Design for Sanitation

How does design influence train toilet hygiene?

Loth, M.

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How does design influence train toilet hygiene?

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Marian Loth

Design for Sanitation

How does design influence train toilet hygiene?

Dissertation

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by

Maria LOTH

Master of Science in Industrial Design Engineering,
Delft University of Technology, the Netherlands
born in Bunnik, the Netherlands

This dissertation has been approved by the promotors.

Composition of the doctoral committee:

Rector Magnificus	chairperson
Prof.ir. D.J. van Eijk	Delft University of Technology, promotor
Dr.ir. J.F.M. Molenbroek	Delft University of Technology, copromotor

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The toilet touches our lives,
but we do not want to touch the toilet

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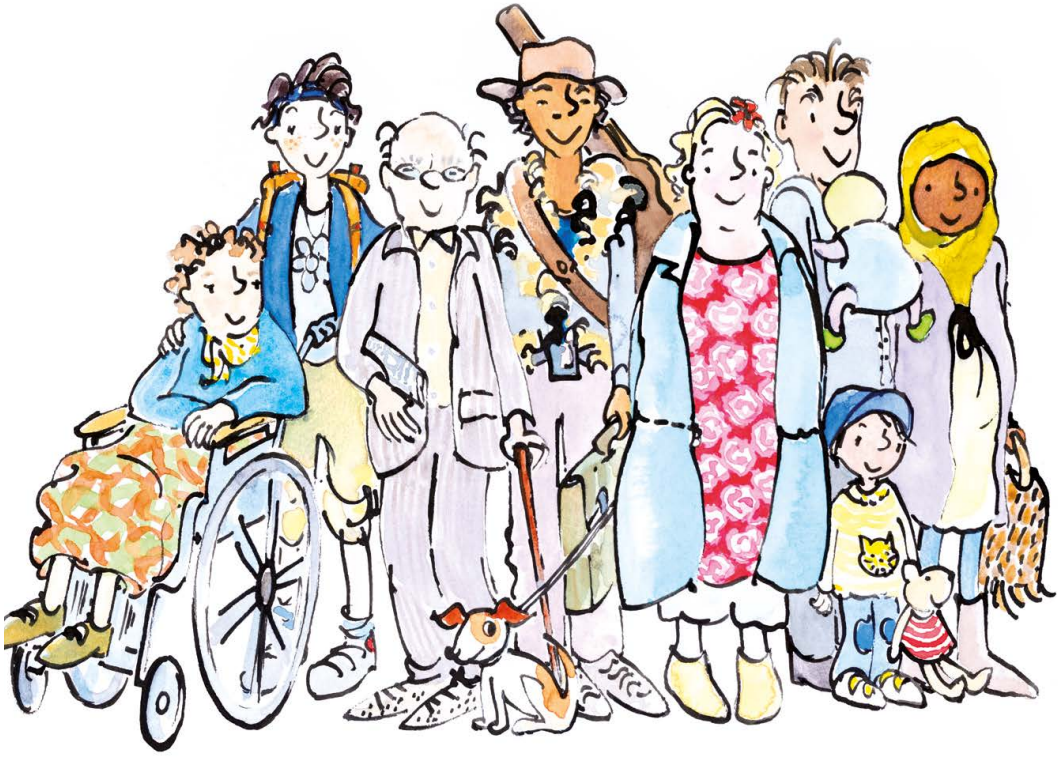
Summary

The toilet touches our lives, but we don't want to touch the toilet! In other words, we try to keep a distance from toilets, particularly from public toilets. It is the availability, accessibility and hygiene of these toilets that make it possible for us to move away from home. However, due to the lack of (accessible and clean) public toilets, some people decide to stay at home. Others try to avoid the few (accessible) public toilets they encounter along their way because they perceive them to be dirty.

A train toilet, a moving public toilet, suffers from the same problem. Even more so, because many different people use these toilets intensively to perform all kinds of (conflicting), i.e. dirty (toilet use) and clean (handwashing), practices in an anonymous, moving, confined and gender-neutral environment.

Dutch train travellers commonly complain about the poor hygiene in train toilets; 83% state that they try to avoid using them. However, a number of traveller-groups have specific and (often) urgent need for using a train toilet; these include people with restricted mobility, older adults, and families with younger children. For them, a dirty train toilet can even become a barrier to travel.



A wide variety of people use train toilets ©Astrid Keizer-Huijsing

Train toilets become soiled because they are intensively used and infrequently cleaned. However, users themselves also play a role in keeping the toilets clean. Few studies have examined primary toilet use (i.e., urination and defecation) in relation to hygiene. This is the knowledge gap on which this study focusses. It addresses how Dutch train passengers use train toilets and how their usage affects hygiene or cleanliness. Our study was essentially initiated to reduce the barrier to travelling by train, and more specifically, to inform the design of Dutch train toilets. How can design improve the usability of train toilets and related hygiene issues so that users will leave the toilet cleaner and tidier for the next use. The central research question is therefore: **How does design influence train toilet hygiene?**

The research project is divided into three main sections: PART A (chapters 2 and 3) covers LITERATURE AND SURVEYS. PART B (chapters 4-6) describes the EXPERIMENTS, subsequently Part C (chapters 7 and 8) addresses the DESIGN section. The thesis closes (chapter 9) with the CONCLUSION.

In **part A** (chapters 2 and 3), we explored the phenomenon of hygiene based on literature research and a questionnaire.

In **chapter 2**, we reviewed the literature on hygiene in relation to public toilets and their history.

In the past four thousand years, the human approach towards personal hygiene has transformed from a social activity of pleasure to an individual matter of embarrassment; privacy has become increasingly important. One of the reasons for this is our increased awareness of hygiene, and therefore our tendency to avoid unhygienic or 'dirty' locations. In this thesis, I use the term 'dirt' to describe the opposite of 'hygiene'; according to Mary Douglas', "dirt is matter out of place" and "dirt is essentially disorder". Things need to be in place; we strive to achieve order.

A common finding in the psychology literature on litter is that people leave more litter in a littered environment than in a clean one; in other words, 'dirt attracts dirt'. Train toilet users are confronted with a special form of 'dirt': faeces or urine, defined as human waste/dirt that people find repulsive, especially the dirt left by strangers. My bodily privacy is invaded by the intimacy of others. Moreover, public toilets, including train toilets, are considered dirty, so the norm is already exceeded or is unclear. In brief, a dirty train toilet is what is expected.

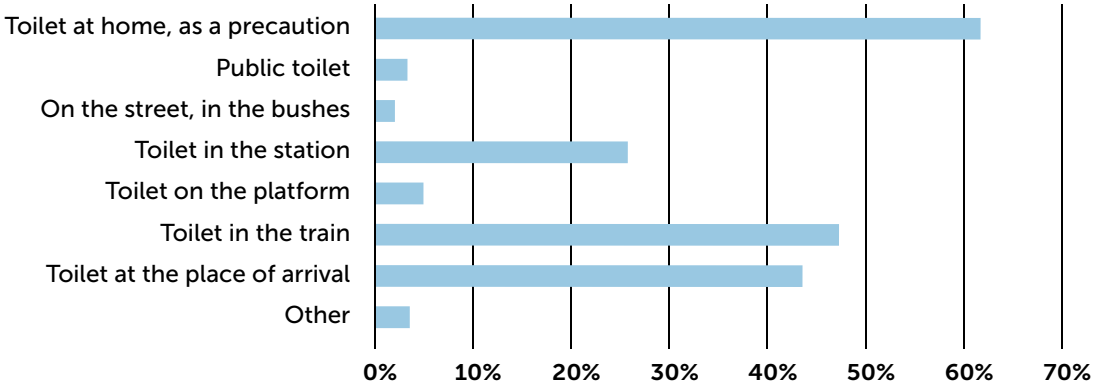
It is not clear whether people are more careless in a public toilet environment than they would be normally, because it is already dirty. In general, it is plausible that by improving the user environment, people will react by taking more care of 'their' train toilet. However, currently, even with regular cleaning, train toilets are not generally perceived as being hygienic. Deeply embedded mechanisms such as the emotion of disgust cause us to avoid dirt, or excrement. As a result, people ***distance*** themselves

from public toilets. This concept forms the underlying model for this research project in which we look at three levels of distance: Physical (P), Mental (M) and Social (S).

In **chapter 3**, we discuss an online questionnaire designed together with NS and completed by 1267 Dutch train travellers regarding their toilet perception and usage.

Results show that train travellers are a diverse group, and that the train toilet does not meet their different uses and needs. The main human characteristics that affect toilet usage are gender, age and physical ability. Older age groups and travellers with younger children are more in need of toilet facilities. They frequently travel in off-peak hours, the time when more seats are available on the train as the occupancy rate is under 40%. Moreover, they travel with associated mobility and access issues, and have indicated that they would more frequently travel by train if clean(er) toilets were available.

The train toilet fulfils an important function in the journey; the longer the journey the greater the need.



A train toilet fulfils an important public toilet function throughout the train journey

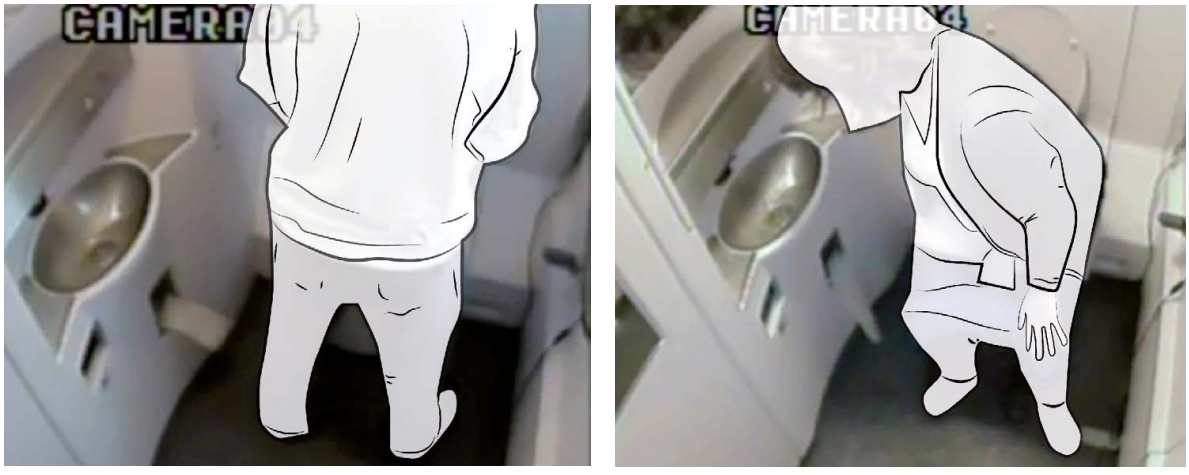
However, there are a number of issues associated with travellers' choices regarding toilet use. Firstly, what should travellers do with their luggage when using train toilets. This theme is further researched and discussed in chapter 4. Secondly, when in the toilet, travellers mainly use the toilet for urination, in a standing (men) or hovering (women) posture. They are confronted with unexpected train movements, which necessitate support when using the toilet.

In **part B** (chapters 4 to 6), we conducted observational experiments on participants who used a train toilet, resulting in 45 observations, on both occasions real time in an NS train travelling between two stations in the Netherlands. The NS allowed us to use these trains specifically for this purpose.

In **chapter 4**, based on the questionnaire results, we focussed on the issue of what travellers do with their hand luggage when using a train toilet. This chapter details the setup of the observational research conducted in a moving NS train, including camera positions and the anonymisation of the videos.

We found that travellers' maintain the largest physical distance possible (P) between their hand luggage and dirty locations; they tried to store their hand luggage far away from the (dirty) toilet bowl, and the majority did not place their luggage on the (dirty) floor. Rather than using the currently available storage hooks, male users used their body and mainly their backs as storage place. In contrast, women, who have a greater need for a hand luggage storage facility, are less able to store their hand luggage on their bodies, as they use toilets while seated or in a hovering position, with their backs to the wall. We note that the function of the storage hook was unclear to travellers due to its flat design and its high position: out of sight and reach.

In **chapter 5**, we used similar observational techniques to capture the details of urinary performance. We observed that most men stood while urinating, and that women hovered or remained seated in equal numbers. This corresponds to males' first nature; they are reluctant to adopt seated usage. In contrast, sitting is women's second nature, gradually adapted from a first nature of squatting. As Urinary Hygiene (UH) measure following urination, male participants mainly used agitating and squeezing, while women dabbed with toilet paper, reflecting first and second nature, respectively.



Observational research in toilets of moving trains to capture the details of urinary performance. Outlines:Fleur Derks

To measure urine spillage in the sit toilet of moving trains ("dirt as matter out of place"), we placed a thin sheet of paper to catch spillage resulting from fine sprays of urine. We observed that spillage was strongly related to the standing urination posture of male participants. The urine stream had to bridge a long distance until it reached the toilet bowl, resulting in a backsplash that ends in spray outside the bowl, such as on the toilet seat, which is perceived as dirty. Our observations also showed that support actions were commonly performed to achieve posture stability and to counterbalance the train's shaking movements. Spillage directly linked to the train's movements occurred in several observations.

In **chapter 6**, we designed three laboratory experiments to test the effect of distance, backsplash and dispersion to inform the design of urinals.

In our first experiment, we demonstrated that urine spillage caused by backsplash via the inside of the urinal is the main cause of soiling on the floor. In experiment 2, we focused on the distance of the urine stream, and in particular, on the last falling part, where dispersion of the urine flow occurs. We note that spillage due to the dispersion was less than expected; no soiling appeared on the floor as a result of the dispersion. Therefore, to reduce backsplash when using a urinal, the physical distance (P) between the human body and a urinal needs to be reduced, and in particular, the horizontal distance.

As an implication for design, in a clean urinal men can be encouraged to stand closer to the toilet by introducing support options, and by using a simple 'target' like a fly. Furthermore, the urinal surface curvature and depth of the basin should be able to contain the stream of urine along with its backsplash. In experiment 3, we demonstrated that to counter the effect of train motion, the urinal should be placed at an angle of 60 degrees to the longitudinal axis of the train.

In **part C** (chapters 7 and 8), we translated the knowledge gained from the literature (part A) and from our (observational) experiments (part B) into physical mock-up designs of a hygienic train toilet. In particular, we observed and, using questionnaires, we assessed the ergonomic needs of 173 participants regarding whether they understood the main features in the mock-ups.

In **chapter 7**, we built a train toilet mock-up 1 with a separate family sit-toilet and separate urinal and conducted observational mock-up testing with 26 participants.

We designed a family sit-toilet for people who would prefer to sit, including men who want to use the toilet while seated. We introduced a separate urinal to facilitate standing urination, thereby reducing the physical distance (P) between male body and the toilet, which results in less urine spillage and improves hygiene. Furthermore, a urinal reduces the mental distance (M), related to dirt because the reduced level of urine backsplash is perceived as less 'dirt', and there is no association with faeces/defecation.

We found that users assessed a split train toilet of a family sit-toilet and separate urinal as adequate. However, a number of design improvements were noted. We provided users of the sit toilet with additional support bars to counter the train's movement, we used a redesigned toilet seat, and added children's platforms and extra sanitary facilities. A platform for small boys was necessary for them to be able to use the urinal.

In train toilet mock-up 1, we observed that the separate urinal module was a 'male domain' and that this increased the social distance (S) between men and fellow train passengers. This fact contradicted the nature and aim of our project, which was to create an inclusive, thus also gender-neutral train toilet environment. Another premise of mock-up 1 was that men would wait their turn should the separate urinal be occupied, however in practice they could choose to use the family sit-toilet to urinate in a standing position, even though the design encourages seated usage.

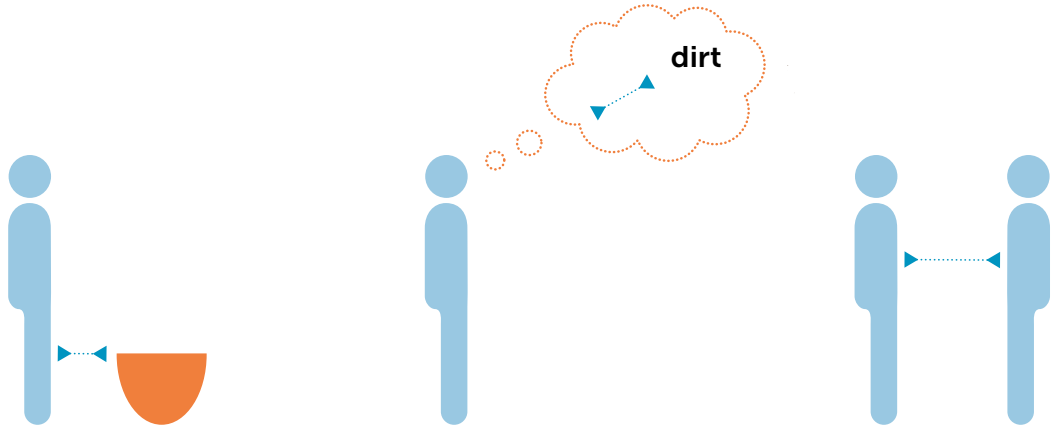
These findings led to the design of mock-up 2, which combined the elements of the family sit-toilet with those of a urinal to reduce the three underlying distances, i.e., physical, mental, and social distances (P, M, S) between the toilet, dirt, and people/ train travellers, respectively. This toilet included child platforms, a baby-station, extra support options, and greater accessibility for wheelchair and walker users.

In **chapter 8**, we combined the knowledge and design gained from mock-up 1, and tested the new design of mock-up 2 with 147 participants.

The mock-up 2a tests (n=33) showed that the urinal was accepted, and that a number of minor design adjustments needed to be made. This resulted in an adapted mock-up 2b. More importantly, amongst others, due to the low number of respondents, our partner, the NS found the results inconclusive.

In the mock-up 2b test, we increased the number of participants (n= 114) and included young girls and visually restricted participants. We also dirtied the urinal when assessing its acceptance. Furthermore, we conducted a double-blind test, where the researchers involved had no relation to the chief researcher (author) so that they were in an independent position in relation to the author's dependency on the results. Moreover, the researchers were not informed about the purpose of the research.

The mock-up 2b results confirmed the mock-up 2a findings and were accepted by the NS as being more conclusive. The concept of a urinal in the toilet was accepted by train toilet users who do not use the urinal such as women and wheelchair users; they recognised its added hygienic value. A number of minor improvements were suggested to the final design, including comments regarding a more varied use of decorative wall coverings, a safer baby-changing table, door transparency, and the height of a number of features. Furthermore, we noted that the presence of a urinal needs to be better communicated, especially to the community of visually-restricted people.



a. Reducing physical distance (P) to the facility

b. Reducing mental distance (M) related to dirt

c. Reducing social distance (S) between people

Design influences hygiene positively by reducing the physical (P), mental (M) and social distances (S).

In **chapter 9**, we propose a hygiene model of sanitation, applying the knowledge gained in parts A, B and C. In the model, we describe Hygiene (H) as a function of the Physical (P), Mental (M) and Social Distance (S). The perception of hygiene is improved by reducing these distances; these three underlying distances (P, M, S) are interconnected as reflected in the formula. Further, a,b,c are weighting factors to be determined in future research.

$$H = \frac{a}{P} + \frac{b}{M} + \frac{c}{S}$$

Our final train toilet design ensures that the underlying physical (P), mental (M), and social (S) distances between toilet, dirt, and train travellers are reduced thanks to the following design features: the addition of a urinal alongside a sit-toilet; added child and baby elements; support options; a natural wall decoration with a large mirror; and the angled urinal. The train toilet is closed by a round sliding door.

On project completion, we recommended the following to the NS:
A urinal combined with a sit-toilet, additional support options for hands including horizontal and vertical support bars and support platforms for children's feet, has to be integrated into train toilets, which are closed by a wide (round) sliding door, to improve usability and related hygiene.

