	Kurt-Schumacher-bridge	2 Segways pass the square coming from the front and disappear to the left side in the picture without perceptible interactions with other traffic participants
5.9.05	14:14	Kurt-Schumacher-bridge	2 Segways pass the square coming from the left side and disappear to the right side in the picture without perceptible interactions with other traffic participants
5.9.05	14:15	Kurt-Schumacher-bridge	2 Segways pass the square coming from the right side and disappear to the bottom side without perceptible interactions with other traffic participants
5.9.05	15:07	Kurt-Schumacher-bridge	2 Segways cross the square coming from the right side without perceptible interactions with other traffic participants
5.9.05	15:13	Kurt-Schumacher-bridge	Coming from the left side, 2 Segways go to a bus (control?), then go back again and disappear to the left side in the picture without perceptible interactions with other traffic participants
5.9.05	15:43	Kurt-Schumacher-bridge	Coming from the back in the picture, 2 Segways cross the square and disappear to the right side in the picture without perceptible interactions with other traffic participants
5.9.05	16:55	Kurt-Schumacher-bridge	End of video recording
5.9.05		Kurt-Schumacher-bridge	No interaction observed

Figure 31: Protocol of the video analysis of the video recordings in Neunkirchen

Date	Time	Position	Description of the situation
14.10.05		Bahnhofstraße	Start of video recording
14.10.05	11:05	Bahnhofstraße	Segway crosses the square, no interaction with other traffic participants observed
14.10.05	11:22	Bahnhofstraße	Segway crosses the square, turns to the kiosk at the end of the square, passes between two pedestrians. No interaction observed
14.10.05	11:23	Bahnhofstraße	Segway comes from the kiosk again, no interaction with other traffic participants observed
14.10.05	11:55	Bahnhofstraße	Segway crosses the square, no interaction observed
14.10.05	13:54	Bahnhofstraße	2 Segways come along with a larger group of pedestrians and afterwards pass them. No interaction observed
14.10.05	14:03	Bahnhofstraße	2 Segways pass the pedestrian precinct without participation of other traffic participants
14.10.05	16:02	Bahnhofstraße	Segway crosses the square, overtakes a group of pedestrians, no interaction observed
14.10.05	16:46	Bahnhofstraße	End of video recording
14.10.05		Bahnhofstraße	No interaction abserved
14.10.05	10:11	Kaiser-str. Karcher-str.	Start of video recording
14.10.05	11:00	Kaiser-str. Karcher-str.	Segway rider comes along the sidewalk, then stops, because a pedestrian addresses him. No interaction observed
14.10.05	11:09	Kaiser-str. Karcher-str.	Segway comes along the sidewalk, passes a notch caused by a car door, approaches a group of pedestrians, one pedestrian gets out of the way. Interaction observed
14.10.05	12:02	Kaiser-str. Karcher-str..	Segway crosses the street at the pedestrian traffic light, meeting with a pedestrian. No interaction observed
14.10.05	12:02	Kaiser-str. Karcher-str.	Segway crosses the street to address a car driver. Afterwards continues its way on the sidewalk. The Segway gets out of the way of a pedestrian. Interaction observed
14.10.05	13:22	Kaiser-str. Karcher-str.	2 Segways go along the sidewalk, come up with a group of pedestrians, adaptation of the Segways speed to the walking speed of the pedestrians. Interaction observed
14.10.05	15:48	Kaiser-str. Karcher-str.	2 Segways cross the crossing at the pedestrian traffic light, no other traffic participants and no interaction observed
14.10.05	17:05	Kaiser-str. Karcher-str..	Several pedestrians and Segway at the traffic light. Sudden stopping of the Segway, traffic light turns red. The Segway rider speaks to a pedestrian and bends forward, which leads to the Segways unintentional moving forward towards the pedestrian. The rider corrects immediately. Interaction observed
14.10.05	17:14	Kaiser-str. Karcher-str.	Segway crosses the street at the traffic light, no interaction observed
	17:32	Kaiser-str. Karcher-str.	End of video recording
14.10.05		Kaiser-str. Karcher-str.	4 interactions observed
24.11.05	11:32	Bahnhofstraße	Start of video recording
24.11.05	12:04	Bahnhofstraße	2 Segways come along the pedestrian precint towards the pedestrian crossing. Pedestrian crosses the way. Pedestrian and Segway stop and adjust their reaction. Segway gives precedence to the pedestrian. Interaction observed
24.11.05	12:24	Bahnhofstraße	2 Segways pass the pedestrian crossing and very slowly pass the group of pedestrians. One pedestrian wants to cross the way. Pedestrian and Segways stop and adjust their reaction. Segways give precedence to the pedestrian. Interaction observed
24.11.05	12:39	Bahnhofstraße	Segway passes the pedestrian precinct towards the pedestrian crossing. No interaction observed
24.11.05	14:59	Bahnhofstraße	2 Segways pass the pedestrian precinct towards the pedestrian crossing. No interaction observed
24.11.05	15:02	Bahnhofstraße	Segway passes the pedestrian precinct towards the pedestrian crossing. No interaction observed
24.11.05	15:09	Bahnhofstraße	2 Segways pass the pedestrian precinct towards the pedestrian crossing. They slowly go through a larger group of pedestrians. No interaction observed
24.11.05	15:31	Bahnhofstraße	2 Segways pass the pedestrian precinct towards the pedestrian crossing. They slowly go through a group of pedestrians. No interaction observed
24.11.05	15:35	Bahnhofstraße	2 Segways pass the pedestrian crossing and the pedestrian precinct. No interaction obeserved
24.11.05	15:42	Bahnhofstraße	Segway passes the pedestrian crossing with speed and turns into the pedestrian precinct. No interaction observed
24.11.05	17:04	Bahnhofstraße	2 Segways slowly pass the pedestrian precinct towards the pedestrian crossing. They pass some single pedestrians. No interaction observed
24.11.05	17:22	Bahnhofstraße	2 Segways pass the pedestrian crossing and the pedestrian precinct. They very slowly go through a greater group of pedestrians. No interactions observed
24.11.05	18:02	Bahnhofstraße	End of video recording
24.10.05		Bahnhofstraße	2 interactions observed

Figure 32: protocol of the video analysis of the video recordings in Saarbrücken

- Conflicts of the Segway in road traffic
- Problems with the technique and the handling of the Segway
- Accident potentials of the Segway

but also

- Insights in the special characteristics and difficulties in every day use.

In the first round of interviews, which took place three weeks after the pilot study started, the questions were whether and how often such situations occurred that had to be recorded with the riding recorder. Another question was whether the riding recorder was in fact used for such incidents. It turned out that several incidents were not recorded because of different reasons. Therefore all participants were then told during the interviews that a complete documentation was more important than a timely one and they were asked to deliver the corresponding documentation later. If necessary incidents could also be documented after the shift or on the following day, in the course of the ongoing pilot project.

Results

In the three-months test period nine incident have been recorded to the six voice recorders.

You will find a survey of all known incidents, which only partly originate from the riding recorder, in chapter 4.6.1 »Incidents and accidents«, page 45.

Generally one can say that the participants recorded considerably less incidents than expected in the beginning. This partly may be due to the fact that

- Few corresponding incident happened
- The participants underestimated the importance of incidents in some cases (»this was no more than a trifle«)
- The participants could not use the voice recorder timely because they had no time and had to fulfil important official services
- concerning voice recording after a couple of days it was not possible to reconstruct the incident exactly according to the requirements of the guideline and therefore the participants left out the recording

Date	Time	Weather	Ground condition	Incident	Street/place	Remarks
26.08.05	10:30	dry, sunny	cobble-stone pavement	passing over filled fire-hoses failed, the intention was given up	n.n.	recorded later
26.08.05	13:00	dry, sunny	coal-tar, lawn	self caused accident, wheels rotate on lawn, the rider looses control over Segway	n.n.	recorded later,accident, nothing happened
26.08.05	15:11	n.n.	different pavements	with high speed the road behaviour of the Segway diminishes	Kaiserslauterer-street in Saabrücken	spring suspension wanted
26.08.05	16:25	n.n.	n.n.	empty accu, had to be recharged	Leienpfad-street at the Saar-river in Saarbrücken	Test rider did not hear the acoustic signal because of surrounding noise
05.09.05	n.n.	n.n.	laminated stone pavement	with high speed the Segway swings, because of lacking spring suspension	Löbener-square/inner city, Saarbrücken	spring suspension wanted
15.09.05	n.n.	n.n..		no incidents	inner city Neunkirchen	
14.10.05	10:50	dry, sunny	area with pebbles	Segway sinks into the pebble up to the platform, has to be pulled out	playground Leienpfad- street at the Saar-river	Nothing happend to the rider and the Segway
20.10.05	n.n.	dry	different grounds and rails	pedestrian suddenly comes from behind arcade posts, emergency braking with the slow-going Segway, nothing happened	Saar-galery, Saarbrücken	mostly pedestrian area, with tram area
07.11.05	11:30	clouded, rain about 2h before	wet forest way, slippery	self caused accident, Segway looses grip on wet leaves with one wheel, other wheel maintains grip, the Segway is rapidly turning around, rider falls, Segway continues to go on for about 4m, then stops	Saar-path, Saarbrücken	Participant rode up a wet forest way with low speed

Figure 34: Survey of incidents documented on the voice recorders

All together the participants did not follow exactly the guideline for the voice recording, for example the documentation of the weather was often missing.

The participants did not use the clip-on microphones.

4.4 Hotline

The participants used the offered telephone hotline for questions or problems of all kinds only once. It turned out in discussions with the participants during the pilot phase and in the second round of interviews that

- Almost all questions or problems could be solved among the colleagues or were not important enough for a call
- There were no technical problems with the units

(and that the hotline was mainly considered to be a technical hotline)

- For the few serious conflicts or incidents the voice recorders and the interviews were considered to be the right media and therefore the use of the hotline did not seem necessary

This was true for all cases except one case in which the hotline was used because of a broken steering grip and the further procedure (see chapter 4.6.1 »Incidents and accidents – fall on wet ground«., page 46

4.5 User interviews

Handling of the device

Generally it can be noted that the asked participants of the pilot study could well handle the Segway (question 2.1, median mark 1.8). Only rarely did they find the handling of the Segway difficult (question 2.2 median mark 2.9 in the first interview round, 2.4 in the second round). Almost all participants made better assessments at the end of the pilot phase, afterwards the handling of the Segway was no longer considered to be difficult. One exception was the riding on wet, slippery or loose grounds – that is and was often considered to be difficult. It can be assumed that the experience in three months of the pilot study and several incidents are responsible for the mark 4.5 in the second interview round. In all these cases the difficult ground conditions were mainly made responsible.

In the second round the participants had to answer the question how useful the Segway is in bad weather according to their impression. The Segway is a good-weather-device, was the tendency in most answers, like on a bicycle one is exposed to wind, rain and splash. Especially when riding for a long time one realizes the lack of motion, the riders unanimously stated that they quickly became cold. On snow and ice the Segway cannot be used any longer because of the insufficient traction. Correspondingly the devices were rarely used in bad weather during the pilot study period.

Device characteristics

The participants assessed the device characteristics with good marks, too (median mark 1.6 in the first interview round, 1.8 in the second round), but gave slightly worse marks for the track-holding capacity of the Segway. They stressed that already a slight side gradient of the terrain leads to a cornering of the Segway, the same effect had different inflation pressure, which happened quite often.

Varying or missing inflation pressure was the main technical problem mentioned in the second interview round, in the first round there were none. In one known case

2.1 How did you manage the unusual method of handling the Segway	First interview	
keeping balance	1,5	
Stopping	1,8	
Steering	2,0	

(marks from 1 »very good« to 6 »poor«)

Figure 35: results of interviews, question 2.1

2.2 Were there situations in the handling of the Segway, which you found difficult ?	First interview	Second interview
Speed	2,4	1,8
topography	2,7	2,7
ground conditions	3,9	4,5
riding situation	2,4	2,0
Combination of different factors	3,7	2,8

(mark 1 »very rarely« to 6 »very often«)

Figure 36: results of interviews, question 2.2

the steering grip broke as a result of a fall, once the device could not be started.