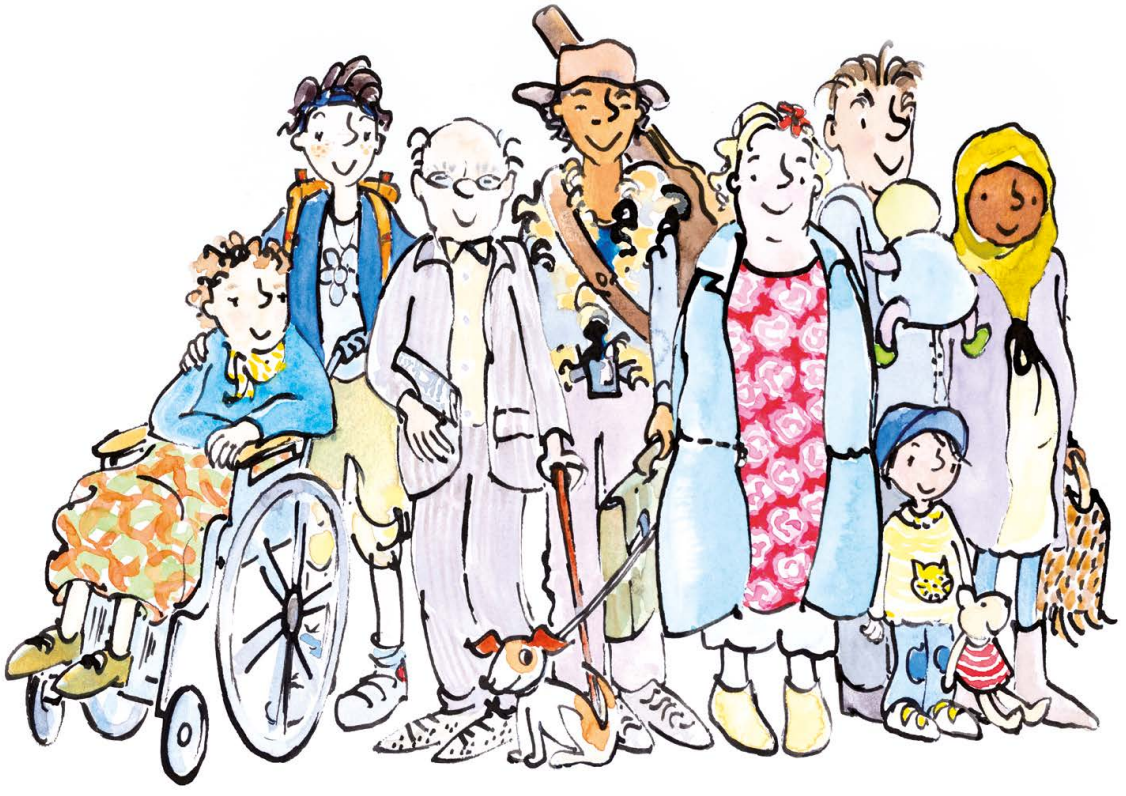
To conclude: this train toilet design is currently being implemented in NS intercity trains.

NS train toilet designed by the author in cooperation with NS currently being implemented in intercity trains

Samenvatting

Het toilet raakt ons leven, maar wij willen het toilet niet aanraken! Met andere woorden, we proberen afstand te houden van toiletten, met name van openbare toiletten. De beschikbaarheid, toegankelijkheid en hygiëne van deze toiletten stellen ons in staat om van huis weg te gaan. Echter, door het gebrek aan (toegankelijke en schone) openbare toiletten voelen sommige mensen zich genoodzaakt om thuis te blijven. Anderen vermijden de weinige (toegankelijke) openbare toiletten die ze onderweg tegenkomen omdat ze er vies van zijn.

Dat geldt in het bijzonder voor de treinWC als openbaar toilet in beweging. Dat komt doordat veel verschillende mensen de WC's in de trein intensief gebruiken om in deze anonieme, mobiele, besloten en sekseneutrale omgeving allerlei handelingen te verrichten die met met elkaar in strijd zijn: 'vieze' (toiletgebruik) en schone (handen wassen).



Vele en veel verschillende mensen maken gebruik van treinWC's ©Astrid Keizer-Huijsing

Nederlandse treinreizigers klagen vaak over de slechte hygiëne in het treintoilet; 83% geeft aan dat ze het gebruik ervan proberen te vermijden. Een aantal reizigersgroepen heeft echter een specifieke en (vaak) urgente behoefte aan het gebruik van een treinWC. Dit zijn onder meer mensen met beperkte mobiliteit, ouderen en gezinnen met jongere kinderen. Voor hen kan de angst voor vieze treintoiletten zelfs een belemmering zijn om te reizen.

TreinWC's worden vies doordat ze ondanks intensief gebruik niet vaak worden schoongemaakt. Gebruikers spelen echter zelf ook een rol bij het schoonhouden van de toiletten. Er zijn maar weinig studies waarin primair toiletgebruik (urineren en defeceren) is onderzocht in relatie tot hygiëne. Dit is de kennisskloof waarop deze studie zich richt. Deze gaat in op hoe Nederlandse treinreizigers gebruik maken van treinWC's en hoe hun gebruik de hygiëne of netheid beïnvloedt. Ons onderzoek is in wezen gestart om de drempel voor treinreizen te verlagen, en om het ontwerp van Nederlandse treinWC's te specificeren. Hoe kan het ontwerp de gebruikerservaring met treinWC's en gerelateerde hygiënekwesties verbeteren, zodat gebruikers het toilet schoner en netter achterlaten voor de volgende gebruiker? De centrale onderzoeksvraag is daarom: **Hoe beïnvloedt het ontwerp de toilethygiëne in de trein?**

Het onderzoeksproject is onderverdeeld in drie hoofddelen: DEEL A (hoofdstukken 2 en 3) behandelt LITERATUUR EN ONDERZOEKEN. DEEL B (hoofdstukken 4-6) beschrijft de EXPERIMENTEN, DEEL C (hoofdstukken 7 en 8) behandelt het ONTWERP-gedeelte. Het proefschrift wordt afgesloten (hoofdstuk 9) met de CONCLUSIE.

In **deel A** (hoofdstukken 2 en 3) hebben we het fenomeen hygiëne onderzocht op basis van literatuuronderzoek en een vragenlijst.

In **hoofdstuk 2** hebben we de literatuur over hygiëne in relatie tot openbare toiletten in de loop van de geschiedenis besproken.

In de afgelopen vierduizend jaar is de menselijke benadering van persoonlijke hygiëne getransformeerd van een sociale activiteit van plezier naar een individuele kwestie van schaamte; privacy is steeds belangrijker geworden. Een van de oorzaken hiervoor is ons toegenomen bewustzijn van hygiëne, en daarmee onze neiging om onhygiënische of 'vieze' locaties te vermijden. In dit proefschrift gebruik ik de term 'vies' om het tegenovergestelde van 'hygiënisch' te beschrijven; volgens Mary Douglas is "het vies als dingen niet op hun plaats zijn" en "viezigheid is in wezen wanorde": De dingen horen op hun plaats omdat we streven naar ordelijkheid.

Een veel voorkomende bevinding in de psychologie-literatuur over zwerfafval is dat mensen meer zwerfafval achterlaten in een vervuilde omgeving dan in een schone omgeving; met andere woorden: 'vuil trekt vuil aan'. Treintoilet-gebruikers worden geconfronteerd met een bijzondere vorm van viezigheid: uitwerpselen of urine, gedefinieerd als menselijk afval / vuil dat mensen weerzinwekkend vinden, vooral als

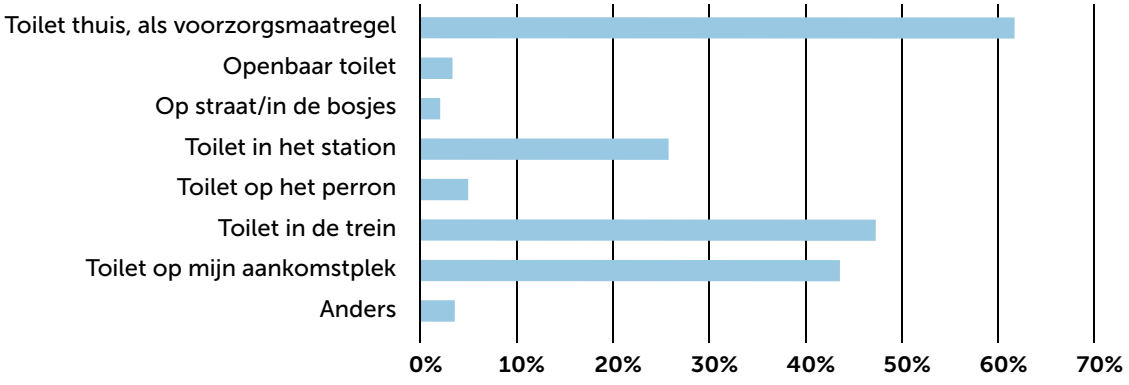
het is achtergelaten door vreemden. Mijn lichamelijke privacy wordt aangetast door de intimiteit van anderen. Bovendien worden openbare toiletten, waaronder treinWC's, a priori als vies beschouwd, dus in gedachten wordt de norm al overschreden of is deze onduidelijk. Kortom, een vies treinWC is wat men verwacht.

Het is niet duidelijk of mensen in een openbare toiletomgeving onzorgvuldiger zijn dan ze normaal zouden zijn omdat deze al vies is. Het is aannemelijk dat als de gebruikersomgeving verbeterd wordt, mensen in reactie meer zorg zullen dragen voor 'hun' treintoilet. Momenteel worden treinWC's over het algemeen niet als hygiënisch ervaren, zelfs als ze regelmatig worden schoongemaakt. Diep ingebedde mechanismen zoals het gevoel van walging zorgen ervoor dat we vuil en uitwerpselen vermijden. Als gevolg hiervan houden mensen ***afstand*** van openbare toiletten. Dit gegeven vormt het onderliggende model voor dit onderzoeksproject, waarin we kijken naar drie afstandsniveaus: Fysiek (P), Mentaal (M) en Sociaal (S).

In **hoofdstuk 3** bespreken we een online vragenlijst over toiletbeleving en -gebruik die in samenwerking met NS is opgesteld en door 1.267 Nederlandse treinreizigers is ingevuld.

De resultaten laten zien dat treinreizigers een diverse groep vormen en dat de treinWC niet aansluit op hun uiteenlopende gebruik en behoeften. De belangrijkste menselijke kenmerken die het toiletgebruik beïnvloeden, zijn geslacht, leeftijd en fysieke mogelijkheden. Ouderen en reizigers met jongere kinderen hebben meer behoefte aan sanitaire voorzieningen. Ze reizen vaak in de daluren, de tijd dat er meer zitplaatsen beschikbaar zijn in de trein, gezien de bezettingsgraad die dan onder de 40% ligt. Bovendien gaat hun reis gepaard met mobiliteits- en toegangsproblemen en hebben ze aangegeven dat ze vaker met de trein zouden reizen als de WC's schoon of schoner zouden zijn.

De treinWC vervult gedurende de reis een belangrijke functie; hoe langer de reis, hoe groter de behoefte aan toiletgebruik.



De antwoorden op de vraag 'waar gebruik je een toilet tijdens je complete reis?' laten zien dat de treinWC gedurende de hele reis een belangrijke toiletfunctie vervult.

Er is een aantal bijkomende problemen verbonden aan de keuzes van reizigers met betrekking tot toiletgebruik in de trein. Ten eerste: wat moeten reizigers met hun bagage doen als ze in de trein naar de WC willen? Dit vraagstuk wordt verder behandeld in hoofdstuk 4. Ten tweede gebruiken reizigers het treintoilet voornamelijk om te plassen, in een staande (mannen) of hangende (vrouwen) houding. Ze worden dan geconfronteerd met onverwachte treinbewegingen die maken dat ze ondersteuning nodig hebben.

In **deel B** (hoofdstukken 4 t/m 6) hebben we observationele experimenten uitgevoerd bij deelnemers die een treinWC gebruikten, resulterend in 45 observaties, in real-time in een NS-trein die tussen twee stations in Nederland reed. De NS stond ons toe twee treinen specifiek voor dit doel in te zetten.

In **hoofdstuk 4** hebben we ons op basis van de resultaten van de vragenlijst geconcentreerd op de vraag wat reizigers doen met hun handbagage bij het gebruik van een treintoilet. In dit hoofdstuk wordt ingegaan op de opzet van het observatieonderzoek in de rijdende NS-treinen, inclusief plaatsing van de camera's en het anonimiseren van de video's.

We ontdekten dat reizigers de grootst mogelijke fysieke afstand (P) aanhouden tussen hun handbagage en vieze plekken; ze probeerden hun handbagage ver weg van de (vieze) toiletpot te zetten, het merendeel plaatste hun bagage niet op de (vieze) vloer. Mannelijke WC-bezoekers gebruikten hun lichaam en vooral hun rug als opbergplek in plaats van de beschikbare ophanghaken te benutten. Vrouwen, die doorgaans meer behoefte hebben aan een opslagruimte voor handbagage, kunnen hun lichaam minder goed gebruiken als opbergplek omdat ze het toilet zittend of met de rug tegen de muur hangend erboven gebruiken. We bemerkten dat de functie van de opberghaak voor de reizigers onduidelijk was vanwege het platte ontwerp en de hoge positie: buiten het zicht en directe bereik.

In **hoofdstuk 5** hebben we vergelijkbare observatietechnieken toegepast om de details van het plassen vast te leggen. We zagen dat de meeste mannen stonden tijdens het urineren en dat vrouwen in gelijke aantallen bleven hangen of gingen zitten. Dit komt overeen met de eerste natuur van mannen; Zitten is daarentegen de tweede natuur van vrouwen, voortkomend uit de eerste natuur van het hurken. Als hygiënische maatregel na het plassen doen mannelijke deelnemers voornamelijk aan schudden en knijpen, terwijl vrouwen met toiletpapier deppen, wat respectievelijk de eerste en tweede natuur weerspiegelt.

Observationeel onderzoek in toiletten van rijdende treinen om de details van het urineren vast te leggen. Outlines:Fleur Derks

Om het morsen van urine in het zittoilet van rijdende treinen te meten ("viezigheid als materie op de verkeerde plaats"), hebben we een dun vel papier aangebracht om het morsen van fijne urinedruppels op te vangen. We zagen dat morsen sterk gerelateerd was aan de staande plaspositie van mannelijke deelnemers. De urinestroom moest een lange afstand overbruggen tot deze de toiletpot bereikte, wat resulteerde in een spatgebied dat tot buiten de kom loopt, zoals op de toiletbril die daarom als vies wordt ervaren. Wij namen ook waar dat vaak steun moest worden gezocht om een stabiele houding aan te nemen en om de schokkende bewegingen van de trein te compenseren. Bij verschillende waarnemingen trad morsen op dat direct verband hield met de bewegingen van de trein.

In **hoofdstuk 6** hebben we drie laboratoriumexperimenten opgezet om het effect van afstand, opspatten en verspreiding te testen om het ontwerp van urinoirs te specificeren.

In ons eerste experiment hebben we aangetoond dat het morsen van urine door opspatten vanaf de binnenkant van het urinoir de belangrijkste oorzaak is van vervuiling van de vloer. In experiment 2 hebben we gekeken naar de lengte van de urinestraal, en in het bijzonder naar het laatste deel, waar de verspreiding van de urinestroom zich voordoet. We merken op dat het morsen als gevolg van verspreiding minder was dan verwacht; door de verspreiding kwam er geen viezigheid op de vloer. Om opspatten bij het gebruik van het urinoir te verminderen, kan daarom worden volstaan met het verkleinen van de fysieke afstand (P) - vooral de horizontale afstand - tussen het menselijk lichaam en het urinoir.

Dit impliceert voor het ontwerp dat het bieden van ondersteuningsmogelijkheden en het aanbrengen van een eenvoudig 'doelwit' zoals een vlieg, mannen aanmoedigt om dichterbij het urinoir te gaan staan zodat het toilet schoner blijft. Bovendien moeten de kromming van het urinoir en de diepte van het bassin de stroom urine en het spatwerk kunnen verwerken. In experiment 3 hebben we aangetoond dat het urinoir onder een hoek van 60 graden ten opzichte van de lengteas van de trein moet worden geplaatst om het effect van treinbewegingen tegen te gaan.

In **deel C** (hoofdstukken 7 en 8) vertaalden we de kennis opgedaan uit de literatuur (deel A) en uit onze (observationele) experimenten (deel B) naar fysieke mock-up ontwerpen van een hygiënisch treintoilet. We hebben specifiek getoetst of de deelnemers (n = 173) de belangrijkste kenmerken van de mock-ups begrepen door middel van observatie en met behulp van vragenlijsten over de ergonomische behoeften van de deelnemers.

In **hoofdstuk 7** hebben we treintoilet mock-up 1 gebouwd met een familie-zittoilet en een afzonderlijke urinoir-module. We hebben met 26 deelnemers observationele tests van de modulen uitgevoerd.

We hebben een familie-zittoilet ontworpen voor mensen van alle leeftijden - ook mannen - die het liefst zittend gebruik willen maken van het toilet. We hebben voor staand plassen een apart urinoir geïntroduceerd dat de fysieke afstand (P) tussen het mannelijk lichaam en het toilet verkleint. Dit resulteert in minder urineverlies en een betere hygiëne, hetgeen de mentale afstand (M) verkleint die correleert met viezigheid, omdat een lager niveau van urineresten als minder vies wordt ervaren en er geen associatie is met fecaliën en defeceren.

We ontdekten dat gebruikers een treinWC met een familie-zittoilet en een apart urinoir als voldoende beoordeelden. Er werden wel ontwerpverbeteringen aangedragen. We hebben het zittoilet voorzien van extra steunmogelijkheden om de beweging van de trein tegen te gaan, we hebben een vernieuwde toiletbril gebruikt alsmede opstapjes voor kinderen en extra sanitaire voorzieningen toegevoegd. Een opstapje voor kleine jongens was nodig om het urinoir te kunnen gebruiken.

In treintoilet mock-up 1 zagen we dat de aparte urinoirmodule een 'mannelijk domein' was en dat dit de sociale afstand (S) tussen gebruikers en medetreinreizigers vergroot. Dit feit was in tegenspraak met de aard en het doel van ons project, namelijk het creëren van een inclusieve, dus ook sekseneutrale treintoiletomgeving. Een ander uitgangspunt van treintoilet mock-up 1 was dat mannen op hun beurt zouden wachten als het aparte urinoir bezet zou zijn, maar in de praktijk konden ze ervoor kiezen om het familie-zittoilet te gebruiken om staand te urineren, ook al stimuleert het ontwerp zittend gebruik.

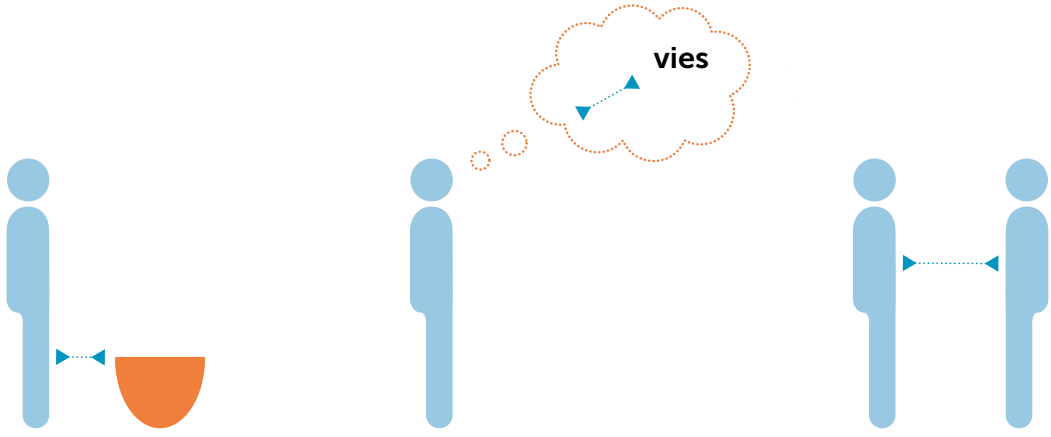
Deze bevindingen leidden tot het ontwerp van treintoilet mock-up 2, dat de elementen van het familie-zittoilet combineerde met die van een urinoir om de drie onderliggende afstanden te verkleinen, namelijk de fysieke, mentale en sociale afstanden (P, M, S) tot respectievelijk het toilet, viezigheid en medereizigers. Dit treintoilet omvatte opstapjes voor kinderen, een babyverschoontafel, extra streunopties en een betere toegankelijkheid voor gebruikers van een rolstoel of rollator.

In **hoofdstuk 8** hebben we de kennis en het ontwerp uit treintoilet mock-up 1 gecombineerd en het nieuwe ontwerp van treintoilet mock-up 2 getest met 147 deelnemers.

Uit de mock-up 2a-tests (n = 33) blijkt dat het urinoir werd geaccepteerd en dat een aantal kleine ontwerpaanpassingen nodig was. Onder meer vanwege het lage aantal respondenten vond onze partner NS de resultaten niet doorslaggevend. Dit resulteerde in een aangepaste mock-up 2b en uitbreiding van de onderzoeksgroep.

In de mock-up 2b-tests verhoogden we het aantal deelnemers (n = 114) en namen we jonge meisjes en visueel beperkte deelnemers op. We hebben ook het urinoir vervuild bij de beoordeling van de acceptatie ervan. Verder hebben we een dubbelblinde test uitgevoerd, waarbij de betrokken onderzoekers geen relatie hadden met de hoofdonderzoeker (auteur), zodat ze in een onafhankelijke positie stonden ten opzichte van de auteur en haar afhankelijkheid van de resultaten. Bovendien werden de onderzoekers niet geïnformeerd over het doel van het onderzoek.

De resultaten van mock-up 2b bevestigden de bevindingen van mock-up 2a en werden door de NS als meer sluitend aanvaard. Het concept van een urinoir in het treintoilet werd geaccepteerd door mensen die het urinoir niet gebruiken, zoals vrouwen en rolstoelgebruikers; dezen erkenden de hygiënische meerwaarde ervan. Er werd een aantal kleine verbeteringen aan het uiteindelijke ontwerp voorgesteld, waaronder een meer gevarieerd gebruik van decoratieve wandbekleding, een veiligere babyverschoontafel, een transparantie deur en de hoogte van een aantal elementen. Verder merkten we op dat de aanwezigheid van een urinoir in de nieuwe treinWC goed gecommuniceerd moet worden, vooral naar de gemeenschap van mensen met een visuele beperking.



a. Fysieke afstand verkleinen (P) tot de faciliteit

b. Mentale afstand verkleinen (M) met betrekking tot viezigheid

c. Het verminderen van de sociale afstand (S) tussen mensen

Het ontwerp verbeterd de beleving van hygiene door het verkleinen van de fysieke (P), mentale (M) en sociale (S) afstanden

In **hoofdstuk 9** stellen we een hygiënemodel van sanitatie voor, waarbij we de kennis toepassen die is opgedaan in de delen A, B en C. In het model beschrijven we Hygiëne (H) als een functie van de Fysieke (P), Mentale (M) en sociale afstand (S). De beleving van hygiëne (H) wordt verbeterd door deze afstanden te verkleinen; deze drie onderliggende

afstanden (P, M, S) zijn met elkaar verbonden, zoals weergegeven in de formule. Verder zijn a, b en c weegfactoren die in toekomstig onderzoek moeten worden bepaald.

$$H = \frac{a}{P} + \frac{b}{M} + \frac{c}{S}$$

Ons uiteindelijke treintoilet ontwerp zorgt ervoor dat de onderliggende fysieke (P), mentale (M) en sociale (S) afstanden van de treinWC-gebruiker tot toilet, viezigheid en treinreizigers worden verminderd dankzij de volgende ontwerpkenmerken: de toevoeging van een urinoir naast een familie-zittoilet; extra elementen voor kinderen en baby's; ondersteuningsopties; natuurlijke wanddecoratie met grote spiegel; en het schuine urinoir. Het treintoilet is afgesloten door een gekromde schuifdeur.
Na voltooiing van het project hebben we de NS het volgende aanbevolen:
Een urinoir gecombineerd met een zit-toilet, uitgerust met extra handsteunen, inclusief horizontale en verticale steunopties, en steunplatforms voor kindervoeten, moet worden geïntegreerd in treinWC's, die worden afgesloten door een brede (gekromde) schuifdeur, ter verbetering van de gebruikerservaring en hygiëne.

Tot slot: dit treintoilet-ontwerp wordt momenteel geïmplementeerd in NS intercitytreinen**.**

NS treinWC ontworpen door de auteur in samenwerking met NS momenteel geïmplementeerd in intercity's

Figure 1.1 Public toilets are perceived to be dirty ©Astrid Keizer-Huijsing

Chapter 1
Introduction

Humans are in transit, travelling by train, and they may need a toilet on the go. It is the availability, accessibility and hygiene of this toilet that enables us to move "away from home" (Bichard, Hanson, and Greed 2005; Greed 2006; van Oord 2010, 13; DTO 2018; BTA 2019). It is "a public necessity" (George 2008: p.129-147). However, due to the lack of (accessible and clean) public toilets, some people decide to stay at home; it restricts how far they can travel from home, referred to by Kitchin and Law (2001) as "the bladder's leash". Others try to avoid the few (accessible) public toilets they encounter along their way. This is because, as figure 1.1 illustrates, people perceive public toilets to be dirty (Schmale 2017; DTO 2018; BTA 2019; Maag lever darm stichting 2019; HogeNood 2019).

A train toilet, a moving public toilet, suffers from the same problem. Even more so, because many different people use these toilets intensively to perform all kinds of (conflicting) personal hygiene practices in an anonymous, moving, confined and gender-neutral environment. As a result, train toilets become soiled; moreover, they are infrequently cleaned.

Human sanitation covers many 'human life' issues such as health, mobility, social, gender equality including trans-people, safety and privacy. In the realm of public sanitation, these issues are mainly reflected in the structural lack of public toilets that are accessible and hygienic (Aquatech 2019; WTO 2019; UN, n.d.).

The lack of toilet provision on public transport systems, and at train and bus stations is a barrier for many to move away from their homes (Greed 2003; Sanchez de Madariaga and Zuchini 2019). For certain groups of travellers, train travel itself forms a barrier. This group can have difficulty with the (steep) stairs, bridging the wide platform gaps when boarding the train, and are afraid of falling due to the movements of the train (Cavanagh and Ware 1990; Steenbekkers and van Beijsterveldt 1998; Buzink et al. 2004, 2005; Dekker et al. 2007).

At the time of starting this thesis, the main problem to be addressed was the poor hygienic conditions of the Dutch train toilet, a moving public toilet. Dutch train travellers complain about the poor hygiene in train toilets, and 83% say that they try to avoid using them (NS Omnibus 2Q 2009; NS Omnibus 2 2009; Loth and Molenbroek 2011).

For grandmothers and baby-boys, a dirty train toilet is a barrier to travel. They are part of a range of traveller-groups which have different needs and habits regarding toilet use. These include people with restricted mobility, older adults, and families with younger children (see chapter 3), who often travel with additional mobility aids such as wheelchairs, rollators, and strollers (Cavanagh and Ware 1990; Greed 2003; Molenbroek, Mantas, and de Bruin 2011; Sanchez de Madariaga and Zuchini 2019). They make more intensive use of the toilets.

Travellers' dissatisfaction with the train toilet is reflected in table 1.1. It shows that passengers in research conducted by Dutch National Railways (NS) assessed the cleanliness of elements related to train toilets as poor: an average of 4.7 on a scale of 1-10 (1=very bad, 10=very good). At the same time, they considered the same elements to be important, with an average of 8.2 (1= very unimportant, 10= very important). The colour red indicates an insufficient assessment: (< 6 (threshold).

The respondents' score for the cleanliness of the train toilet was somewhat milder after using the toilet during the study; see the ratings in brackets in table 1.1 (average cleanliness: 5.2; average importance: 7.8). This suggests that the reputation of the hygiene in a train toilet is worse than the opinion about the actual hygiene after usage, see table 1.1 (NS 1 2007).

Element	Number of respondents n:	Average importance	Number of respondents n:	Average rating
Interior as a whole	3569	7.9	4060	7.0
Outside of the train	3759	5.4	3886	6.5
Floor	3777	7.3	4272	7.7
Seats	3788	8.9	4255	7.2
Table	3775	8.3	4205	7.2
Trash bin	3763	7.8	4216	6.6
Luggage rack	3755	6.8	3897	7.5
Walls	3760	7.2	4212	7.2
Windows	3763	7.5	4266	6.3
Glass of the doors	3786	7.1	4226	6.8
Floor in toilet	3731 (197)	8.1 (7.0)	3903 (214)	4.5 (4.9)
Toilet bowl	3723 (197)	8.8 (8.1)	3085 (214)	4.2 (4.8)
Mirror	3703 (197)	7.6 (7.6)	3050 (214)	5.0 (5.6)
Wash bowl	3697 (197)	8.2 (8.1)	3069 (214)	4.8 (5.4)
Other sanitary facilities	3702 (197)	8.3 (8.1)	3058 (214)	4.9 (5.5)

Table 1.1 Rating cleanliness of train interiors: elements relating to the train toilet are assessed as insufficient (NS 2007)

This assessment of the cleanliness of the train's interior, of which a third can be attributed to the train toilet, is part of a quarterly customer satisfaction survey, in Dutch: klanttevredendheidsonderzoek (KTO). NS's services are assessed on seven determinants: train travel in general, punctuality, availability of seats, the social safety of the train and the station, the cleanliness of the train's interior (table 1.1), customer services, and, lastly, accurate information about calamities (Schreurs 2005).
Table 1.1 provides insights into which aspects require improvement. The KTO is an instrument that enables the government to monitor NS's performance. To achieve this, the government works with a bonus/malus system in which the amount of the bonus or malus depends on the extent to which it has scored above or below the target values. For example, in 2019 NS received a bonus of €6 million and its partner responsible for the railways was fined €75,000 because of bottlenecks on the track (it achieved a score of 5.4 under the threshold of 6) (van Veldhoven-Van der Meer 2020).

Ensuring the cleanliness of the train toilet is a complex issue, so in 2009 a collaborative project was initiated together with TU Delft Faculty of Industrial Design Engineering. A year later, in 2010, the train toilet was excluded from the yearly experience monitor (a different yearly indicator than the KTO). However, at the Ministry's request, the train toilets were re-introduced in the experience monitor in 2012 (Treinreiziger.nl 2012). In recent years, the 'KTO' ratings gradually improved and in 2018, NS received a sufficient grade for the cleanliness of the train toilet. The fact that the level of cleanliness has improved is mainly related to the increased quality of the cleaning.

To improve toilet hygiene, toilets need to be cleaned regularly (Messing, Haentjens, and Doniol-Shaw 1992; Greed 2006). Furthermore, frequent cleaning can prevent the negative spiral that 'dirt attracts dirt' (Wilson and Kelling 1982; Cialdini, Reno, and Kallgren 1990; Kallgren, Reno, and Cialdini 2000; Dur and Vollaard 2014). However, public toilets are not frequently cleaned, often for financial reasons (Kira 1976; Greed 2003); this is also true for cleaning Dutch train toilets. Moreover, cleaners are supposed to clean them within two minutes (BNN-Vara 2017; Andersen 2018), which seems insufficient for proper cleaning. Only in automated toilets does cleaning occur after each usage. This seems ideal, but it is not attractive for everyone to be in a machine like in a car wash. In addition, customer rate the cleanliness of automated toilets in stations as insufficient (information provided by ProRail).

To improve cleanliness of toilets at the station, ProRail (partner of NS) added a pilot system whereby the customer can give 'real-time feedback' immediately after use (NS 2018a, 2019, 21). Schiphol Airport also works with a similar system (figure 1.2).

Figure 1.2 Schiphol public toilet facility hygiene monitor

Another important factor is that the cleaning profession worldwide has a low status. In India for example, cleaners belong to the 'untouchables,' from whom people distance themselves as far as possible (Dellström Rosenquist 2005; George 2008). Moreover, cleaning is an arduous task. Cleaners, particularly women, suffer from muscular issues because they adopt a variety of postures when cleaning train toilets (Messing, Haentjens, and Doniol-Shaw 1992). It would benefit toilet hygiene if the profession of cleaning toilets, or removing dirt in general, was rendered more appealing or given a higher social status.

It seems that we desire clean public toilets, but do not really aspire to keep them clean. Exceptions are found in a few sectors such as Schiphol Airport and 2theloo, as toilet hygiene leads their policy. However, a majority responsible for the availability of clean public toilets keep them at a distance, as do their users. In cities like London and New-York, but also in Rotterdam and Amsterdam, public toilets are being removed. Vandalism and growing repair and cleaning costs have reduced the number of public toilets in the UK by 40% in ten years. There is no legislation that forces urban authorities to provide their residents and visitors with sufficient public toilets (Greed 2006; George 2008; van Oord 2010). This lack of legislation is being challenged by institutions like Hoge Nood, Maag Lever Darm stichting, and others that have joined forces in the toilet alliance, and internationally by the British Toilet Association and World Toilet Association (HogeNood 2019; [Digestive Diseases Foundation] Maag lever darm stichting 2019; BTA 2019; WTO 2019; [Toiletalliance] Toiletalliantie 2021).

City	Number of public toilets	Number of male urinals	Number per inhabitants
Amsterdam	3	35	1: 270.000
Antwerp	3	28	1: 170.000
Berlin	177	15	1: 20.000
Paris	170	1	1: 15.000

Table 1.2 Number of public toilets in European cities. Source: NOS (2017)

Amsterdam, the capital of the Netherlands, has the least public toilet facilities compared to other European cities: 35 public toilets for men and three for women that are open 24 hours a day, see table 1.2. In Paris, 'the former capital of urinals', toilet maintenance was changed from human-cleaning to APCs (automatic public convenience) equipped with sit-toilets instead of urinals; these toilets are automatically cleaned after each use (Möllring 2003), see table 1.2.

In moving trains, a self-cleaning toilet such as an APC could make a promising contribution to improving hygiene. However, people face difficulties in understanding and operating APCs due to unfamiliarity with such systems (Bichard, Hanson, and Greed 2005). The robotic quality contradicts the humanity of toileting. Besides, these refined high-tech automatic solutions with a water and soap system seem unsuitable for a moving train environment that can be prone to malfunctions. Despite the technical ingenuity behind APCs (Möllring 2003), they undermine the usability of toilets, which contrasts with the purpose of this project. One of the project's chief objectives is to improve usability and access to train toilets so that train travellers encounter as few barriers as possible. As a consequence, the self-cleaning solution was not included in this project. However, in India, they adopt an automatic approach towards train toilets: www.youtube.com/watch?v=faFPT_vR7MA.

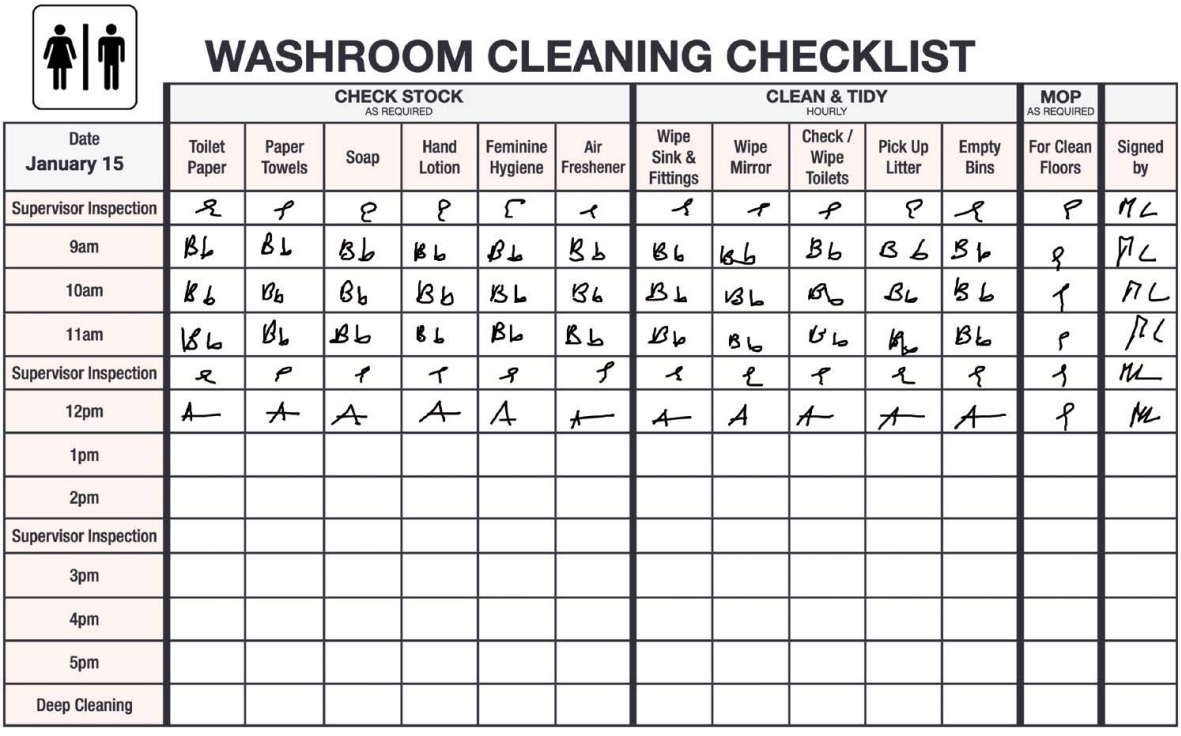
In brief, the main reason why public toilets, including train toilets, become soiled, is that they are intensively used and not frequently cleaned. However, users also play a role in keeping the toilets clean: this is the knowledge gap on which this study focuses. This study addresses how Dutch train passengers use train toilets and how their usage affects hygiene (cleanliness). Furthermore, this research has been constructed to inform design, i.e. how the design of train toilets can improve the usability and related hygiene so that users can leave the toilet cleaner and tidier for the next user.

1.1 Hygiene

Hygiene, as a concept and word, comes from the ancient Greek goddess of Health 'Hygieia' in the 5th century B.C. She 'represented intelligent wholesomeness, purity and well-being' (Smith 2008). They referred to "ὑγιεινή (τέχνη) hugieinē technē": the 'art' of health (Service management 2019). Hygiene is omnipresent and closely related to health and is defined as: "the practices of personal cleanliness that lead to good health" (Winblad and Kilama 1985).

In general, a (public) toilet environment in the Netherlands is perceived as being a reasonably safe place, given the value of the sewage system, the possibilities to perform personal hygiene practices such as hand washing, and fairly regular cleaning (Gerba, Wallis, and Melnick 1975; Hughes 1988; Reynolds et al. 2005). Thus, in fact, the perception could be that public toilets are 'hygienic enough'.

However, public toilets are nevertheless perceived as being unhygienic. A main reason for this is that a toilet is a spot where human waste such as faeces, urine and blood are excreted; the materials that we consider as 'dirty' (Curtis 2007). In addition, they are considered places where the 'journey of diseases' can start (Rheinbaben et al. 2000). Moreover, the fact that 'strangers' are involved reinforces the perception of dirtiness because of the emotion of disgust (Curtis, Aunger, and Rabie 2004; van der Geest 2007). Another factor is that toilet users are often unaware of when the toilet was last cleaned. In a reaction to this, cleaning sheets have become more common, like at Schiphol Airport, to inform users when the toilet was cleaned (figure 1.3).



WASHROOM CLEANING CHECKLIST

	CHECK STOCK AS REQUIRED						CLEAN & TIDY HOURLY					MOP AS REQUIRED	
Date January 15	Toilet Paper	Paper Towels	Soap	Hand Lotion	Feminine Hygiene	Air Freshener	Wipe Sink & Fittings	Wipe Mirror	Check / Wipe Toilets	Pick Up Litter	Empty Bins	For Clean Floors	Signed by
Supervisor Inspection													
9am													
10am													
11am													
Supervisor Inspection													
12pm													
1pm													
2pm													
Supervisor Inspection													
3pm													
4pm													
5pm													
Deep Cleaning													

Figure 1.3 Information to the users of the toilets about cleaning shifts

We share the toilet with unknown people to do something we prefer to do privately which implies a *contradictio in terminis* (Gershenson and Penner 2009). We can be confronted with their dirt, which is an invasion of our privacy. It entails an undesired intimacy, which reinforces the perception of dirtiness (van der Geest 1998, 1999, 2007).

In the Roman period around 100 BC, toilets were social places to meet and greet (figure 1.4). Buttocks were cleaned with a "communal sponge-on-a-stick ("xylesphongia"), "the Roman equivalent of toilet paper". They rinsed these sponges in between uses in the fresh water of the small gutter that streamed by their feet (Lambton 1995; Kamash 2010, 50). In the 17th century, Louis 14th received his guests while he sat on his private latrine and performed his defecation as a grand gesture of honour (Parent 1987). These situations are unthinkable in today's Western society. Toilets have been transformed into individual spots where an "aura of embarrassment" prevails (Elias 2000, 152).

Figure 1.4 In the Roman times, the usage of a toilet fulfilled a social activity. Photo Mirjam Bril

To get a grip on the universal phenomenon of hygiene, we had to determine what the opposite of hygiene is. We termed this dirt: "Dirt is as a matter out of place" (Douglas 1966, 36). Zooming in on what kinds of dirt may be present in the environment of train toilets, two types can be distinguished. Firstly, dirt connected to the human body, which is considered as extremely dirty; for example urine, faecal or blood remains or hairs (Curtis and Biran 1998; Reynolds et al. 2005; Greed 2006). Secondly, dirt connected to the toilet environment; for example muddy water, pieces of toilet paper and hand paper. The absence of these items in the toilet 'are believed to indicate high hygiene standards', and these standards are becoming even stricter (Elias 1982; Drangert et al. 2003; Drangert 2004; Dellström Rosenquist 2005; Elias 2000b). Whatever we do, dirt will remain in the toilet environment after usage. People may not notice this or are not sufficiently engaged to remove it for the next user. It would be optimal to remove the user's dirt immediately after usage. Possible solutions for this are just-in-time cleaning by cleaners, automatic cleaning, or by the users themselves.

1.2 Hygienic Train Toilet (HTT)

Who

This PhD project was initiated in 2009 as a cooperation between Delft University of Technology (TUD) and Dutch National Railways (NS) in an attempt to change the undesirable situation of dirty train toilets that affect people's willingness to travel by train. A reason for NS to participate in this project was to improve their service in

'Intercity' trains by prioritising hygiene in train toilets for longer journeys. Industrial Design Engineering (IDE), a TUD faculty, supported the PhD project to enhance train toilet hygiene through design. IDE has three research programs directly linked to three departments: (1) Human-Centered Design (HCD): *people*, (2) Design, Organisation and Strategy (DOS): *organisation*, and (3) Sustainable Design Engineering (SDE): *technology*. Designing design is our core value.