Among the technical equipment the participants missed and most frequently mentioned the lack of an acoustic signal device or a similar signalling equipment. The device was said to be so noiseless that it startled the passers-by. The participants also mentioned several times a better stand and a spring suspension. In the interview held in the beginning of December the participants mentioned a better lighting equipment. Beside the rear reflector delivered by the manufacturer they wished a search light. Furthermore they mentioned a steering equipment on the right side, too, a rear-view mirror and a trailer coupling. The parking and safely locking of the Segway (in the context of the services) were considered to take too long, be complicated and the parking-stand was classified as unstable.

3.1 According to your actual experience how do you assess the device characteristics?

	First interview	Second interview
Manoeuvrability	1,3	1,5
Acceleration potential	1,4	1,4
Braking delay	1,8	2,1
Bend-manoeuvrability	2,1	2,0
Steering	1,6	1,7
Mounting potential	1,5	1,9
Track holding	2,2	2,3
Range	1,4	1,5
Stable riding position	1,5	1,8

(marks from 1 »very good« to 6 »poor«)

Figure 37: results of interviews, question 3.1

3.2 Did you have technical problems with the device?

	First interview	Second interview
yes	0%	30%
no	100%	70%

Figure 38: results of interviews, question 3.2

4.1 Were there conflict situations with other traffic participants?

	First interview	Second interview
Startling	about 5,2 times/rider	about 7,3 times/rider
Irritations when meeting	about 2,7 times/rider	about 7,5 times/rider
Near-accident	about 1,7 times/rider	about 3,5 times/rider
Crashes	about 0,4 times/rider	about 1,7 times/rider
Accidents	about 0,0 times/rider	about 0,2 times/rider

(retrospectively, according to individual memory, roughly quantified)

Figure 39: results of interviews, question 4.1

4.2 Which traffic areas are suited for the Segway according to your experience?

	First interview	Second interview
Road area, inner city (up to 50 km/h)	4,6	4,5
30-km-zone (up to 30 km/h)	2,5	2,8
Traffic calmed area (up to 7 km/h)	1,5	1,6
Bicycle tracks (on the road)	1,3	1,6
Bicycle tracks (also mixed ones)	1,3	1,6
Walks, sidewalks	2,2	1,8
Pedestrian precinct	1,6	1,2

(marks from 1 »very well« to 6 »poor«)

Figure 40: results of intervew, question 4.2

Interactions in the traffic space

There were some conflict situations in the interaction with other traffic participants, in most cases people got only startled probably because of the unusual sight and the inaudible approach of the device.

Irritations, near-accidents or touchments happened far less frequent. Two of the under 4.6.1 »Incidents and accidents« mentioned incidents were here characterized as accidents. Near-accidents as well as touchments/crashes refered to objects such as doorframes, cupboards or railings.

Asked for their experience in the test period many participants consider the Segway unsuitable for being used on main traffic roads; tracks in a zone with speed limit to 30 km/h of limited suit, because the speed limit is often neglected and the Segways have to compete with motor cars and lorries.

All participants consider the Segway relatively well suited for traffic areas for bicycles and pedestrians such as bicycle tracks, sidewalks, pedestrian precinct and traffic calmed areas – however walks in a limited way, because of uneven pavement or roots, which make riding uncomfortable and require much attention. Or dangerous entrances, through which cars or bicycles come out suddenly, house entrances and notches, where the Segway can hardly get out of the way because of the curbstone.

In the interaction with car drivers or bicyclists the pilot study participants do not consider a speed limit for the Segway necessary, in the interaction with pedestrians three of eleven interviewed participants consider a speed limit to 6-7 km/h (black key) reasonable, seven of eleven a speed limit to 12-13 km/h at most (yellow key) and one participant wants no speed limit at all.

Safety feeling and danger potential

None of the interviewed persons feels unsafe when riding the Segway, detractions from leading the Segway, observing the traffic or from the essential activity by each one of the other tasks occurred rarely.

On the basis of their riding experience the participants estimate the incidence of dangerous situations to be low, the danger potential of theses situations, if they happen, to be rather low. After three weeks 36 % of the interviewed persons considered a protective helmet necessary, after three months 60 %. 40 % of them however think the obligation to wear a helmet depends on the speed – when riding at walking speed no helmet is necessary.

Eight of the eleven interviewed participants stated in the first round of interviews to have physical problems with their feet after a long ride with the Segway, they mentioned feelings of deafness, numb feet and pain, probably caused by the long motionless standing on the device and the lacking spring suspension. Practically all participants mentioned the same problems in the second round of interviews.

5.3 How often happen dangerous situations with the Segway according to your experience?	First interview	Second interview
	5,2	4,7

(Mark from 1 »very often« to 6 »very rare«)

Figure 41: results of interviews, question, 5.3

5.4 How much is the danger potential of these situations?	First interview	Second interview
	4,0	4,3

(mark from 1 »very much« to 6 »very low«)

Figure 42: results of interviews, question 5.4

6.1 Do you believe that you can/could further improve your riding skill on the Segway until the end of the pilot study?	First interview	Second interview
	3,4	3,1

(mark from 1 »very strongly« to 6 »not at all«)

Figure 43: results of interviews, question 6.1

6.3 Has the Segway been a help to you in your personal every day practice?	First interview	Second interview
yes	91%	94%
no	9%	6%

Figure 44: results of interviews, question 6.3

Riding skill and self-assessment

Five of eleven interviewed persons said that the feeling of riding the Segway is a little bit similar to that of walking or riding a bicycle; six of eleven said it was not comparable.

The participants answered in the first round of interviews on an average with »perceptibly« (average mark 3.4) when asked for their individual estimation, whether their riding skill will improve until the end of the pilot study. When asked again after three months they stated again that their riding skill had perceptibly improved on an average (3.1). Astonishingly there was a range between 1 and 6.

Ten of eleven interviewed participants consider the Segway to be helpful in every day practice (see chapter 4.9 »Experiences of utilization of the Segway at Police and Municipal Office«, page 49). The participants assessed the individual riding fun on an average with 1.1 (on a scale from 1 very great fun to 6 no fun at all).