Funding was granted by the Netherlands Enterprise Agency (https://english.rvo.nl), formerly known as SenterNovem. Our project matched their mobility management programme, which aims to encourage people to use the infrastructure in the Netherlands as an alternative to travelling by car (Overheid.nl 2008).

We argued that passengers would feel more comfortable when travelling by improving the hygiene of train toilets. This approach could remove a potential barrier to train travel for specific traveller groups, e.g. older adults, especially those with mobility problems, and families with younger children (SenterNovem 2007, 2008; Overheid.nl 2009).

The Dutch National Railways (NS) has been a major player in the mobility of the Netherlands since 1839. In 2019, NS transported 1.3 million passengers daily, the largest growth since 2008 (NS 2018b). They calculated that only a fraction (500 travellers) would use the relatively expensive toilet infrastructure system (€90 million and €310,000 per system). For example, in the Dutch NS Sprinter trains, toilets replace the seats that passengers desire, and obstruct the view. The toilet therefore hinders social safety and passenger flows when getting on and off the Sprinter. Moreover, it seems that passengers do not really care about the toilets; they are frequently destroyed and soiled, which leads to extra costs for cleaning, maintenance, and repair. As a result, the NS decided to remove train toilets from the Sprinter trains as these are intended for short journeys. They assumed that a toilet would not be necessary for short trips, given their many drawbacks. In other forms of short-term public transport like buses and subways, no toilet is on board either.

However, practice has revealed that sometimes a situation arises when a traveller unexpectedly needs to urinate. Since 2018, the new Sprinters are gradually being re-equipped with toilets (NS 2011; Dutch Ministry of Infrastructure and the Environment 2015; NOS 2018).

Where and what

We approached the project at three levels: the TUD faculty (IDE), the Human Centered Design department (HCD) and the Applied Ergonomic Design (AED) section. Humans are central and the *human-product-interaction* was examined (Molenbroek and van Eijk 2005).

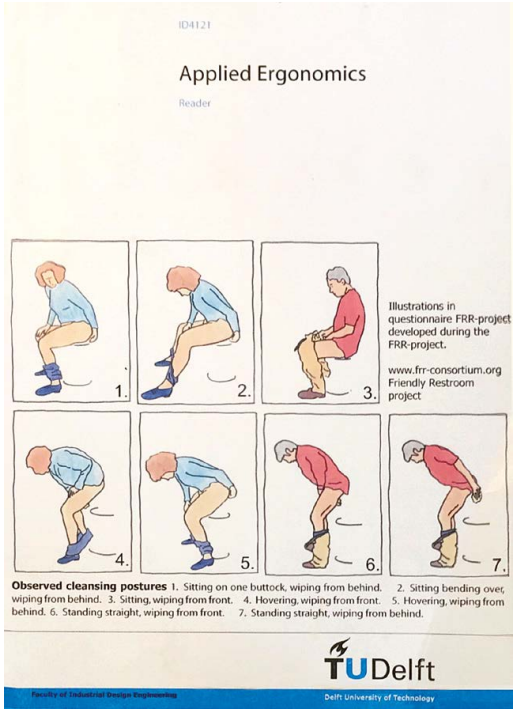


Figure 1.5. Cover of Applied Ergonomics

At faculty level, this project fits in with the social theme 'Mobility' and is one of the three research themes, Health and Sustainability being the other two. We approached it from the perspective of usage, comfort and safety (tudelft.nl 2020b, 2020a, 2013). In this thesis we examine hygiene as an independent phenomenon and evaluate the interdependency with usage. While hygiene has a relationship with both phenomena of comfort and safety (Vink and Brauer 2011), the safety experience of a train toilet is a condition to be able to use it (Van Hagen 2011). In parallel with the terms comfort and discomfort (Vink and Overbeeke 2005; Vink and Hallbeck 2012), we use the terms hygiene, and 'unhygiene', having defined the latter as *dirt*.

1.3 Aim of the thesis

Few studies have examined primary toilet use (i.e., urination and defecation) (Kira 1976; Rawls 1988; Greed 2003; Möllring 2003; van der Geest 2007; Williams 2009; Molenbroek, Mantas, and de Bruin 2011). These studies concern stationary public toilets. We could not find sources on the usage of train toilets in a moving environment. It is apparently about time to add ergonomic train toilet knowledge to Alexander Kira's pioneering work.

This dissertation aims to determine how design can improve the cleanliness of train toilets. The focus is on train toilets in Dutch trains and how train toilet usage affects hygiene. The central research question is therefore: **How does design influence train toilet hygiene?**

Design for sanitation

Even though hygienic problems have been identified and explained in sanitation and human hygienic behaviour, solutions in this area seem inappropriate and unattractive for usage. Design solutions are often technological and water-driven. At the same time, human usage of the toilets seems to be neglected. Therefore, this dissertation aims to complete the knowledge gap by generating ergonomic information about (train) toilet usage in relation to hygiene and in this way, to serve as input for an improved hygienic train toilet design.

Since the phenomenon of hygiene is a human 'life issue' and is therefore interpreted as a broad phenomenon, in this dissertation we studied its counterpart, namely the phenomenon of dirt. People do not really want to be involved with sanitation as they consider it a dirty matter. In other words, they keep a large distance from it. We researched train toilet usage to investigate how train passengers engage with their personal hygiene in the context of train travel. The research model shows the interaction between the 3T's: travellers (personal hygiene), toilet (product hygiene), and the train (environmental hygiene), figure 1.6.

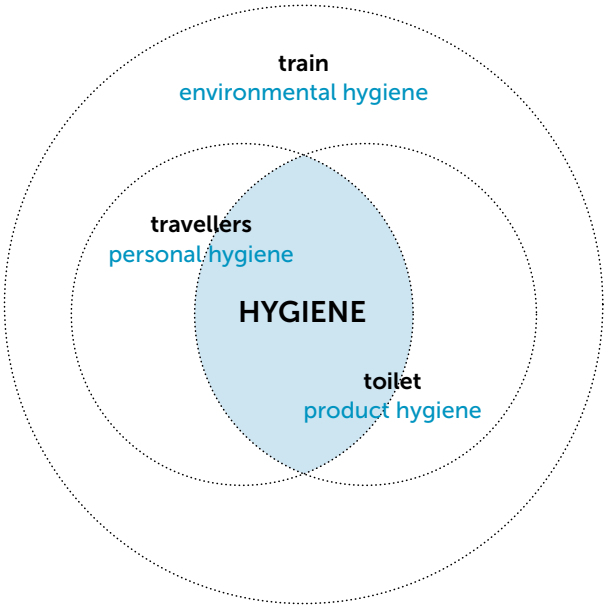


Figure 1.6. Research model

1.4 Research questions

The research is divided into three parts. Each part provides knowledge for the next:
Part A is a theoretical exploration of the broad concept of hygiene and, based on a questionnaire, a study of travellers' personal hygiene needs and toileting usage in the context of train travel.

Part B uses this knowledge in experiments that study the interaction between toilet usage and hygiene.
Finally, part C translates the resulting knowledge into a physical design to draw up specifications for a hygienic train toilet. The study aims to answer the following research questions:

PART A: LITERATURE AND SURVEYS

RQ A: Why are train toilets perceived as being dirty?

Chapter 2 Hygiene in public toilets: a literature review:
RQ A1: What has been researched in public/train toilets and hygiene domain?

Chapter 3 Train travellers' needs and usage of the toilet: a questionnaire
RQ A2: How does train travel affect train toilet users' needs and usage?

PART B: EXPERIMENTS

RQ B: How does its usage affect train toilet hygiene?

Chapter 4 Hand luggage in the train toilet
RQ B1: What do travellers do with their hand luggage when using the toilet?

Chapter 5 Observing urination in moving trains
RQ B2: How do train movements affect urination performance?

Chapter 6 Reducing the spilling of urine
RQ B3: How can urine spillage be reduced when using a urinal?

PART C: DESIGN

RQ C: What are the implications for design of a hygienic train toilet?

Chapter 7 Mock-up testing 1: a separate family sit-toilet and urinal
RQ C1: What are the implications for design through mock-up testing 1?

Chapter 8 Mock-up testing 2: a combined train toilet of a family sit-toilet and urinal
RQ C2: What are the implications for design through mock-up testing 2?

CONCLUSION

RQ How does design influence train toilet hygiene?

Chapter 9 Conclusions and recommendations

1.5 Methods

Several research methods were used to tackle the research questions, see appendix A.1.1 for an overview. We reviewed internal NS surveys and researched the literature using the 'snowball' method (chapter 2). An online questionnaire was set up. Train travellers (n=1267) were approached via the NS panel in which the needs and usage routines of train toilet users were questioned (chapter 3). Six master students graduated as part of this project: van Oord (2010); van Dijk (2010); Louts (2011); van den Meiracker (2011); Buizer (2014), Rosendahl (2014). Louts (2011) conducted post-toilet use observations. He counted how many train travellers used the toilet during a whole day's travel through the Netherlands, and secretly inspected how clean they left the toilet behind.

The author attended a number of NS focus groups sessions related to train toilets at research agency Arachnea (arachnea.nl). Furthermore, the research team used the 'research through design method' in the field of ergonomics (Dul et al. 2012; Stappers and Giaccardi 2017; Van Boeijen, Daalhuizen, and Zijlstra 2020).

A design development process (of a physical product, a service or an app) consists of a series of divergences (explorating) and convergences (focusing) with iterations in between. For this thesis, we first explored; we gained a thorough understanding of the problem to be solved from a human (user) perspective (Human- Centered -Design) using literature, surveys, and experiments. This in turn led to the programme of requirements. Subsequently (design), a focus that results in a programme of requirements. We then determined the functional specifications of a hygienic train toilet. The resulting knowledge was translated into three concepts/ mock-ups, which were tested with 173 participants, resulting in an appealing design proposal which improves toilet usability (and the related hygiene) in the way the designers determined through their research. The final product will, of course, be different in practice.

Observational research of participants using cameras forms the principal part of the experiments (part B) and assessments in the various mock-ups (part C) 'Observation before innovation'. This method minimises the extent of interpretation or missing information in which people use the toilet, characterised by a wide variety of routine actions and movements. Using this method, all actions are directly recorded. In contrast, other research methods such as questionnaires, manikins, or drawings through which people can also express their toilet usage only reflect this indirectly (Molenbroek, Mantas, and de Bruin 2011: p.xi, 69-79, 187, 202). Therefore, observational research offers the opportunity of capturing 'second nature' practices through video recordings (Bichard, Hanson, and Greed 2005, 2; Curtis et al. 2003; Kanis and Rooden 2005; Molenbroek, Mantas, and de Bruin 2011).

In brief, the project used a range of research methods. Approximately 80 IDE students were involved as researchers, allowing the project to be conceived from different angles.

1.6 Structure of the thesis

This thesis describes the three research parts and is divided into nine chapters (see figure 1.7).

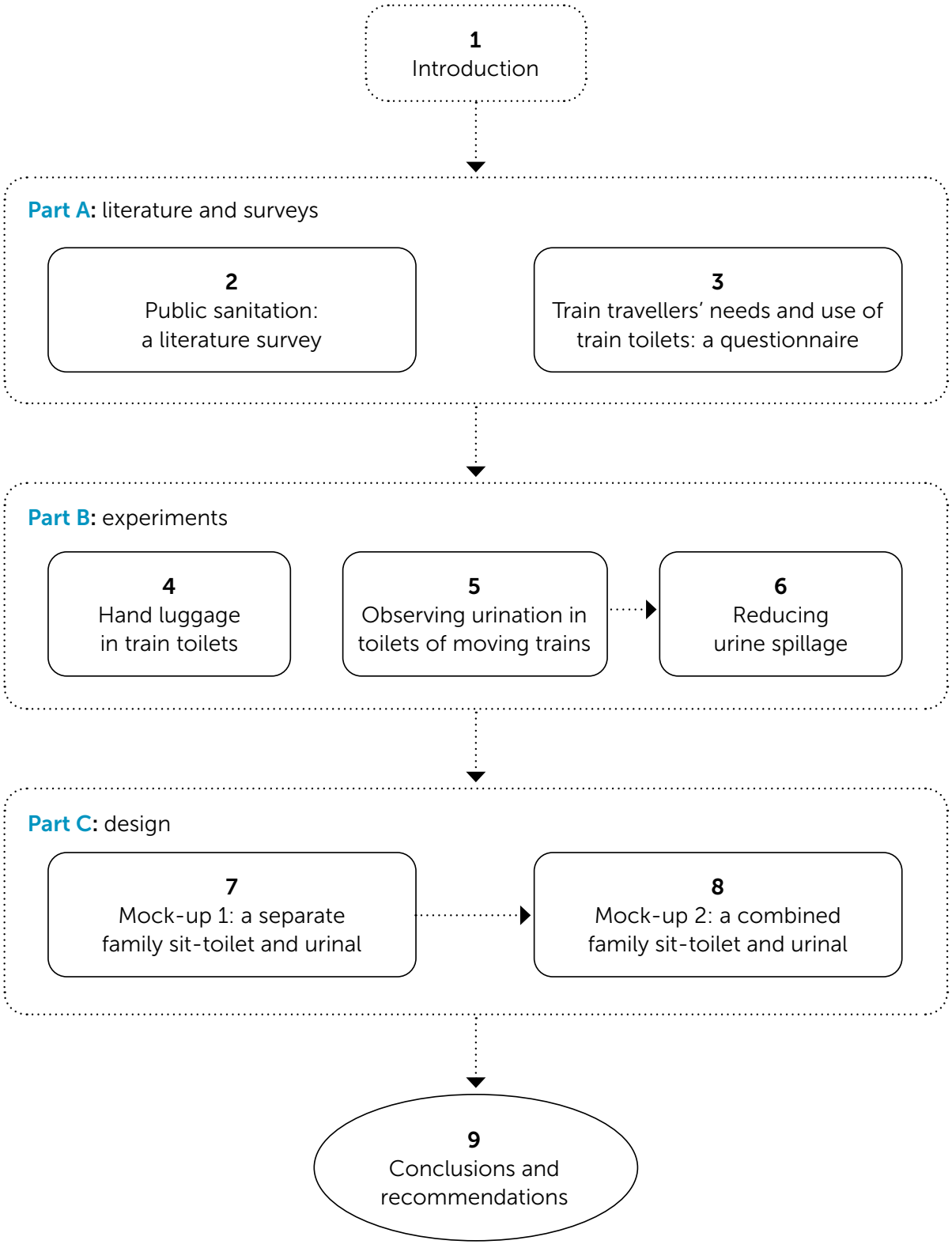


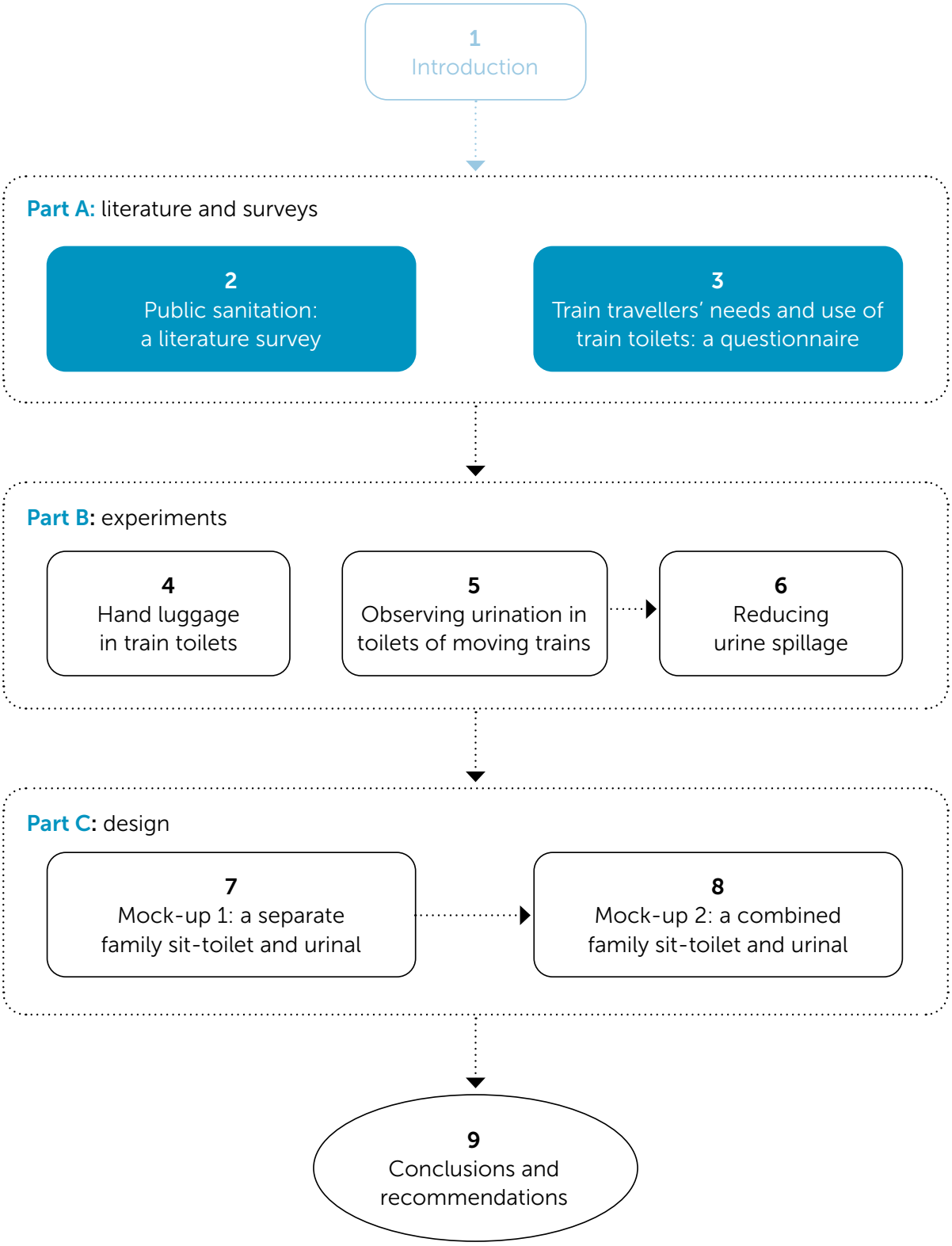
Figure 1.7. Outline of the thesis

In Part A, chapter 2, we present a literature survey of the themes of sanitation, and the history of public hygiene and toilets. Internal NS studies in the field of train toilets are also included. Chapter 3 presents the results of a questionnaire in which 1267 train travellers described their needs and use of toilets in the context of train travel.

The results of part A set the scene for the experiments in Part B. The 'umbrella' for these experiments were 'real' observations of 41 participants to explore how they used the train toilets in moving trains. Ethical approval with informed consent was obtained, while the privacy of the participants was safeguarded (Appendix A.5.1). The focus of these observations was on hand luggage (chapter 4) and urination (chapter 5) in train toilets. Chapter 4 addresses the issue of carrying hand luggage, a typical characteristic of travellers. The questionnaire in chapter 3 revealed that a visit to the train toilet with (hand) luggage could be such a problem that it forms a barrier to using it. In chapter 5, we show how people urinate in train toilets, the main reason why people use toilets. We found that train toilet users frequently urinate outside the toilet bowl. Therefore, in chapter 6 we analysed the types of soiling caused by urine streams in a number of experiments. We also describe the results of experiments with urinals and backsplash. Lastly, we reviewed the stability of the human body while standing at a urinal to understand how to better withstand the forces caused by the movements of the train and direct the stream of urine more accurately.

Finally, Part C presents the design development of three mock-ups in chapters 7 and 8. We conducted research through ergonomic design in which ergonomic observations were made in a test setup involving 173 participants, including wheelchair and walker users, visually restricted participants, and children.

Chapter 9 completes the thesis with conclusions and recommendations for further research.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Introduction
Part A: literature and surveys
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Public sanitation:
a literature survey
3
Train travellers' needs and use of
train toilets: a questionnaire
Part B: experiments
4
Hand luggage
in train toilets
5
Observing urination in
toilets of moving trains
6
Reducing
urine spillage
Part C: design
7
Mock-up 1: a separate
family sit-toilet and urinal
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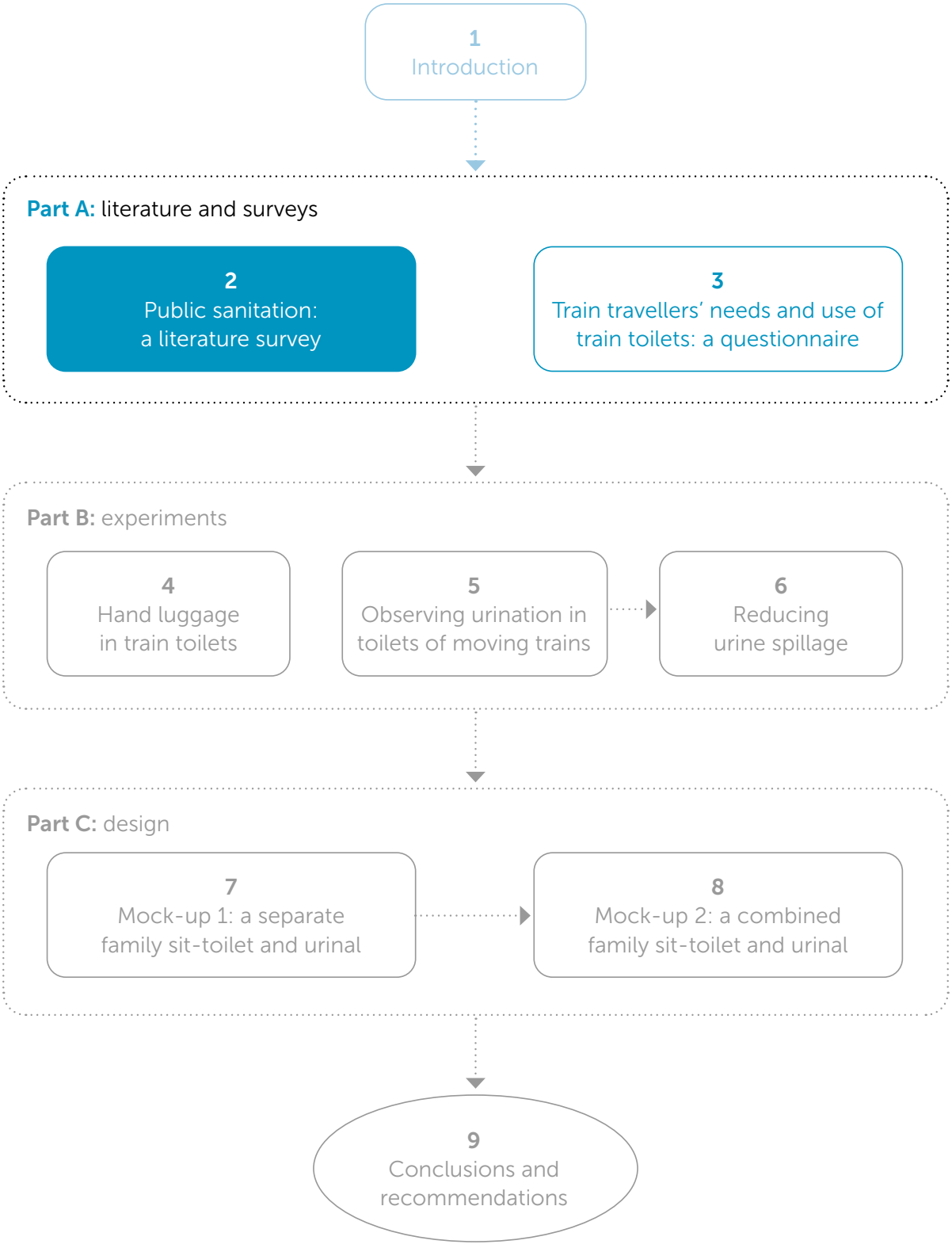
Mock-up 2: a combined
family sit-toilet and urinal
9
Conclusions and
recommendations

Part A: literature and surveys

Introduction

This dissertation is divided into three parts as illustrated above.
In part A, we set out to answer the research question: **'Why are train toilets perceived as being dirty?'**

The research process and findings answering the two sub-questions of part A are discussed in chapters 2 and 3. In chapter 2 we answer the sub-question **A1: 'What has been researched in public/train toilets and hygiene domain?'** with a review of the literature on sanitation and the history of hygiene in relation to public toilets. Furthermore, it describes the surveys of the Dutch National Railways (NS), in particular, the findings of their customers. Subsequently, in chapter 3, we place the needs and usage of train toilet users in the context of train travel. Together with the NS, we designed an online questionnaire that was sent out to the NS travellers' panel to answer sub-question **A2: 'How does train travel affect train toilet users' needs and usage?'**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Chapter 2
Public sanitation: a literature survey

2.1 Introduction

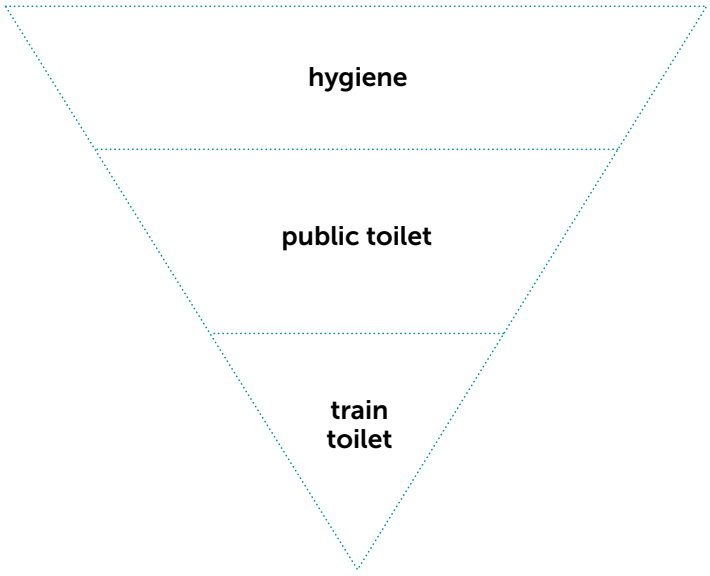


Figure 2.1 Literature search model

In this chapter, we provide an overview of what has been researched in the field of public hygiene, including train toilets. This sets the scene for addressing **research question A: why are train toilets perceived as being dirty?**

In section 2.2, we highlight the hygienic conditions in developing countries to illustrate the "big necessity" of a WC (George 2008). In section 2.3.1, we describe the history of the phenomenon 'hygiene', in other words, the changing environment of the past four thousand years in which personal hygiene has been performed. In section 2.4, we illustrate the history of the 'product' toilet, from private, to public. Section 2.4.2 specifically covers the train toilet, its history, and NS (Dutch Railways) studies on train toilets. In section 2.5, we review studies by Kira (1976) and the "Friendly Restroom" project by Molenbroek et al. (2011), who also conducted experiments on toilet usage.

The information from the literature review was non-specific and thus difficult to implement in this design research project. Therefore, in section 2.6, we used the snowball method for two critical sources of the literature survey: Greed (2003), and

George (2008), which led in 2.6.1 to an analysis of books by Douglas (1966) and, in 2.6.3 by Elias (1982, 2000). Mary Douglas introduces the term 'dirt', and Norbert Elias shows the background to why we are increasingly *distancing* ourselves from toilets. Both books helped provide direction to our research.

Following the introduction of the concept of dirt (2.6.1), we make a leap to a very fine level of dirt in section 2.6.2, namely microbiology. Subsequent, in 2.7, we discuss human behaviour in relation to litter. Finally, we close the chapter in section 2.8 with conclusions and recommendations. Figure 2.1 provides a framework for the literature review.

2.2 Sanitation

Sanitation is a principal instrument to protect health and therefore to break the vicious cycle of poverty (Bartram et al. 2005; Mara et al. 2010). Adequate sanitation includes access to safe facilities for the management of human waste (urine, faeces) in the form of toilets and latrines, as well as water for drinking and washing hands (WHO and Unicef 2017; WHO 2018; WTO 2019). Humans have a basic need: nutrition; the product that collects and disposes of the excreted nutrition is also considered a basic need (figure 2.2).

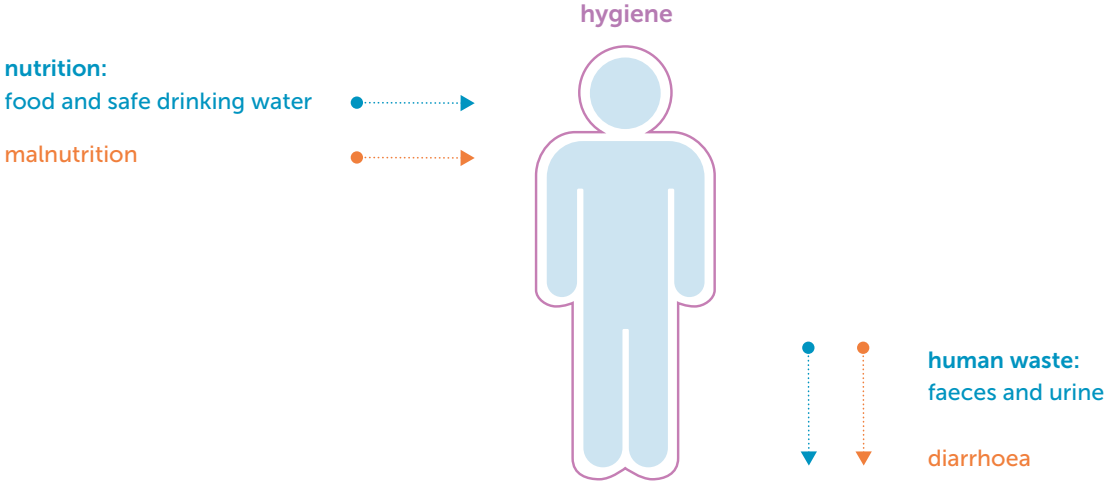


Figure 2.2 Hygiene and toileting

Accordingly, in 1980, the World Health Organisation (WHO) announced that in 1990, everybody should have access to proper toilet facilities (van der Geest 1999). Subsequently, the UN gave sanitation a prominent place in the achievement of the Millennium Goals. They declared 19 November to be World Toilet Day and the year 2008 as International Year of Sanitation (UN water 2008; UN 2019b). Furthermore, the Bill and Melinda Gates Foundation initiated the "Reinvent the Toilet Challenge" (RTCC). For example, they invited eight universities, including TU Delft, to develop solutions to improve sanitation in developing countries (TU Delft 2011; Gates foundation 2009-2019.; Melgarejo 2012; Rosendahl 2014). The Millennium Development Goal (MDG) for drinking water to halve the proportion of people without access to safe drinking water by 2015 has succeeded

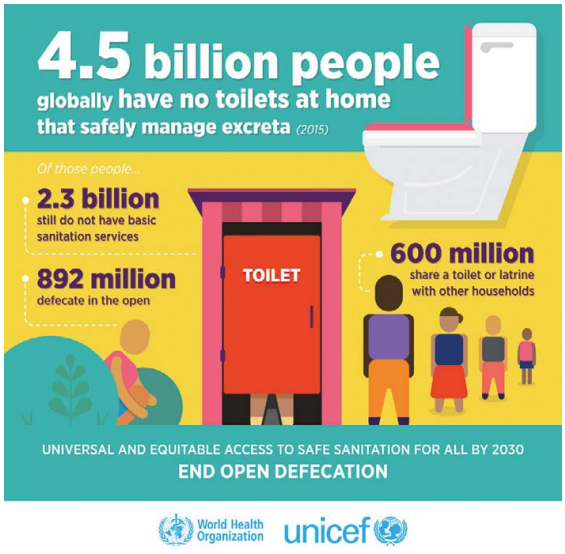


Figure 2.3 The status of sanitation in 2015

(UN 2019). However, the sanitary targets are still 40 years behind the target set (figure 2.3).

Of the world population in 2020 of 7.8 billion people, one third - 2.3 billion people - still lack access to basic sanitation facilities such as toilets and latrines. Of these, 892 million have to urinate or defecate under the sun and the stars ('open defecation'). As a result, in developing countries, diarrhoea is the primary cause of death: the highest hurdle a child needs to jump. It starts with the bacteria in the faeces that humans deposit on fields and in gutters that eventually ends up in the drinking water. In addition, no taps are available to wash hands after using the toilets. Furthermore, some women in India run the risk of being raped during their nightly hike to defecate in the open air, which strengthens them to suggest to their future groom to offer a toilet as a dowry. Girls in South Africa miss education when they start menstruating because they prefer to stay at home under better hygienic conditions (Curtis 1998; Bartram et al. 2005; UN water 2008; Water, n.d.; Cairncross et al. 2010; Bartram and Cairncross 2010; Rosendahl 2014; UN 2015; Greed 2016; WTO 2019).

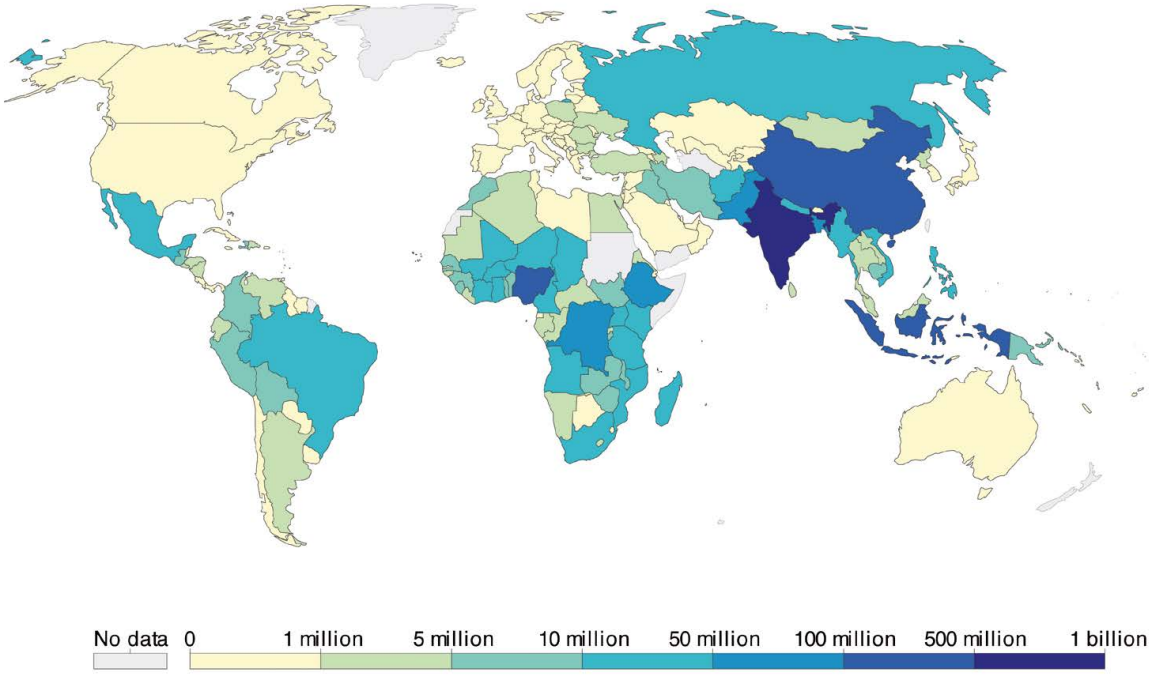


Figure 2.4. Number of people without access to improved sanitation, 2015
Source: Our World in Data based on the World Bank, World Development Indicators

These examples show that the poor hygiene provided by sanitation facilities (figure 2.4) undermines humans' position in the less developed areas of our planet. As a result, they face health, poverty, safety, gender equality, and education problems (Dellström Rosenquist 2005; Bartram and Cairncross 2010; Rosendahl 2014; UN 2015; Aquatech 2019; WTO 2019).

The quality level of sanitation reveals the contra-distinction between developed and less developed countries (Bartram et al. 2005; Bartram and Cairncross 2010; Cairncross et al. 2010). Despite the considerable differences, residents in developing countries and Dutch train travellers share a commonality: they maintain *a distance* from their public toilet facilities because they perceive them as dirty. As a result, they opt for radical alternatives. People from less developed areas prefer using their land as a toilet; they practice 'open defecation' (WTO 2019). In contrast, Dutch train travellers, particularly older adults, choose to use their own toilet at home. As a consequence, the dirty train toilet keeps them at home, preventing them from travelling by train and visiting family and friends (Kitchin and Law 2001; Greed 2006; Schmale 2017; DTO 2018; BTA 2019; Maag lever darm stichting 2019; HogeNood 2019).

In this dissertation, we focus on the western, Dutch situation in which sanitation is taken for granted, and 33 litres of clean drinking water per person per day are used for flushing the toilet at home (Thiel 2017). Nevertheless, the Dutch public toilet domain, including train toilets, is under pressure. For example, the capital of the Netherlands has the least public toilet facilities compared to other European cities, see table 1.2 (NOS 2017; Maag lever darm stichting 2019), only one public toilet is available for 24 hours per 270,000 Amsterdam residents. Furthermore, in 2008, Dutch train travellers were confronted with toilet-less short-distance trains. The Dutch National Railways (NS) decided four years earlier not to equip their short-distance Sprinter trains with sanitary facilities based on the theory that they would be unnecessary for short distance travellers, as is the case in subways and buses.

In this project, we worked together with NS who wanted to prioritise improving the hygiene of train toilets on their longer journey Intercity trains as well as to compensate for the decision regarding the lack of toilets on Sprinters (Dutch Minister of Transport Public Works and Water Management 2010; Dutch Ministry of Infrastructure and the Environment 2011).

2.3 Hygiene

The ancient Greeks worshipped the goddess of health 'Hygiea' (figure 2.5), who became prominent after a plague epidemic in Athens in the 5th century BC. She was the daughter of Asclepius, god of medicine who carried a rod around which a serpent was entwined, the so-called rod of Asclepius symbol of the medical sector. She "represented intelligent wholesomeness, purity, and well-being" (Smith 2008: p.81,82). The word hygiene is

Figure 2.5 Goddess of health 'Hygiea': Gustav Klimt (1901). Source www.artchive.com/artchive/k/klimt/klimt_hygeia.jpg.

derived from her (van der Sijs 2010).

Hygiene is closely linked to health. Even though the spread of diseases via germs was unknown, people were already aware of the importance of being 'clean' for health. Several religious texts, from the Bible to the Koran, contained references to the importance of cleansing (Curtis 1998; Service management 2019). Current definitions are from a sustainable, microbiological perspective, and dictionaries define hygiene as follows: "the practices of personal cleanliness that lead to good health" (Winblad and Kilama 1995), and as "the set of behaviours of animals, including humans, use to avoid infection" (Curtis 2007), and finally, "the degree to which people keep themselves or their surroundings clean, to prevent disease", (International Dictionary of English 1995).

The purpose of human life is basically to survive by staying fit (Darwin 1859), moreover, "our practices are solidly based on hygiene" (Douglas 1966). *Hygiene* is hence an all-embracing concept that approaches the meaning of human life. In section 2.3.1, we describe the history of personal hygiene, which means the changing environment in which personal hygiene, i.e., the cleansing of the human body is performed.

2.3.1 History of personal hygiene

Five stages can be distinguished in how we have cared for our bodily hygiene in the past 4000 years. Our attitude towards personal hygiene has gradually shifted from a ritual to a technical approach (figure 2.6) in which we relate to others and our own bodies with increasing *distance*.

Beginning in antiquity, the Greeks and Romans visited bathhouses. In the Greek Gymnasia, sports, through bathing and showering, were symbolically linked to intellectual pursuits; a clean body reflected a pure spirit. The toilets were located in a small space adjacent to the Gymnasia. Personal hygiene consisted of communal rituals.

In the Roman epoch, personal hygiene changed into a joy of abundant wellness. The spas were places to meet and greet, located near market squares (fora) and theatres.

The corresponding latrines, the public toilets, also fulfilled a social function, see figure 1.4, section 1.2. Around 350 AC, the collective bathing turned into a hedonistic affair ("balnea mixta") (Parent 1987), which embodied the decline of the Roman period.

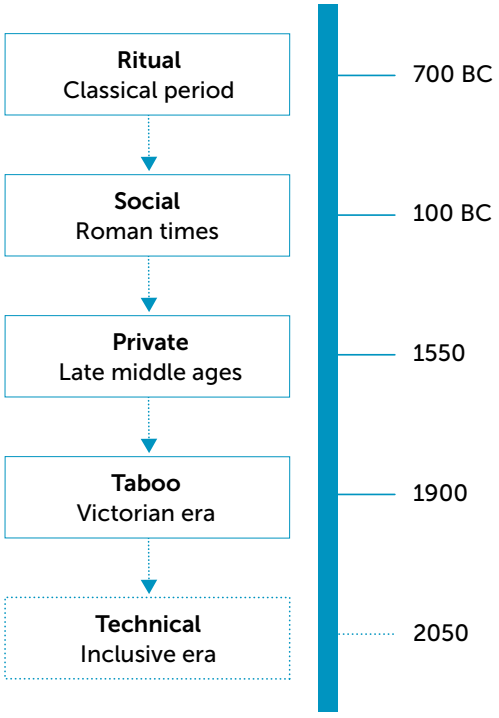


Figure 2.6 History of personal hygiene

In the Middle Ages, the Christian Church introduced a *moral hygiene*. Diseases such as the plague and syphilis spread throughout Europe. The Church rejected communal bathing, which they regarded a source of sensuality and syphilis (Curtis 1998; Dillon 2007). Bathing became less popular and toileting shifted to the family circle, the private sphere (Parent 1987). This was the beginning of the contemporary individually oriented bathrooms and toilets, characterised by an "aura of embarrassment" (Elias 2000, 152).