4.6 Handling of the Segway

Basically the handling of the Segways is very easy and intuitive, all participants understood within a very short time how to use the device. Nevertheless there were a number of incidents and other points, which limited the handling of the Segway.

4.6.1 Incidents and accidents

Especially in the first three weeks of the pilot study several minor incidents happened, which were due to fact that the participants were still learning how to handle the Segway. Minor abrasions happened by touching doors, walls, cupboards and so on, especially when riding in narrow areas as it is the case in buildings or on narrow paths and doorways. This may be due to the fact that the concentration effort is considerably higher caused by the probability to collide with things or persons. During the interviews almost all participants agreed that everyone had smaller bagatelle incidents in the first three weeks.

Beside these eight greater incidents happened, which have been documented on voice recorders, communicated via hotline and explained in the interviews.

Fall during test riding in Kaiserslautern

During first riding tests at the Technical University of Kaiserslautern (TU KL) a rider stopped on loose grit ground. Thereby the device lost grip, the rider control and came to fall. Trying to keep balance the rider jumped off and hit the steering grip. The plastic material broke. Beside the damage to the Segway the rider got some blue marks.

Interpretation: In this case the grip of the ground has been misjudged.

Fall during braking tests in Kaiserslautern

During the braking tests in Kaiserslautern one rider stopped by leaning backwards very strongly. However the balance steering seemed not to work - the device lost almost no speed and without counteracting force the rider fell backwards. The unit continued going for about ten meters until a slope stopped it.

Based on the report of the rider and on the video recordings it was unclear whether a technical failure or a false use caused the accident. In cooperation with Segway Company Llc. the electronic event log of the device was evaluated and together with the video pictures analysed. The event log records the last six exceptional incidents.

According to the analysis the accident happened because before the fall in all probability the rider leaned very strongly forward to gain speed and came past the speed limiter, which in such a case pushes the rider a little backwards. At the stopping line the tall and strong rider tried to stop strongly by jerkily and quickly flinging back. The log shows that in this moment the steering electronics steered the wheels backwards, which by the force of the impulse lost grip and the rider still further flung back. The different speed of the two wheels recorded in the protocol supports the thesis. The protocol showed, too, that the Segway was moved backwards past the tilt limit of 60°, and after that point the electronics can no longer balance the tilts. Because in such a case the rider looses control over the device and is not in the position to gain control again, the unit cuts off as safety measure, to avoid uncontrolled movements of the device.

Interpretation: By the quick and extreme backward movement the unit lost in due course the grip first, then exceeded the tilt limit and as a consequence cut off. In the safety video and in the training manuals Segway Company explains the physical limits of the device, which obviously had been overestimated by the rider.

Fall on wet ground

The pilot study participant rode on an unpaved way uphill, the gradient was between 10 % and 20 %. It had rained the same day and the ground was wet.

The device was standing and the rider tried to start from standstill uphill on muddy ground that was covered with foliage. The wheels started rotating and after a while the wheels found grip on one side. This lead to a jerky 180°-rotation of the Segway around the second wheel, which was still rotating. Thereby the rider came to fall and the device went some meters downhill. The steering grip bounced off the ground, rose again and hit the ground on the other side. Thereby a piece of the steering grip broke, the element had to be replaced. No injuries happened.

Interpretation: In this case there was a false estimation concerning the firm grip of the ground.

Fall at a curb stone

The Segway rider wanted to get over a curb stone right up from below but the curb stone was either too high or the rider approached it too slowly – the device could not get over the difference in elevation and the rider came to fall. There were neither damages nor injuries.

Interpretation: The rider falsely estimated the height of the curbstone and his ability to get over the curbstone with full speed and without dismounting.

Fall while riding backwards very fast

When demonstration the dynamic riding capacity of the Segway to a TV team the participant rode quickly backwards, the automatic alarm system induced the vibrating of the device. The rider became irritated and lost control over the Segway and fell down. There were neither damages nor injuries.

Interpretation: Without sufficient view and without necessity as well as riding backwards too fast, the device is designed to corner and go forward instead.

Fall of a bicyclist

A bicyclist wanted to overtake the quickly going Segway in a park, the bicyclist strongly worked the pedals and shifted towards the left and the right side. Because he wanted to pass the Segway too closely, the handlebar of the bicycle and the steering grip of the Segway met and the bicyclist fell down. The Segway rider stopped. There were neither damages nor injuries of the Segway rider; the bicyclist can continue his ride after a while and with a couple of blue marks.

Interpretation: Dangerous behaviour of the bicyclist.

Fall after emergency cut off

By using a Segway during two shifts the accumulator was empty after the second shift and the device cut off. Because of the noisy traffic conditions the rider did not hear the alarm signal of the emergency cut off nor did he feel the warning vibrations while riding on uneven terrain. The emergency cut off caused an involuntary and unexpected «step down" which fortunately did not lead to further consequences nor injuries. There were neither damages nor injuries.

Interpretation: The alarm signals of the device before an emergency cut off are clearly and well audible, but it is not improbable that they are not realized in special traffic situations, especially if the whole attention of the rider is directed to the traffic conditions.

Fall at step

The driver tried to climb up a step with the Segway. According to wet leaves on the ground the devices grip was bad. It was not able to transcend the step and was stopped abruptly at te curb. The inherent kinetic energy mad the driver for falling over the handlebar – the driver managed to intercept the fall. No damages or injuries have been recorded.

Interpretation: The Segway is not able to climb up steps over about 10 cm. To do so it needs a certain amount of impetus and grip. This fall results in the attempt to transcend a to high step with to less grip.

General consequences of the incidents

Some physical characteristics and the physical extreme situations, which the user might experience, are as unusual as the device is for car drivers and bicyclists. Some extreme situations can never be experienced with other devices. As was seen in the incidence during the braking tests in Kaiserslautern, the user overestimates at the same time, to what extent the electronics can interfere with corrections in extreme situations. A basic difference represents the importance of the grip – in cars and bicycles grip is necessary for traction, in the Segway it is additionally necessary for keeping the balance, because the steering of the balance is effected via position balancing by the motors and wheels. If there is no grip, the car driver cannot keep track and skids, the Segway rider additionally looses its balance and falls.

The obligatory trainings carried out by the manufacturer explain the physical limits of the device and the resulting risks several times especially with regard to standard situations such as the passing over steps, riding at a slope and changing grounds. In the handling instructions and the safety film reference is made to these situations, too. These limits seem to be sufficiently mentioned, but obviously cannot replace the personal riding experience.

Beside the physical limits the power of the two 1.5 kW driven motors are often underestimated as showed the situation at the curbstone or the start uphill on wet ground. If the electronics steer correspondingly strong

the motors by a strong tilt of the device, this can result in strong and jerky movements, which can throw the rider off.

There also exists a certain risk for injuries and accidents if the device continues to go on for some meters and for example gets into the traffic flow or if it raises up while going on, hits the ground again and thereby the steering grip hits a passer-by.

Basically all of the shown major incidents represent handling faults or false estimations of the user. These risks could be reduced by small alterations of the device:

- The alarm signal before emergency cutting offs could be made better perceptible
- The going on of the device after cutting off could be reduced by an automatic, progressive brake mechanism
- If the device cuts itself off due to technical reasons it can afterwards be restarted like normal in some situations and be used again - critical conditions of the device can so be overlooked, conditions, which could lead to accidents. By a time limit lock for the restart the user could be informed that there was a technical problem and that he should ride with special care and attention.

4.6.2 Limitation to use

The Segway cannot optimally be used in all cases, its handling is limited in case of long rides by the physical discomforts of the users and in case of bad weather.

Physical discomforts

Especially during longer rides (over 1.5 up to 2 hours) the long motionless standing on the platform leads in some cases to feelings of numbness, because the whole unevenness of the terrain is only suspended by the two pneumatic wheels and is otherwise directly forwarded to the rider.

Bad weather

All riders stated in interviews and discussions that in bad weather like cold, wind, rain, snow or ice the Segway is only limitedly to not at all usable.

At low temperatures and strong wind the body quickly gets cold because of lacking motion and the rider is freezing. In the last days of autumn some of the participants started to wear long underwear when riding the Segway. When it is raining the limitations are similar to those for bicycles – the rider becomes wet by the rain and to some extent by the splash water. Using an umbrella is almost not possible. With snow and ice the grip is so bad that the risk of accidents increases when using the Segway (see chapter 4.6.1 »Incidents and accidents«, page 45, on the importance of the grip for the Segway).

4.6.3 Steering

In contrast to the intuitivism of riding, accelerating and braking the process of steering needs accustoming with the twist potentiometer on the left arm of the steering grip, in the beginning. It has been observed and reported several times that inexperienced riders falsely handle the steering when being under stress for example when getting out of the way and then go into the opposite direction. The handling of the steering with the left hand is also possible, a short change as it is necessary during an activity on the Segway like opening a door, pushing the lift button and so on is for left handed persons only possible while the Segway is standing.

Test riders and passers-by asked again and again why the steering grip cannot be turned for steering and why the steering device is available only on the left side. For future versions of the Segway such improvements should be considered.

4.7 Technical characteristics and equipment of the Segway

During the pilot study problems and improvement potential was seen in a couple of technical characteristics.

Lighting

The Segways have several times been used in autumn in the evening hours and then some shortcomings in the active and

passive lighting facilities became obvious. The units were equipped with only one bicycle rear light a headlight was missing, but would have been desirable for lighting the way and for being better visible and therefore such a light was missed. The problem with the use of bicycle plug- or clip-light is that the steering grip offers the only place for fixing the light. During a ride the tilt of the steering grip continuously alters and therefore the illuminated area of the headlight. This can easily blind approaching traffic participants. The steering grip is only in a very limited way suited for fixing a rear reflector, because the rider standing on the platform partly covers the lights. The wheels are on both sides equipped with reflector foil, but only a small stripe on both edges of the platform reflects forwards and backwards.

Alarm device

The manufacturer intentionally did not equip the Segway with an alarm device, because Segway riders should behave in a polite and thoughtful manner and not empty the way by signalling. In practice however it became clear, that an alarm device can be necessary for danger signalling and that many passers-by got startled by the Segways unexpected and noiseless approach.

Riding straight on

Some participants criticized that the devices loose quite fast their tyre pressure. The generally low tyre pressure very quickly leads to pressure instabilities between the two wheels and consequently induce a lateral spin during going straight on.

Fault indications

The indication possibilities of the display are limited, some fault indication are almost cryptic and not understandable during the ride and without instruction book. Possibly the acoustic and tactile warnings in case of emergency cut off should be changed (see chapter 4.6.1 »Incidents and accidents«, page 45).

Crash protection

The Segway runs mainly between pedestrian and bicyclists but has a considerable higher mass and therefore a higher kinetic energy if running. The platform of the Segway is positioned on the height of the shinbone and has quite sharp metal edges. Under these circumstances the fixation of a rubber roll to both sides of the platform seems advisable as crash protection.

4.8 Reaction of other traffic participants

The Segway is a very new and unusual device in the townscape. Naturally the traffic participants react to Segway riders in a different way than the do to other traffic participants like bicyclists or pedestrians.

This led to the fact that during the whole pilot study, whenever the policemen stopped, it did not take long before many passers-by gathered. In the first line they were curious to learn about the device, its functioning price and the reason for its use by the police.

According to unanimous statement positive reactions were most common, the reaction always depended on the position and the individual perception of the pilot study participants. Especially in the first weeks some participants felt exposed and insecure and this was increased by some press reports on the device and commentaries of colleagues.

As the results of the interviews showed clearly that both sides got used to the Segway, on the side of the citizens who became familiar with the devices by a vast press campaign and the daily presence of the units in the townscape. This was also true for the side of the pilot participants, who as well got used to their units and became safer in handling the devices. Insecurities vanished in favour of the Segways advantages in the practical service.

4.9 Experiences of the utilization of the Segway at Police and Municipal Office

The experiences in using the Segway during the three-months-pilot study were very positive as discussions with the participated officers, reports during meetings and the two interview rounds showed.