The 19th century is characterised in terms of hygiene as a 'fight against faeces' that increased due to the growth of people in cities (urbanisation). Therefore, the development of sanitary facilities became central to improving hygiene, which resulted in improved living conditions in the Western world. A bathroom connected to the sewer, including a bath, shower, washbasin and separate toilet were gradually installed in private homes: it became a universal status symbol (Wright 1980).

The history behind individual bathrooms was the revolutionary discovery in medical science of bacteria located in water or air that can transmit diseases, known as the Germ theory of disease. Prior to this, Miasma's theory had held sway: polluted air was regarded as the spreader of diseases from stagnant water, piles of dirt on the streets, and human vapours in crowded, poorly ventilated dwellings.

Figure 2.7 Cholera infected pump (Lambton 1995, 18)

This medical revolution established the link between contaminated water from poor sanitation and diseases such as plague, syphilis, typhoid, and cholera. Dr. John Snow (1813-1858) was the first epidemiologist who linked the dirty water caused by faeces in the Thames to the origin of Cholera (Snow 1849; Curtis 2003). As a result, England took the lead in sanitary reform. It responded to Chadwick's Report on the Sanitary Condition of the Labouring Population of Great Britain (1842) with the enactment of the Public Health Act for London in 1848. Chadwick described, supported by statistical analyses, the poor hygienic conditions in the United Kingdom as a result of urbanisation. An increasing number of people used the Thames as a toilet, which led to it being known as the 'Great Stink'. Subsequently, private Water Closets were connected to the Bazalgette's sewage system. Harmful faeces were consequently isolated from drinking water to prevent diseases such as cholera (Lambton 1995; Curtis 1998; Möllring 2003; Dillon 2007; George 2008).

From 1900 in Europe, the existing cesspools were gradually replaced with sewer systems. However, in the Netherlands, this sewage transition took about half a century longer. For example, the (smelly) barrel system that collected and carefully removed excrement at home was used in several cities until the middle of the 20th century. It was preferred above the ingenious but complex pneumatic Dutch Liernur system mainly because of its valuable content, faeces, was used as fertiliser (van Zon 1993; Geels 2006; Penner 2013; Cube Design Museum 2017, 22), see figure 2.8.

Figure 2.8 Barrel-collection system of excrements in Delft 1915.
Source: van Zon 1993, 75.

Currently, we increasingly allow technology to enter our personal hygiene sphere, including toileting, which indicates that we continue to *distance* ourselves from our toilet practices. For example, instead of using toilet paper to remove remains of faeces from the buttocks, it is becoming increasingly popular to press a button so that the buttocks are automatically cleaned with water (Pickering 2010), which is indeed more effective (Dekkers 2014). In line with this, the controversial 'hygiene hypothesis' (IFH 2018) suggests that in western societies 'with high standards of hygiene' the environment is too clean, leading to the development of food allergies and autoimmune diseases (Aiello and Larson 2002; Smith 2008, 348). It is clear that hygiene standards are becoming increasingly important, stimulated by the fear of disease.

2.4 Toilets

In section 2.3, we described the changing circumstances in which personal hygiene was performed. In particular, how the cleansing of the human body transformed from a social event to an individual concern. However, a description of how toilet practices are performed is hard to find in the literature. The Water Closet is typically used for toileting; the development of this industrial product, both private and public, is addressed in this section.

History of the toilet
Urination and defecation, the primary personal hygiene practices to clean the internal body, evolved from dropping from the trees in a seated position or from the ground, to the use of our 'porcelain throne'. For example, chimpanzees do not pollute their nests, and if they have diarrhoea, they use leaves as toilet paper (Dekkers 2014).

Figure 2.9 Street scene in the Netherlands, end of the 18th /19th century. Source: van Zon 1993, 15

At the end of the 19th century, to the surprise of the British who played a leading role in the sanitation reform (van Zon 1993; Möllring 2003), the Dutch mostly relieved themselves in accidental places, as expressed in figure 2.9. Nowadays, as public toilets are generally available on the street, albeit in limited numbers, this is regarded as urination in the wild, ('wildplassen' in Dutch) for which people can receive a fine of 140 Euro (Vos 2017).

Figure 2.10 'Watch out for the water'

When prudery and taboo made their appearance, the culture of defecation and urination changed into a private affair. The chamber pot at home served as a toilet, the contents of which were emptied from the window with the warning to those underneath: 'watch out for the water, 'Gare à l'eau', see figure 2.10. On the street, a man wore the (public) pot who shielded the user with a long coat after some payment. The pot turned into a disguised piece of furniture, a chair with a built-in pot in the living room, and later in a separate room (Lambton 1995; Lamarcq 2012).

In 1596, Harrington was far ahead of his time. In his 'Metamorphosis of Ajax', he described a WC to get rid of faeces using water as an improvement of comfort. It took another 250 years until the described toilet was accepted and understood (Lambton 1995). Eventually, the invention of the 'modern' toilet was a sum of innovations, mainly designed and produced in Great Britain. In 1775, Alexander Cummings received a patent for his hygienic discovery of a water closet (WC) with the characteristic S-bend as an odour trap: since then this design has not been fundamentally altered and has "escaped modernisation" (Molenbroek, Mantas, and de Bruin 2011, 35; Lamarcq 2012).

2.4.1 Public toilet

History of public toilets

Vespasian, a Roman emperor in the 1st century AD, installed public urinals for which he asked money (a urine tax), which resulted in the well-known expression; *'Pecunia non olet'*: money does not stink. Many centuries later, an important event for the development of public flush toilets was the 1851 Great Exhibition held in the Crystal Palace in London, where toilet designer Jennings played an innovative role with his Monkey closet. This was a gathering of 800,000 people who 'moved from home' (BTA 2019) to visit the exhibition and who were supposed to need a toilet. Jennings asked a penny to use the toilet. Thus, the late 19th century became the 'era' of the public toilet (Parent 1987; Lambton 1995; Lamarcq 2012).

For at least half a century in the Netherlands, there has been a shortage of public toilets for women at stations and bus stops or in city centres. This deters them from visiting cities and travelling by public transport, such as trains, as the 'bladders's leash' limits how far people can travel from home (Cavanagh and Ware 1990; Kitchin and Law 2001; Greed 2007). This was less of a problem for men, as for example in Amsterdam, street urinals were common; these are now gradually being replaced by public toilets accessible to women and wheelchair users (Hielkema 2020; Greed 2019).

In 1970, the Dolle Mina's, the figurehead of Dutch feminism, occupied male street urinals to revolt against the scarcity of women's public toilet facilities. In 2017, once again, the action group 'Zeikwijven': (annoying or 'pee' women) addressed the same issue. (In Dutch, 'zeik' is slang for both complaining and urine, and 'wijf' wife - for woman). They endorsed a Dutch woman who refused to pay a €140 fine for urinating in public. She

was forced to use a spot close to the Leidseplein in Amsterdam as a toilet because she urgently needed to urinate , and there were no public toilets anywhere in the area open at night (Wolthuizen 2017; Vos 2017). In 2013, the Dolle Mina's urinated in a tub/bucket (teil) with a screen to protest against the lack of a toilet in the Sprinter (short distance) train (Volkskrant 2013). Results from the questionnaire (chapter 3), show that the train toilet fulfils an important public toilet function; it is one of the few free accessible and available public toilets in the Netherlands that is accessible to everyone able to travel.

As noted in chapter 1 and section 2.2, the current number of public toilets in prominent cities such as New York and London has been greatly reduced (Greed 2006b; van Oord 2010). In the Netherlands, compared to other cities in Europe, the least public toilets are available 24 hours a day, see table 1.2 (Maag lever darmstichting 2017; NOS op 3 2017). Semi-public toilets are often used as an alternative to public toilets, but they are not available 24 hours a day as are public toilets. These toilets are not fully public, and their users and accessibility are related to where they are located, such as restaurants, cafes, libraries, supermarkets, and train station toilets.

In this study, we focus on public toilets in the Western situation, where people in general use sit-toilets in a sitting or hovering position in combination with wiping, using toilet paper for perineal cleansing. In addition, public toilets are commonly provided with urinals used by men in standing posture without toilet paper dispensers (Rawls 1988; Gallagher 2008; Demirbilek 2011). However, no urinals are currently installed on trains and airplanes.

2.4.2 Train toilet

History of train toilets

The demand for a traveller's toilet arose in the 18th century when people travelled by horse-drawn carriages that contained a 'sanitary unit' called a coach pot, the forerunner of the current widely produced chemical toilet (Lamarcq 2012). In the middle of the 19th century, as a follow-up to the first train toilet installation for Queen Victoria, train pots were installed in first class carriages, the so-called 'carriage pots' meant for urination. In the US, train passengers were already provided with a complete train toilet (also for defecation) around 1850. Second-class passengers in England had to wait another 25 years before this was introduced (Jongbloed and Sloot 2006; Lamarcq 2012).

In her book 'Bathroom' Barbara Penner shows a 1906 photo of a "toilet facility in a train with toilet, washbasin, hot and cold water and electric lighting" that looks more luxurious than the current toilets on board trains (figure 2.11). It illustrates that public toilet availability and maintenance received more attention compared to the current era. It seems that people were proud of the public toilets, as demonstrated in the public toilet environment of the Paris and London subways, which were similar to temples (Parent 1987; Lambton 1995; Lamarcq 2012).

Figure 2.11 A British train toilet in 1906
Source: (Penner 2013, 138)

In the Netherlands, train toilets were also initially installed in first class carriages, subsequently becoming available in second class in the middle of the 20th century (Lamarcq 2012). Until recently, human waste disappeared from the train toilet by operating the flush handle, which opened a valve through which the waste was dropped directly onto the rails. This was a similar approach to sanitation the Middle Ages, when people could use the toilet separately while their waste fell into the moat (figure 2.12).

Figure 2.12a Toilet inside the Castle
Source: Wright 1980,35: "sociably within hearing but decently out of sight"

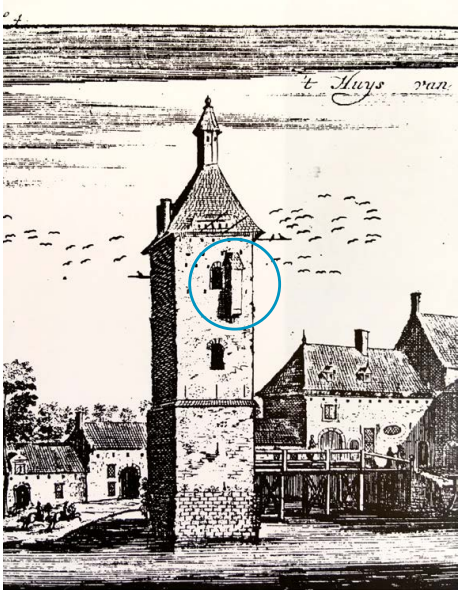


Figure 2.12b Toilet outside the Castle
Human waste fell into the moat (within blue circle).
Source: Lamarcq 2012,57

Figure 2.12 Sanitation in the Middle Ages

Therefore, Dutch train travellers are aware that the use of a train toilet on arrival at a station is prohibited, however this is no longer the case in the new (modernised) trains. Currently, a train toilet is connected to a 'closed' vacuum system with a large bioreactor; a kind of modern version of the Dutch barrel system as described in section 2.3.1 and shown in figure 2.8. It separates the solids (faeces and toilet paper) from the liquids (urine, flushing water, hand washing water, and soap). Bacteria in the bio bin clean the aqueous substance biologically, i.e., in an environmentally friendly way without chemical additives to the greywater that is regularly dispersed in 5 litres volumes on the track. The faeces and toilet paper remain behind and are periodically discharged into the sewer (information provided by Dutch Railways NS). However, even in 2020, several Dutch trains are in operation that do not have a closed system, so that human waste is still being disposed of on the rails. It takes several decades to implement a renewal in trains, because the lifespan of a train is about 40 years (Treinreiziger.nl 2019).

Train travel itself creates barriers for certain groups of travellers, for example those travelling with mobility aids such as wheelchairs, walkers or strollers (Cavanagh and Ware 1990; Greed 2003). Moreover, people with disabilities and older adults avoid travelling by train in the Netherlands due to difficulties in boarding caused by platform gaps (Steenbekkers and van Beijsterveldt 1998a) or the risks of falls due to the train's 'shaking' movement (Buzink et al. 2004, 2005).

Availability of public toilets including train toilets

The lack of toilet provision on public transport systems and at train and bus stations deters people from leaving home to, for example, use the train to visit a city (Kitchin and Law 2001; Greed 2004, 2006a, 2007; Sanchez de Madariaga and Zuchini 2019; Greed 2019). The lack of toilets at train stations combined with the fact that people travel longer than the determined maximum travel time of 30 minutes in the Sprinter (short distance) trains (Steer Davies Gleave 2010) was the main reasons for NS to reconsider their decision to remove train toilets from every train; see section 3.5.1, and figure 3.13,. There is no advice or legislation determining the number of public toilets and whether they should be available on public services like trains, as there is in urban planning (Greed 2004, 2006a). The NS see the provision of train toilets as 'something for the comfort of travellers' i.e., in the same sense that they also offer first class services.

Accessibility for travellers with hand luggage, older adults, people with mobility aids, trans-people and women

The accessibility and features of train toilets also deter travellers from leaving home. For example, baby changing tables are not available in the new NS train toilet and it is difficult for wheelchair users to use a train toilet if wheelchair-toilet transfer is frontal instead of lateral; see figures 2.13 and 2.14. The issue of storing hand luggage, a typical characteristic of travellers, another obstacle to using a train toilet is discussed in detail in Chapter 4.

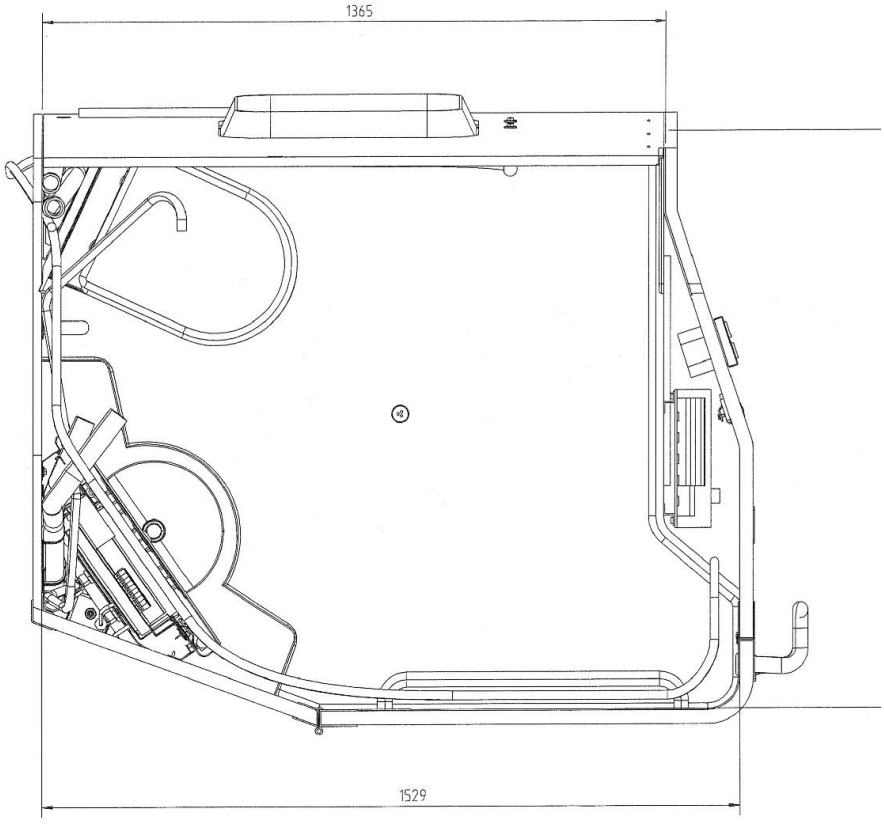


Figure 2.13 Dimensions train toilet depicted in figure 3.5, chapter 3

The pursuit of gender neutrality in public toilets has raised the issue of public toilet accessibility for transgenders as these toilets are commonly gender-segregated, which can lead to hostile reactions for trans-people. However, women have difficulties in sharing female toilet intimacy with men, for example in relation to their need for privacy for menstruation, incontinence or applying make-up. The presence of men outside the toilet cubicle can influence safety concerns, whereas a public toilet is a safe refuge in a public space. As a result, trans-gender neutral toilets are detrimental for women, this is compounded by the general lack of public toilets (Greed, Bichard, and Ramster 2018; Greed 2019). .

In accordance with the principles of inclusive design, we aimed to account for as many different groups of people as possible (Greed 2003; Bichard, Hanson, and Greed 2005; Molotch and Noren 2010; Molenbroek, Mantas, and de Bruin 2011; University of Cambridge 2017). In our design, also based on DDZ train toilet (figure 8.2) a lateral transfer from a wheelchair is enabled, including a folding support (figure 8.4 and 8.7). Wheelchair accessibility in the train and toilet was the guiding principle for the balcony layout and train toilet dimensions, see Appendix A.7.1 , A.8.2, and figure A.7.1. The balcony is equipped with one or two wheelchair space(s) of 1200 x 800 mm (depending on the length of the train based on TSI PRM, 4.2.2.3, 113-115), which influenced the walking routes of passengers on the balcony along the train toilet and wheelchair spaces according to TSI 4.2.2.3. In addition, a train toilet is located on the balcony close to the wheelchair zone(s) in accordance with TSI standard 4.2.2.6, 118-121. We also included a

baby changing table (700 x 500 mm), height between 800 and 1,000 mm from the floor is conform TSI PRM 4.1.2.7.2 (TU Delft 2004; Europese Unie 2007; European Union 2007; EuroSpec 2014). And finally,to tackle the gender neutrality issue, Dutch train toilets are unisex and can therefore be used by men, women, and trans-people.

2.4.3 NS train toilet surveys

NS conducted several surveys to remedy the poor reputation of their train toilets. These can be found in the appendix and have a common message: train toilets are perceived as dirty. Two studies are described.

1. Cleanliness assessment

The first of these is the quarterly cleanliness assessment of 15 elements of the train interior as part of the 'KTO' customer satisfaction survey, five of which relate to the train toilet. The second study is the Omnibus annual NS survey 2010, where we were able to add three questions about the train toilet.

NS strives for a basic quality of the five train toilet elements, i.e., that their cleanliness is assessed as sufficient, which is structurally not the case. In the KTO, travellers assessed, on average, these 5 elements with a low rating of 4.7 on a scale of 1-10 (1=very bad, 10 =very good). In contrast, they considered these elements as being important, with an average score of 8.2 (1=very unimportant, 10 = very important).

As part of this study, NS held qualitative personal interviews with 214 customers who had just used the train toilet to determine their perception of the cleanliness of the train (toilet). They assessed the toilet elements on average as being 0.56 higher, but still insufficient for the NS. For example, the interview toilet bowl rating was 4.8, while in the KTO study this was 4.2. In these interviews, customer rated the average importance of the toilet elements as 0.42 lower than the NS KTO survey, reducing the average importance from 8.8 to 8.1, depicted in brackets in table 1.1. Even though the toilet elements' assessment were still insufficient to achieve NS targets, it seems that travellers who actually used the toilet are somewhat milder than those who completed a questionnaire without using the train toilet (NS 1 2007).

2. Omnibus survey

In the 2009 Omnibus survey, we were able to introduce three questions on train toilets. The main finding was that 83% of the 666 train traveller participants said they tried to avoid using the train toilet because of its uncleanliness. In contrast, the remaining 17% did not mind using the train toilet because they were satisfied that a toilet is available. Dirty aspects of the train toilet in order of 'dirt' were the toilet, the toilet seat, the toilet bowl, the floor, and the smell. Furthermore, they mentioned the following items as clean: washbowl, toilet paper, walls, hand paper, and mirror.

We note that participants gave either vague answers or did not even answer the open questions (35%), while they answered the two closed questions significantly more often (Loth and Molenbroek 2011). Their input formed a starting point for the design of the questionnaire described in chapter 3.

Figure 2.14 Dutch train toilet on the 'balcony'
Source: NS

In this dissertation, we focus on the (semi) public toilet under moving conditions- the train toilet, figure 2.14. Train toilets are a form of public toilet. The train toilet is defined as the sit-toilet within the confined, wheelchair accessible space, and provides personal care facilities, such as a toilet paper dispenser and facilities for hand hygiene. Its door can be locked and has a hook to hang a coat and bag. It is a unisex toilet for use by both men, women and gender-neutral people.