The policemen especially stressed their higher flexibility and mobility, which in comparison to the patrol duty on foot allows them to supervise a 2.5 to 3 times larger patrolling area. Their action range has become wider; in sensible areas they are present in a higher frequency. By the speed of the devices the policemen are faster, which means faster at the place of mission and faster in tracking a fugitive. In the pilot period, according to the statement of the patrolling police ten to fifteen arrests were due to the use of the Segway and would otherwise not have been possible. The higher standing on the platform of the device was positively mentioned for the mission of police and Municipal Office – the officials had a better view and were more present.

In contrast to other police means of transportation like police cars, bicycles or C1-motor cycles the acceptance of the device is quite good in pedestrian areas, especially in such areas that can hardly be reached by other means or only on foot the Segway has made service easier.

According to the reports of the pilot study participants the Segway is very well suited for every day mission of the police and the Municipal Office.

4.10 Transferability of the pilot study results

During the pilot study the units have been used regularly and intensively almost every day and for many hours is a large city as well as in a medium-sized town. In this time, all participants used the Segways as integral part of their official duties in all arising traffic situations, according to the rules of the traffic regulations and the exemption permit.

Therefore the results of the pilot study can be looked at as a model, which is transferable to daily use. Under these conditions the results allow conclusions how the device fits into the general traffic situation of the public spaces when used appropriately and suitably and without running unnecessary risks.

5 Questions

With regard to the questions put forward at the beginning of the pilot study the answers are the following:

5.1.1 Questions on registration

Does the Segway correspond to the needs of the road traffic registration regulation (StVZO) concerning wheels, steering facility and braking systems?

According to the requirements of the road traffic regulations (StVO) the wheels and the steering facility are sufficient and represent no problem. The road traffic regulations (StVO) demands two independent braking systems for all motorcars and bicycles. The Segway possesses an electronic steered generator brake, its steering electronics, power source and stopping motors are laid out redundantly and in case of the failure of one steering unit the other can independently influence both motors. It is within the interpretation range of the legislator whether the generator brake is recognized as braking system and the two redundant systems as two separate and independent braking systems. For motor vehicles such as passenger cars, light motor vehicles and electric wheel chairs the legislator demands a minimum full delay of 5.0 m/s² resp. 3,5 m/s² for the technical brake equipment. Based on his special construction the stopping performance of the Segway can only be assessed in combination with the technical equipment and the rider. Thereby median values of over 3.5, resp. over 5.0 m/s² are reached, however the deviation range is very high – for more than half of the measured braking tests a delay of 3.5 m/s² was not reached.

How can we handle the lack of a seat for the rider?

The lack of a seat for the rider does not present a legal problem, but because of technical reasons the attachment of a seat is difficult although desirable for longer rides with regard to the strain of the legs and feet while standing.

How much signalling - and lighting equipment is necessary?

The amount of signalling- and lighting equipment depends on the kind of registration. It is clear that a signalling- and lighting equipment are required and necessary. The requirements should at least be similar to those for bicycles. For bicycles a white headlight is required without full beam and without defined luminous power and ankle, furthermore a red light and two rear lights, one in the front and one at the back are necessary. The lighting facility should work even when the device is standing.

In which form can the Segway be registered, how must it be dealt with concerning an obligation to have a number plate, riders licence, and insurance and to wear a helmet?

The registration within the existing rules is difficult, the registration as a mofa or electric wheel chair could be possible but the Segway needed some corresponding technical adaptations. Then the Segway had to correspond to the requirements of each with regard to number plate, riders licence, insurance and obligation to wear a helmet.

Alternatively the Segway could be registered as vehicle with a construction-based maximum speed 6 km/h, in this case it must be technically secured that the device cannot run faster.

Can the Segway be registered in the frame of the existing legal rules or are alterations or amendments necessary?

Yes, under certain conditions, see the question before.

With a corresponding change of the legal basis one could imagine additional registration modalities: with an exemption prescription the use of the Segway registered as mofa on cycle tracks and eventually on pedestrian traffic areas, with an alteration of the weight requirements of the light mofa exemption prescription as motor-assisted bicycle, with a change of § 16 (2) of the road traffic registration regulations (StVZO) as »special means of transport« or as a separate new type of device, which then had to be integrated into the road traffic registration regulations (StVZO).

5.1.2 Questions concerning safety

How fast can one learn to ride the Segway safely, which knowledge of the device, its road behaviour and its use in public spaces are necessary?

The riding of the Segway can be learned very quickly, within about one hour, the manual and safety video give a first impression of the devices safety requirements. To ride the Segway safely in the traffic it needs above all riding skill, experience with the special characteristic and physical limits of the device. Only consideration and knowledge of the traffic rules are necessary for using the Segway in public spaces.

How great is the conflict potential of the Segway in the interaction with other traffic participants and objects in public spaces?

Naturally the conflict potential depends strongly on the behaviour and consideration of the rider. Basically the conflict potential on cycle walks is similar to that one of bicycles, on pedestrian traffic areas it is smaller than that of bicycles but higher than that of pedestrians. By the intuitive steering the speed of the Segway can be adapted very easily. The device is very manoeuvrable, its floor space is small therefore one can easily get out of the way and avoid conflicts with objects and persons in the public space.

Where can the Segway run most safely for all traffic participants with regard to its conflict potential with other traffic participants and to its road behaviour?

According to the experience of the pilot study the Segway can safely run on all cycle tracks and pedestrian traffic areas; on both the device fits very well into the traffic system. On pedestrian areas the Segway should not run faster than at a walking speed, on narrow sidewalks special consideration of the Segway rider is necessary.

Is the set up of a minimum age for the usage of the Segway reasonable and necessary?

Little children will have physical difficulties in steering the device. Because the steering is balance based the manufacturer demands a minimum weight of 45 kg for a safe steering. Above that the pilot study has not given any hint why an age adapted limita-

tion for the use of the Segway should be reasonable. If a person has the mental and physical maturity and the necessary knowledge to take responsibly part in traffic there is no reason, why this person should not use the Segway. In Germany children of an age of 10 years can fully participate in normal traffic and have at that age received elementary traffic training in school, as a rule. With an age of 14 years boys and girls have a median body weight of over 45 kg. Therefore children under 14 years of age should not ride a Segway. For mofas for example a minimum age of 15 years is required, in some countries resp. US federal states the use of the Segway is permitted for an age of 16 years. In Germany, an age limit for the use of the Segways seems reasonable.

5.1.3 Questions with regard to the importance

For which usage and which user groups is the use of the Segway interesting?

Generally the Segway is interesting for anybody who regularly moves in distance areas between classic walking distances and car distances. The Segway could be of interest not only for healthy people, but also for mobility handicapped.

Which point of view in city and traffic politics could arise when the Segway is used on a larger scale?

The more Segways in use, the stronger is the need to find an appropriate registration form, which allows a wider use of the Segway without too much conflict with other traffic participants. By a permit to use the Segway on cycle tracks and pedestrian traffic areas the usage area for the Segways was correspondingly high. If Segways are used extensively one has to consider that further adapted rules like for example signposting are necessary.

III. Recommendations for regulation

6 Regulation of the Segways in Germany

For the regulation of the Segway an important basis for the decision is that the Segway fits well into the existing traffic structure with regard to traffic flow and its conflict potential. For that purpose the road performance, the devices equipment as well as the handling and the learning of the Segways handling have to be taken into consideration.

6.1 Potential ways of regulation

Basically one has to ask whether the Segway can be categorized for registration into the existing legal standards or whether it does not fit into the rules because of its special technical characteristics. In that case the legal prescriptions had to be modified or amended for registration of the Segway. One example for a possible modification of the existing prescriptions is the exemption prescription for light mofa, which describes the technical characteristics of bicycles with auxiliary motors, so called light mofas, and exemptions of certain rules of the road traffic regulations (StVO) and road traffic registration regulations (StVZO).

For the registration of the Segway there are more alternatives within and outside of the existing regulation frame, which require either some modifications of the device, a more generous interpretation of the existing regulations on a means of transportation which is not characterized in the regulations or corresponding legal alterations.

Characterization of Segways as mofa

Would the Segway be characterized as mofa, the registration and the obligation to have a riding licence were unnecessary. Nevertheless the device needed insurance and the rider had to wear a helmet.

The characterization of the Segway as mofa would restrict its use to pedestrian traffic areas, any other use had to be agreed on in a special exemption prescription.

The then necessary construction modifications were: an alarm signal, corresponding lighting facilities, blinker, mirror as well as a speedometer. Furthermore a technical prove had to assess whether the braking equipment corresponds to the legal requirements.

Characterization of Segways as electric wheel chair

Would the Segway be registered as electric wheel chair no registration and no riding licence and no obligation to wear a helmet were necessary. But the device needed insurance and according to construction had to be appropriate for the use by physically feeble or handicapped people.

As electric wheel chair the Segway was generally only permitted to roads and must not go beyond the maximum speed of 15 km/h. Any other deviation had to be agreed on in a special exemption prescription.

The then necessary construction modifications were: an alarm signal, corresponding lighting facilities and mirror. The braking device must have a median full delay of 3,5 m/s^2 and it must be technically proved whether the braking equipment corresponds to the legal requirements.

Characterization of the Segways as motor-assisted bicycle (light mofa)

If the Segway was characterized as motor-assisted bicycle there were no need for registration, riding license or obligation to wear a helmet. But the device required insurance.

As light mofa the Segway had to use bicycle tracks, where a usage obligation exists, otherwise it can use the road tracks. However the weight limit to 30 kg of the light mofa exemption prescriptions had to be adapted.

According to the draft of the bicycle-equipment-prescriptions the Segway with its total performance of 3 kW and the exclusive and not assisting motor would not be a motor-assisted bicycle. The draft had to be changed and amended correspondingly.

The then necessary construction modifications of the device were: an alarm signal, corresponding lighting facilities, mirror as well as a speedometer. It must be technical-

ly proved whether the braking equipment corresponds to the legal requirements.

Characterization of the Segways as special transport mean

If the Segway was characterized as special transport mean this would say that no registration, no riding permit no insurance and no helmet were necessary.

The Segway as a special transport mean would be restricted to pedestrian traffic areas with a corresponding adapted speed.

Because of its motorization it does not count as motorcar according to the road traffic registration regulations (StVZO) and therefore cannot be characterized as special transport means, § 16 (2) StVZO had to be modified correspondingly.

In this case no construction changes of the device and no technical assessment of the braking system were necessary.

Characterization of the device as motor car with construction based maximum speed of 6 km/h

Would the Segway characterized as motorcar with construction based maximum speed of 6 km/h; this would mean that no registration, no riders licence, no insurance and no helmet were necessary.

But the Segway then had to be correspondingly technically modified; it could be that the delivery with the black key only was sufficient.

Characterization of the Segways as motor car of special type

If the Segway was characterized as motor car of special type e.g. as »electric mobility assistance« the requirements of registration, riders licence, insurance, obligatory helmet and technical equipment could be shaped according to need and with respect to the specialities of the device.

A corresponding vehicle type had to be added to the road traffic registration regulations (StVZO) or had to be agreed on as an alternative to an existing type of vehicle in a corresponding exemption prescription.

6.2 Recommendation for regulation of the Segway

The German road traffic regulations define requirements and prerequisites for means of transportation, their assigned traffic areas and their road behaviour in public spaces according to type of device and not according to application. The characterization of new and innovative devices is correspondingly difficult, which do meet the existing schemes only partly or not at all.

All attempts to define the Segway within existing categories, for example mofa or electric wheel chair will therefore lead to the fact, that requirements to be met are technically difficult to fulfil or are unreasonable with respect to the Segways use. It could happen that the Segway would be classified to a traffic area in which it does not fit properly and in which the conflict – and danger potential is very high for the rider as well as for other road users. Or the Segway cannot use its specific advantages for example if it was registered with a maximum speed of 6 km/h.

To fulfil all theses requirements and to reflect the results of the pilot study we recommend integrating the Segway as a electric personal assistive mobility device, as motorcar of special type, into the road traffic registration regulations (StVZO).