The NS surveys confirmed the poor reputation of NS train toilets, and provided the reason for this: the poor hygienic condition. However, they indicated an unclear ergonomic direction for improving the hygiene of train toilets in relation to design. For this reason, we prepared a new questionnaire about train travellers' needs and user habits concerning train toilets; this is addressed in chapter 3.

2.5 Toilet usage

Few studies have examined primary toilet use (i.e., urination and defecation) in relation to design, including related perineal (urinary and anal cleansing practices (Kira 1976; Rawls 1988; Greed 2003; Möllring 2003; van der Geest 2007; Williams 2009; Molenbroek, Mantas, and de Bruin 2011). This is probably due to the perceived taboo that the subject embodies.

Urination and defecation are the (biological) personal hygiene practices to remove 'internal dirt' from the human body. Depending on culture, people both defecate and urinate in squatting, sitting or hovering posture, as well as urinating in a standing posture. The related perineal cleansing actions are water, toilet paper, or the hands by manipulating the penis to void the last drops of urine. On average, people urinate six times a day, depending on their bladder capacity (Kira 1976).

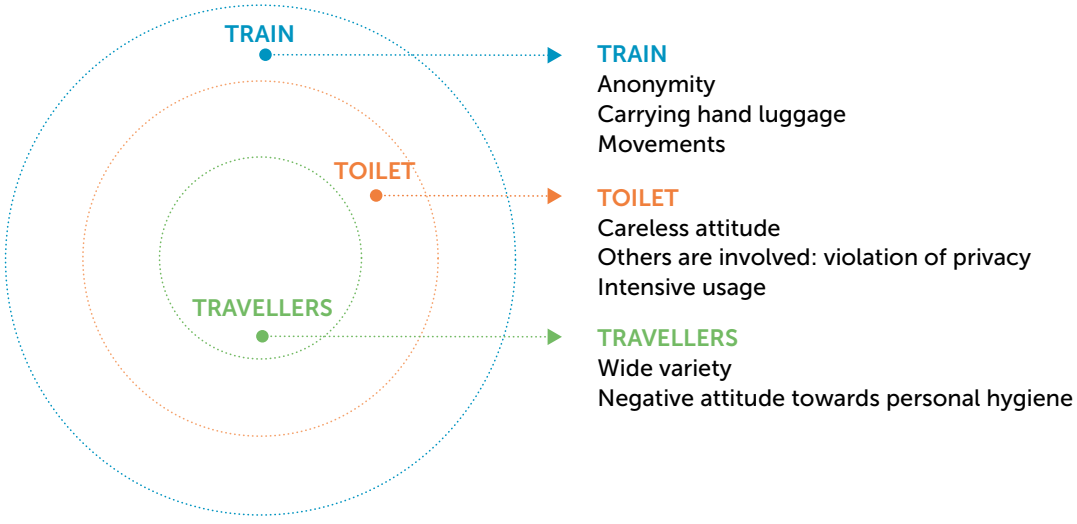


Figure 2.15 Summary Kira: The conditions in a train toilet reinforce the negative perception of personal hygiene

Alexander Kira's pioneering book, "The Bathroom", even though written half a century ago, still comes closest to the heart of the subject. Ten years later, in 1976, he extended it with the themes of hygiene of public facilities and personal hygiene practices of aged and restricted people. He describes a relationship between toilet usage and hygiene, and provides design criteria to improve personal hygiene performance. From his work, it can be concluded that the conditions of train toilets worsen people's perceptions of hygiene as they are intensively used by a wide variety of people in an anonymous environment, see figure 2.15.

Toilet usage was also studied in "A Friendly Restroom" project by Molenbroek et al. (2011). However, their focus was on residents in retirement homes who mostly do not travel by train because of its movements and the risk of falling.

In this thesis, we focus on public toilets in the Western situation, where people generally use sit-toilets in a sitting or hovering position in combination with wiping using toilet paper for perineal cleansing (Hughes 1988).

2.6 Highlights from the toilet literature

In previous sections, we see that the NS have found it difficult to get a grip on the cleanliness of their toilets. In the review of the literature, we also found understanding the broad phenomenon of hygiene to be a complex process.

Therefore, to further extend our literature research, we used the 'snowball method' with books by Clara Greed and Rose George (Wohlin 2014). Apart from the above described Kira, Greed is also a pioneer in toilets, focusing on public toilets at the centre of urban marketing. She also pays attention to others than healthy men, i.e., women, older adults, and people in wheelchairs and other disabilities such as colostomy bag-users, and children who depend on adequate toilet facilities. She emphasises inclusive design. Otherwise, the city is an unfriendly, non-hospitable place in which to participate. She states that the toilet is a symbol of mobility that makes it easier for people to move away from home. She provided design guidelines to designers, architects, and policymakers and, with her great knowledge of public toilets, she contributed to the British Standards Institution (Greed 2003; BSI Standards Publication 2012).

Figure 2.16 Pictogram wheelchair accessibility

The toilet is accessible for everyone who is able to travel by train. Therefore, pictogram figure 2.16 should be superfluous to indicate accessibility of public toilets for wheelchair users.

In accordance with inclusive design, in this research project we aimed to account for as many different groups of people as possible (Greed 2003; Bichard, Hanson, and Greed 2005; Molotch and Noren 2010; Molenbroek, Mantas, and de Bruin 2011; Greed 2016; University of Cambridge 2017). Another aim was that accessibility of the toilet could be theoretically expressed in one pictogram instead of the current 'wheelchair-user' pictogram (figure 2.16).

In her book, Rose George provides a full overview of the nature of sanitation. She particularly refers to Mary Douglas and Norbert Elias (George 2008) who have given direction to the next sections.

2.6.1 Dirt

Mary Douglas, a British anthropologist who wrote her book "Purity and Danger" half a century ago, provided a key direction for this dissertation with her eye-opener sentence: "Dirt is as a matter out of place, where there is dirt, there is a system. Dirt is essentially disorder "(Douglas 1966, 2,36). In this way, she helped us to focus this research on *the opposite of hygiene*: this is basically defined as dirt. Therefore, in this project, we used the terminology of comfort and discomfort (Vink, Overbeeke, and Desmet 2005; Vink and Hallbeck 2012), in this context, hygiene and defined an unhygienic situation as *dirt*. Dirt should be found in the intended places, i.e., not be "out of place", for example, not on the floor or other unintentional spots within the train toilet environment.

Two types of dirt that occur in the train toilet can be distinguished. First, dirt connected to the human body: 'human dirt', i.e., human waste such as urine, faeces, blood (and related sanitary towels and tampons), and remains of nails and hair (Curtis 1998; Curtis and Biran 2001; Reynolds et al. 2005; Greed 2006). Further, dirt related to the toilet environment; 'toilet dirt', for example, (muddy) water, pieces of toilet paper and hand paper. Dirt remains in the toilet environment after people have used it, which they either do not notice or they are not engaged in removing it for the next user.

A finer level of dirt that cannot be perceived with the naked eye, but can still be present in a public toilet environment are bacteria that can be detected with the microscope. This invention by Anthony van Leeuwenhoek in Delft in 1670 created a demarcation in the hygienic and medical science. Prior to the invention of the microscope, it was thought that diseases were caused by inhaling 'dirty' air (Miasma theory) (Curtis 1998; Möllring 2003; Dillon 2007).

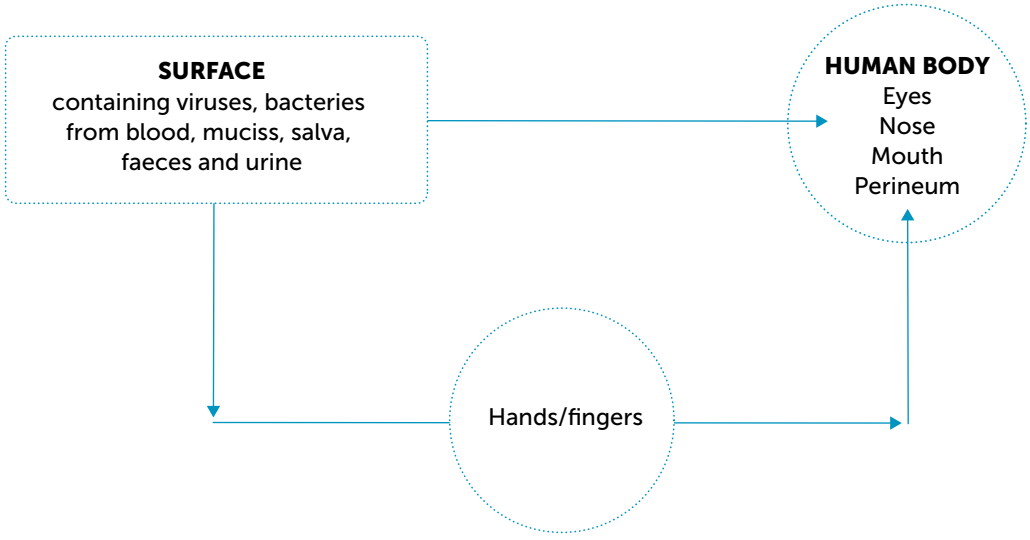


Figure 2.17 Direct and indirect route (via hands) of transmission of disease (Gerba et al. 1975; Reynolds et al. 2005)

However, later on it was found that touching a surface full of harmful bacteria can also transmit diseases - the Germ theory - (figure 2.17), with the faecal-oral pathway being a prominent route. Thus, harmful germs find their way through the orifices of the human body (Curtis 1998; Barker and Bloomfield 2000; Curtis et al. 2003; Rheinbaben et al. 2000; Gerhardts et al. 2012).

2.6.2 Microbiome

The detection of microbiome, the collective term for bacteria, fungi, viruses etc., and their genes which inhabit our environment and the human and animal gut, respiratory tract, skin, etc." (IFH 2018, 7), falls outside this research scope. However, technically, the hygienic condition of a (train) toilet is related to the number of bacteria detected in the environment. Bacteria are also released in the environment when the toilet is flushed, while the lid remains open. This has not been reported as being an issue (Gerba et al. 1975; Barker and Bloomfield 2000; Barker and Jones 2005; Best, Sandoe, and Wilcox 2012; Johnson et al. 2013). The bacteria are microscopic dirt particles that cannot be traced by the naked eye; spots where bacteria are found more or less correspond to the places perceived as dirty in the toilet environment - for example, the toilet seat and the floor (NS Omnibus 2 2009; Loth and Molenbroek 2011; Flores et al. 2011).

The extent to which a public toilet is a vulnerable or even a dangerous place where disease can spread depends on many aspects, such as regular cleaning, the presence of harmful bacteria, the healthy condition of the recipient, and whether the hands are washed after using the toilet. Blood, faeces and urine are excreted in a toilet; these are key materials from which an infection can be contracted (Rheinbaben et al. 2000). In this sense, a (public) toilet is a vulnerable place where a disease can be caught. However, public toilets are cleaned regularly therefore, bacteria have little chance of surviving in this environment (Reynolds et al. 2005). The extent to which the user is susceptible to illness; in other words, the healthy condition of the user, is a universal phenomenon that falls outside this research scope.

2.6.3 Distance

Norbert Elias described the human civilizing process from the Middle ages to the 20th century. He described the gradual development of toileting behind the scene, especially through cultivated feelings of embarrassment resulting from the growing interdependence in society. In the Middle Ages, for example, food was served on the table, which people then cut up and ate with their hands. Nowadays, food is prepared behind the scenes and served at the table, unrecognisable its source, and, we now eat our food using cutlery.

Toileting gradually enveloped in an "aura of embarrassment"; Elias describes the increased distance to our private bodily practices (Elias 1982, 2000). The literature

review revealed three types of distance. First, the Physical distance of the human body and toilets. The second was the Mental distance, related to dirt and the third was the Social distance between travellers (Hall 1966; Elias 1982, 2000; Dellström Rosenquist 2005; van der Geest 2007).

Physical distance (P)

A toilet seat is designed for comfortable seated use (McClelland and Ward 1982). Nonetheless, men opt to avoid touching the toilet seat with their buttocks, they prefer to stand in front of the toilet; for the same reason, women prefer to hover over a public toilet seat. Therefore, in public toilets, a majority of men and women (85%) prefer to urinate in either standing or hovering position (Moore et al. 1991; Misterpoll 2008). In other words, they prefer to keep a *physical distance* (P) between their bodies and the toilet. However, the hygiene will have a higher value if this physical distance is smaller because of less spoiling, This aspect is an important subject of this study.

Mental distance (M)

In a train toilet environment, 'out of place' materials are found such as urine drops on the floor, traces of defecation in the pot, and traces of sanitary towels or paper on the floor. Mental distance relates to the type of dirt (out of place) being encountered. Traces of faeces and blood are perceived as being dirtier than urine (Curtis 1998; Curtis and Biran 2001; van der Geest 2007; Pickering 2010). The perception that faeces (out of place) are dirty was reinforced in the 19th century as people became aware that faeces can also initiate infection (Douglas 1966; Gerba, Wallis, and Melnick 1975; Aiello and Larson 2002; Reynolds et al. 2005; Boone and Gerba 2007). This awareness went hand in hand with an increased need for privacy, i.e., social distance, and a prudish approach, see figure 2.6, Section 2.3.1.
In addition, the toilet environment includes a sanitary towel bin, which is associated with another type of dirt, i.e. blood. Therefore, the product that is mentally related to faeces (and blood), the toilet, is perceived as dirty, with the result that people maintain a *mental distance* from the toilet, a metaphor for dirt.

Social distance (S)

The hygienic perception of three types of toilets, namely the private toilet, the semi-public toilet, and the public toilet depends on the different environments in which they are located. It deteriorates as the number of strangers using these toilets increases (Curtis, Aunger, and Rabie 2004; Dellström Rosenquist 2005; van der Geest 2007).

The private toilet concerns users who are familiar with it i.e. between whom the *social distance* is minimal. It is thus considered as a different environment, for purposes of our study. In contrast, public toilets, have a high degree of anonymity because strangers use

the toilet, between who there is a large *social distance*. We are then confronted with their dirt, which entails an undesired intimacy, an invasion of our privacy, for which we feel disgust (van der Geest 1998, 1999, 2007).

Personal hygiene practices take place in a public environment where people wish to be private (Kira 1976; Dellström Rosenquist 2005; Gershenson Penner 2009), which implies a contradiction in terms that is not beneficial to a hygienic perception. A 'public' toilet implies shared usage with 'strangers' between whom the *social distance* is maximal, i.e., there is no relationship between the users of the toilet, which reduces the perception of hygiene. On the other hand, the anonymity of the dirt also softens its perception, because the anonymity of the dirt means it has no identity, " the intrusion is superficial"(van der Geest 2007, 6).

2.7 Discussion

The opposite of hygiene, which we define as dirt, is explained in section 2.6.1. We reviewed the literature for what can be found about dirt, types of dirt, or the phenomenon that 'dirt attracts dirt'. According to Mary Douglas, "dirt is essentially disorder". People eliminate dirt as "a positive effort to organise the environment" .Things need to be in place, we strive to achieve order (Douglas 1966, 2).

A common finding in the psychological literature on litter is that people leave more litter in a littered environment than in a clean one; in other words, "dirt attracts dirt". In this thesis, we aimed to describe solutions to stop this phenomenon. However, the findings on litter cannot easily be translated to a public toilet environment.

First, a littered environment is found in the open air instead of the confinement of a public toilet. Secondly, the described litter is a different waste phenomenon than faeces or urine, human waste that people find disgusting, especially faeces from strangers (Curtis, Aunger, and Rabie 2004; Dellström Rosenquist 2005; van der Geest 2007). On the other hand, the anonymity of the dirt also mitigates the degree of perception of 'unhygiene'. The dirt has no identity, the degree of dirt perception as a metonymic representation of the other betrays the character of our relationship with that other person"(van der Geest 2007, 7).

Thirdly, Cialdini, Reno, and Kallgren 1990; Keizer, Lindenberg, and Steg 2008; Dur and Vollaard 2014 wrote about norms being exceeded. Public toilets, especially train toilets, are considered dirty, so the norm is already exceeded or is unclear. In brief, a dirty train toilet is what is expected.

For further research in this dissertation, we found it to be important to determine whether people are more careless in a public toilet environment if it is already dirty. In general, it is plausible that by taking care of the toilet users' environment, people will

react by taking care of their train toilet environment. This phenomenon is known as the theory of broken windows (Wilson and Kelling 1982).

We define interaction and behaviour as usage; "behaviour in the water and sanitation section is mostly related to the use of a [sic] sanitation system' (Mosler 2012, 434). We examined the relationship between the usage of a train toilet and hygiene, or how the interaction between humans and toilets leads to dirt being left behind in a train toilet environment.

2.8 Conclusions and recommendations

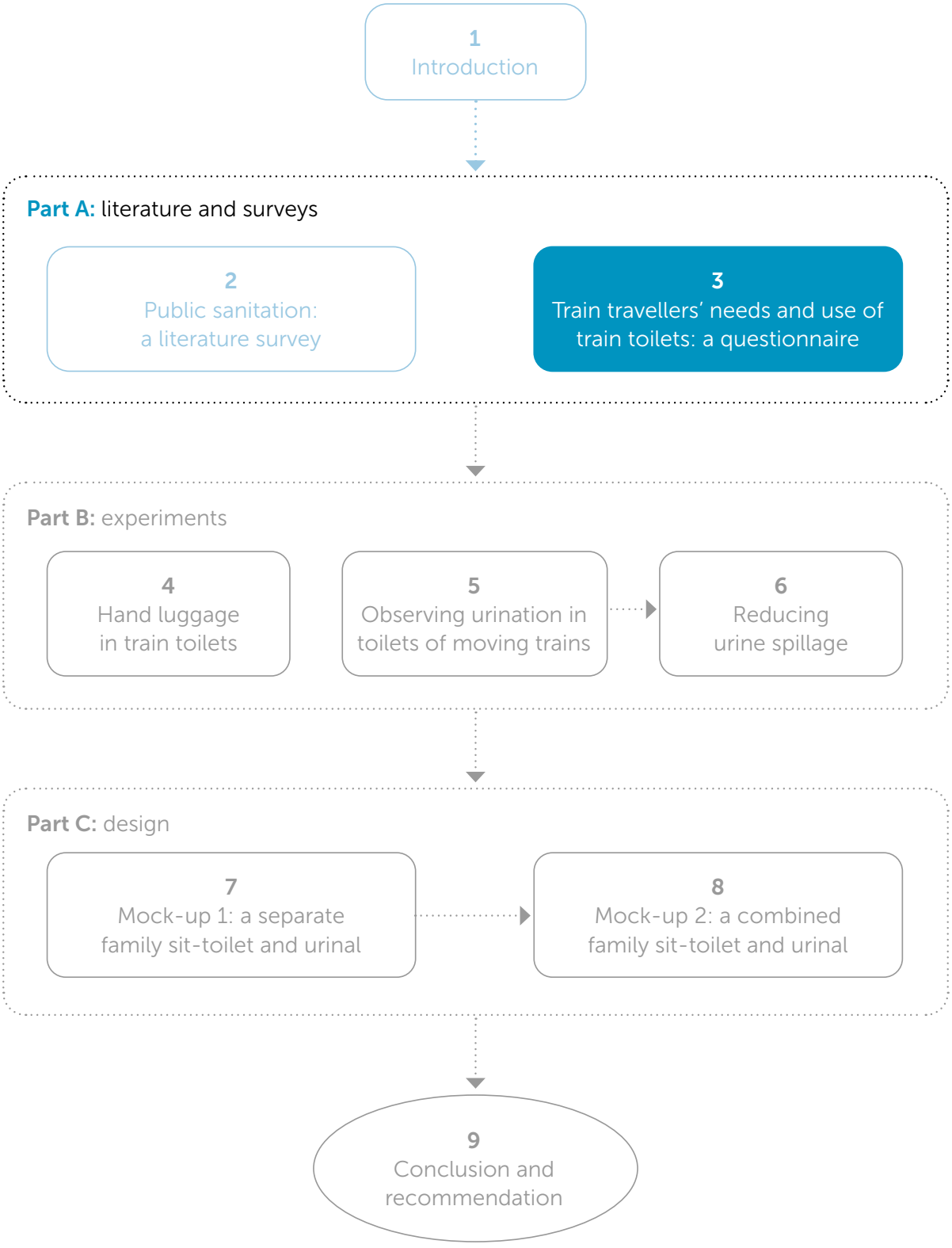
Conclusions

1. People prefer to flush a toilet with water because it provides minimal contact with human waste and gives status. Water has a (symbolic) hygienic value that underlies the age-old experience of cleansing the body and playing with water.
2. The journey of infection can start from faeces, urine or blood: i.e. human waste excreted in the toilet. Thus, a toilet can be a vulnerable place that may transmit an infection, unless it is cleaned regularly. Overall, a train toilet is a reasonably safe environment.
3. A (public) toilet environment in the Netherlands can be considered sufficiently hygienic mainly due to regular cleaning. However, the reverse is the case: it is not perceived as being hygienic.
4. Widespread and deeply embedded mechanisms such as the emotion of disgust ensure that we keep excrement at a *distance*, and consistently distance ourselves from the product, a toilet, that is closely associated with it.
5. This distance is on a, Physical (P), Mental (M), Social (S) level, also with regard to sight and smell, and even talking about it. As a result, humans try to avoid public toilets. In other words, they keep a distance to public toilets.