6.2.1 Traffic areas

As the pilot study showed the use of the Segway is best for cycle tracks and in pedestrian traffic areas. Here it fits well because of its maximum speed of 20 km/h and its manoeuvrability. Here, great conflicts are not to be expected. On roads the speed difference between the traffic participants is much higher, as well as the danger potential for the Segway rider.

Therefore we recommend to limit the use of the Segway with adapted speed, i. e. at a walking speed, to walks, sidewalks and traffic calmed areas and additionally allow the Segway on cycle tracks when existent, with the construction based maximum speed of 20 km/h. The different keys allow a directed adaptation of speed and reduction of speed.

6.2.2 Minimum age

The manufacturer demands for a safe steering of the device a minimum weight of 45 kg, which is reached with 14 years on an average. Also with regard to the safe behaviour in traffic we recommend for the use of the Segway in Germany a minimum age of 15 years, as it is required for mofas up to 25 km/h speed.

6.2.3 Insurance

Especially when motorcars are affected even bagatelle accidents can easily become very expensive. By the high weight of the Segway and its construction considerable kinetic impulses are reached, which in the case of accidents can cause damage to objects and persons. Also with regard to the high acquisition price of the Segway the obligatory assignment of a liability insurance can be reasonable.

The law regulating the compulsory insurance demands a compulsory insurance for all motorcars with a construction based maximum speed of more than 6 km/h., which implies for the Segway, too. An alteration of this law does not seem necessary.

6.2.4 Number plates

The provision of an official number plate for the Segway does not seem to be necessary, similar to the regulation for small motor cycles, light mofas and motorized wheel chairs we recommend an integration of the Segway into the exemption catalogue of § 18 (2) StVZO, according to which these vehicles do not need registration.

An insurance plate has to be fixed, to avoid sharp edges one should consider, if the plate can be attached as foil.

6.2.5 Riding permit

Because the Segway should not be used on public roads according to our recommendation (with the exemption of traffic calmed zones), a riding permit according to § 4 of the drivers licence regulations is legally not necessary. During the training and in the safety video of the manufacturer all physical limits and all other aspects concerning the use of the Segway are discussed, As the pilot study showed above all the riding practice and experience increase the safety in handling the Segway.

6.2.6 Obligation to wear a helmet

Falling to the side is more unlikely with the Segway than with the bicycle. Falls over the handlebar as it happens with bicycles are extremely seldom, but falling backwards happens more often. 60 % of the pilot participants considered a helmet necessary after three months, at least for higher speed. If the Segway is allowed to run on cycle tracks and in pedestrian areas, the accident risk of falls from the Segway is similar to the risk of bicycles or even less.

Therefore we favour a regulation, which is similar to that one for bicyclists. the wearing of a helmet should be recommended, but not be compulsory.

6.2.7 Technical equipment of the device

Brakes

According to our opinion the two redundant technical systems, which also steer the stopping process of the Segway, can be regarded as two independent brakes in the sense of the road traffic registration regulations, because they are independently of each other in the position to stop the device quickly.

Because the realistically attainable braking performance of the Segway cannot be assessed by a pure observation of the technical equipment but only in dependence of the rider, the obligatory definition of a minimum full delay is not reasonable, according to our opinion. Already a riding experience of ten hours resulted in the study in very good values in 95 % of the cases, but with delays of more than 5.0 m/s^2.

Lighting

Because the Segway should only run on cycle tracks and pedestrian traffic areas we recommend to orientate the requirements for headlight, rear lights and reflectors on those of bicycles, and by the fact that fixed

reflectors can be powered by the accumulators of the device, there is the same situation concerning stand light function as will be demanded by the bicycle equipment regulation.

The variations in the illumination ankle of the headlight by the mobile chassis are accepted because the being visible of the Segway is most important.

Signalling device

The Segway should be equipped with a bell.

Rear-view mirror

Because of the good manoeuvrability of the Segway a rear mirror does not seem necessary, because the rider can turn with the device at any time.

Speedometer

A speedometer is not necessary.

IV. Annex

6.3 Survey of figures

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Ausnahmegenehmigung für den Betrieb von Fahrzeugen des Herstellers Segway

Gemäß § 46 Abs. 2 Satz 1 der Straßenverkehrs-Ordnung (StVO) wird den Mitarbeitern des Ordnungsamtes der Stadt Neunkirchen sowie den Mitarbeitern der Polizei der Polizeiinspektion Saarbrücken-Stadt im Wege der Ausnahmegenehmigung gestattet, im Rahmen eines Pilotversuches vom 26. August bis 30. November 2005 mit Fahrzeugen des Herstellers Segway auf Fußgängerverkehrsflächen und Radwegen am öffentlichen Verkehr teilzunehmen. Hierbei ist auf den Fußgänger- und Radverkehr besondere Rücksicht zu nehmen.

Gemäß § 70 Abs. 1 Nr. 2 der Straßenverkehrs-Zulassungs-Ordnung (StVZO) werden in Abstimmung mit dem Ministerium für Wirtschaft und Arbeit für die im Rahmen des Pilotversuches eingesetzten Fahrzeuge Ausnahmen von der Zulassungspflicht, der Betriebserlaubnispflicht, der Kennzeichnungspflicht sowie den Bau- und Betriebsvorschriften der StVZO erteilt.
Gemäß § 74 Abs. 1 Fahrerlaubnis-Verordnung (FeV) wird für die Personen, die während des Pilotversuchs die Fahrzeuge der Fa. Segway fahren, in Abstimmung mit dem Ministerium für Wirtschaft und Arbeit eine Ausnahmegenehmigung von § 74 Abs. 1 FeV erteilt, sofern diese Personen über eine Fahrerlaubnis der Klasse B verfügen.

Ich bitte, diese Ausnahmegenehmigungen an die für die Durchführung von Versuchsfahrten verantwortliche Person auszuhändigen. Diese ist gegen Unterschrift auf die Verantwortung für die Einhaltung der in der Ausnahmegenehmigung festgelegten Auflagen/Bedingungen und den verkehrssicheren Zustand der Fahrzeuge hinzuweisen.

Im Auftrag

gez.

Bernhard Strube

Durchschrift: Projektbeteiligte

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