Recommendations

Many books and publications on toilets have described their history and confirm the negative sentiments about public toilets. For this dissertation it is relevant to understand this history. However, more research is needed to gain knowledge that can lead to guidelines/ specifications for an improved design that enhances train toilet hygiene.

The interaction between travellers and the train toilet needs to be further investigated in the context of train travel. Therefore, we developed a questionnaire to ask train travellers about their need for a toilet and the perception of hygiene in relation to travelling by train. This is described in Chapter 3.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Chapter 3
Train travellers' needs and use of train toilets: a questionnaire

3.1 Introduction

Humans are different, as are their needs and habits regarding toilet usage. In this chapter we analyse the wide variety of people, from grandmother to babies, who travel by train in the Netherlands in relation to their train toilet usage. Even though they are very different, Dutch train travellers have in common that they score train toilets badly in questionnaires because of the poor hygiene (NS 1 2007; NS Omnibus 1 2008; NS Omnibus 2 2009).

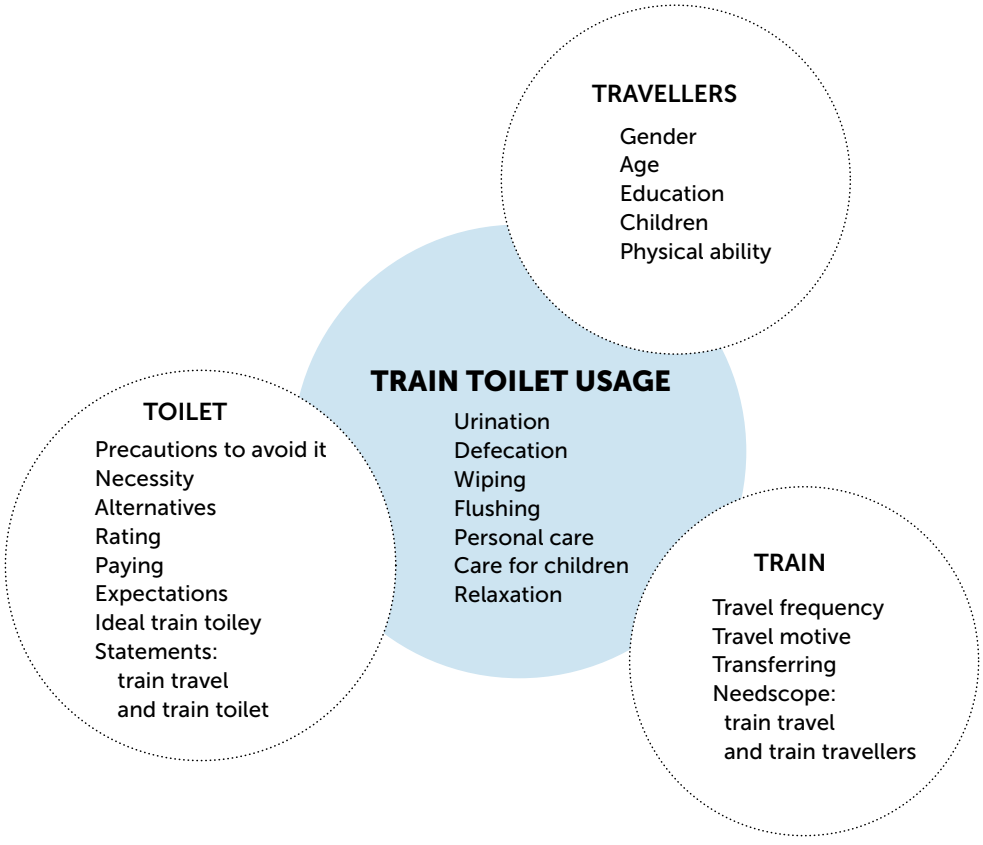


Figure 3.1 Questionnaire model

The literature study in chapter 2 began by identifying reasons for the low rating of the train toilet cleanliness. In this chapter, we further examine this low rating by asking train travellers a number of questions about the problems they encounter when using train toilets, i.e. extending the research and concentrating it within the context of train travel.

Therefore, we contacted 3960 travellers of the NS panel by email to ask them about their needs, wishes, and use of train toilets. Of those invited, 1267 completed the survey, a response rate of 32%. In addition, the results of the questionnaire formed guidance for the topics of the experiments which constitute part B of the research (Chapters 4, 5, and 6).

In this chapter we aim to answer *RQ A2: How does train travel affect train toilet users' needs and usage?*

Figure 3.1 shows the questionnaire model, presenting the 3 T-determinants (*train-toilet-travellers)* whose interaction as impact on hygiene is examined in this research project (also see research model figure 1.6).

In section 3.2 we explain the questionnaire methodology, followed by section 3.3 that discusses its representativeness of *travellers* and *train*. Subsequently, 3.4 gives a summary of the results of *travellers*, *train* travel, and the *toilet*. Finally, we close this chapter with sections 3.5: discussion, and 3.6: Conclusions and recommendations.

Research questions
Research questions 3.1 and 3.2 serve as introductory questions to answer the research question A2:
RQ 3.1: What are the characteristics of train travellers?
RQ 3.2: How do they use the train toilet?

3.2 Questionnaire

Enquête Treintoiletruimte

Best anoniem panellid,

Deze enquête wordt gehouden voor een onderzoek naar het treintoilet, hiermee bedoelen we zowel het toilet zelf als ook de overige voorzieningen die aanwezig zijn in deze ruimte, die afgesloten wordt met een deur. De bedoeling is om mede met uw antwoorden een verbeterd treintoilet voor de toekomst te ontwikkelen. De vragenlijst neemt ongeveer 15 minuten in beslag. Iedere gedachte die in u opkomt kunt u opschrijven, voel hier alstublieft geen gêne voor. De resultaten van dit onderzoek worden strikt anoniem bewaard.

Namens de NS en TU Delft wil ik u hartelijk danken voor uw medewerking!

Marian Loth
Onderzoeker
TU Delft

Kim Hauwert
Projectleider
NS Marktonderzoek & Advies

Figure 3.2 Welcome screen online survey train toilet

The online questionnaire was developed together with NS. See appendix A.3.1 for the approximately 75 questions (in Dutch). This section describes how the survey was designed, methods to encourage respondents to complete it, and lastly, how the results were analysed.

3.2.1 Design of the questionnaire

Two parties, TUD and NS, were involved in the development of the questionnaire content (75 questions). Furthermore, MetrixLab, a research agency specialised in online market research (www.metrixlab.com), managed the data 'infrastructure'. Respondents received mostly closed responses to 'persuade' them to choose one predetermined option from a series of multiple-choice answers.

From the Omnibus survey described in chapter 2, section 2.4.3, we concluded that closed questions provided more (useful) information than open questions. We ensured that participants could still add comments by providing open text boxes so they could 'escape' from the closed answer options. In addition, to encourage respondents to be as frank as possible, we added peculiar options, especially for questions on toilet usage. By asking respondents about other and different forms of use, we hoped that respondents would feel more comfortable. In this way, we attempted to prevent them giving socially desirable answers, a general danger of questionnaires (Tourangeau and Yan 2007). Specific example questions can be found in appendix A.3.1, questions 8a, 9.2, 9.4, and 9.5. 'Routing' options were provided to guide respondents through the online survey effectively. For example, questions could be skipped if irrelevant, or relevant questions could be added, depending on the answers given. See appendix A.3.1: For example, questions 2a, 4a, b, c, d and e.

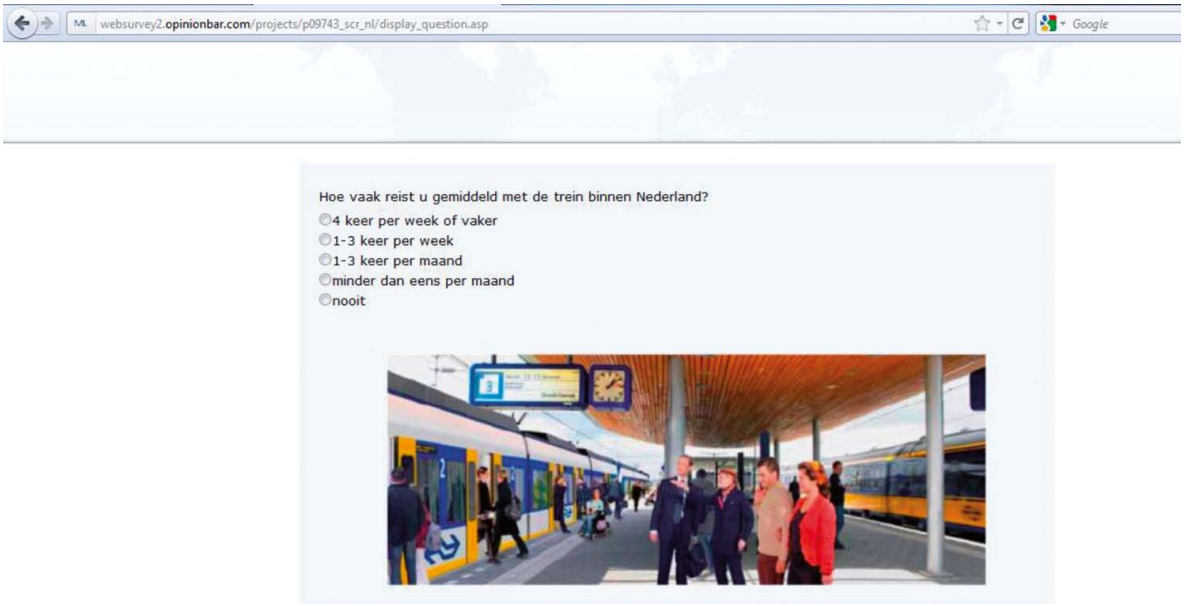


Figure 3.3 First question online survey train toilet

The first question divided respondents into two groups; frequent train travellers, those who travel more than 1-3 times a month denoted as 'NS', and non-frequent train travellers 'NSnf'. For the NSnf i.e. those who travel by train less than once a month, or never, see A.3.1 and figure 3.3, the questionnaire automatically skipped or changed irrelevant-questions for this group. For example, questions about the train toilet were replaced by questions on a public toilet, as we assumed that people who rarely travel by train would use a public toilet instead of a train toilet. We filtered these respondents in the analysis, but they were included with respect to the background information of the sample. In brief, we gave more weight to NS traveller findings in the analysis and based our conclusions mainly on their responses compared to NSnf travellers.

Metrixlab included variations to answering the questions and added images to make the questionnaire more vivid (figures 3.4 and 3.5) to encourage respondents to complete the questionnaire and prevent them from dropping out.

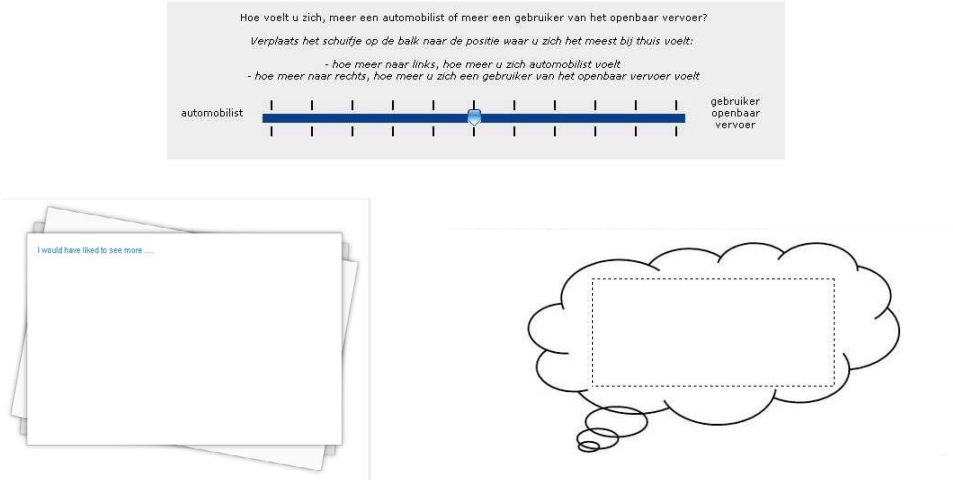


Figure 3.4 Variation in questions

Figure 3.5 Examples of pictures in the questionnaire

After the questions were checked by a linguist to ensure they were clear and written in correct Dutch, Metrixlab organised a pilot with 7 respondents. This resulted in some minor changes being made, such as altering the font size to a larger 11 pts instead of the original 9 pts font size, which was found to be too small and difficult for some people to read. Furthermore, they administered the raw data in a manageable format (SPSS in combination with Excel files).

3.2.2 Analysis

On 21 January 2010, NS approached 3960 NS panellists online from approximately 100,000 registered train travellers (http://nspanel.nl/). They were asked by email to participate in this train toilet survey. Subsequently, one reminder email was sent two weeks later, to which 245 additional respondents reacted. Finally, 1267 panellists completed the survey before closing on 15 February 2010, a response rate of 32%. We used SPSS 16.0 software program to manage and analyse the data; the results are described (in Dutch) in the report of the Bruin & Loth 2013.

Unexpectedly, many respondents gave extensive explanations in the open text boxes or answers to the few open questions. An online text analysis program (www.tagcrowd.com) was used to manage these numbers of comments and open-ended questions, converting these into word clouds (figure 3.6). It is a simple analysis tool that gives a quick impression of the content of the answers. Conclusions based on this type of analysis need to be drawn with caution; a more in-depth analysis of the responses to the open questions may be necessary.

Figure 3.6 Word Cloud of answers on 'most ideal train toilet' ('schoon' means clean in English)

3.3 Representativity

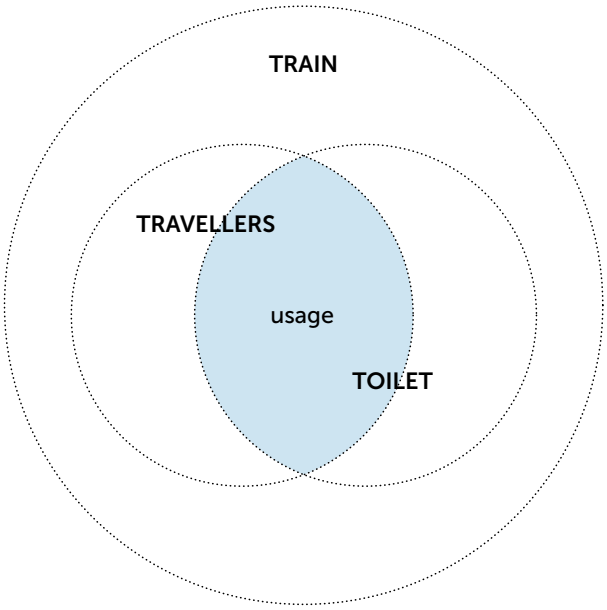


Figure 3.7 The three T's (Train-Toilet-Travellers) determinants

We start by describing the validity of the panellists. Standard demographic variables of the sample such as gender, age, and education were compared with the NS standard Dutch train traveller (NS standard, 2008) and the Dutch Population (CBS 2009; Nationaal Kompas 2009). We also accounted for Stated Preference research (Steer Davies Gleave 2010). Subsequently, in this section, we address the representativeness of train travel and discuss how the respondents' travel motives and frequency relate to the NS standard and Stated Preference research.

Figure 3.8 Variables of train travellers' representativity

3.3.1 Train travellers

The variables, gender, age, and education are discussed with regard to the representativeness of train travellers; see figure 3.8.

Gender

A larger number of female respondents participated in this questionnaire, both in the total sample, including NS and NSnf train travellers (n = 1267, 46.9% male, 53.1 % female). In the NS group (n=1058) women made up 51.5% of the respondents. The answers of the NS group (n=1058) were central in this study.

The skewed gender distribution is comparable to the gender distribution of NS standard (NS 2008). Thus, the sample is representative of Dutch train travellers for gender. However, for the other two demographic variables, age, and education, the sample was less representative.

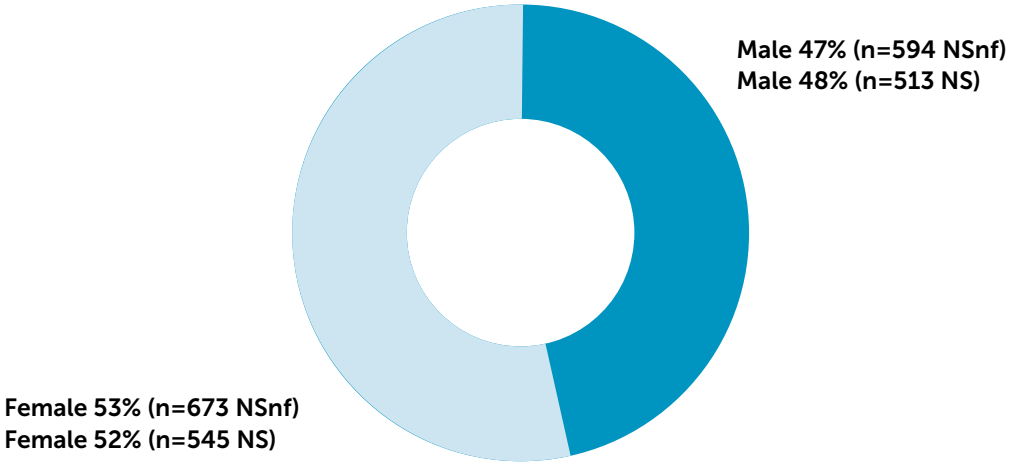


Figure 3.9 Gender distribution of the sample (NS: travel> 1-3 times a month, NSnf travel < 1 time a month)

Age

Many respondents aged 46-65 partook in the study, see figure 3.10. This age group is more likely to be more engaged with the subject than younger people who have relatively fewer physical, and bladder problems and are less dependent on a toilet (Norg 2008; Bauer and Huebner 2013; Maag lever darm stichting 2019; HogeNood 2019). In addition, the male respondents were older than the female respondents on average; there was a weak association between gender and age. A variation in age was also found with respect to when travellers take the train; train travellers who commute during peak-hours are, on average, younger than those who travel during off-peak hours.

The percentages of age groups travelling in peak-hours are 26-35 years (21.9%), 36 to 45 (22.5%), and 46 to 55 (28.4%). In comparison, 30.9% and 21.3% of off-peak-off travellers were aged 56-65 and 66+ respectively. We found a fairly strong association between age-group and travel time.

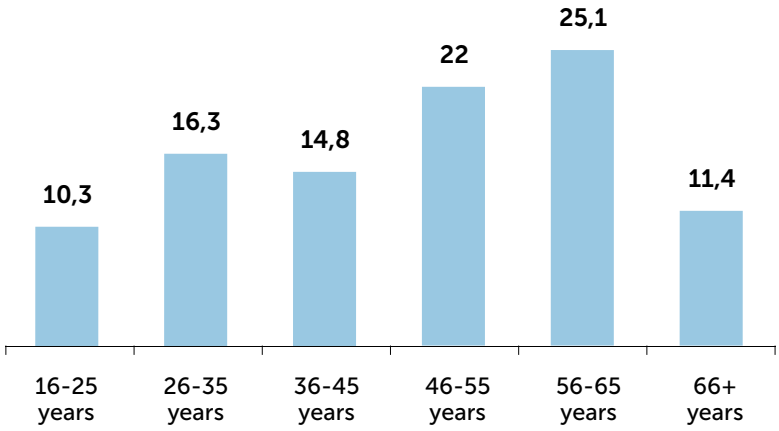


Figure 3.10 Age category of the sample (% of n=1267)

Thus, the time when people travel by train has a correlation with age, which is logical because 65+ is the age at which people in the Netherlands retire. As a result, they are less likely to be commuting in rush hours. Moreover, NS encourages their customers to travel outside peak-hours; they offer a 40% discount for travel in off-peak hours in order to spread traveller numbers more evenly. More seats are available on the train during off-peak hours, as the occupancy rate is under 40% (2013.nsjaarverslag.nl). Therefore, avoiding rush hours is attractive. It is worth noting here that the retirement age in the Netherlands will gradually shift to 67 years in 2023 due to the increasing costs of an ageing population (Dutch Minister of Social Affairs and Employment 2017).

Education

Finally, approximately two-thirds of the respondents had a theoretical education type, (higher education 36.5% and university 28.7%) For example, people with low-literacy levels would be unlikely to complete this questionnaire; 1 in 9 Dutch people aged between 16-65, or approximately 2.5 million adults (Stichting lezen en schrijven 2017; Rijksoverheid 2018). In terms of type of education, the sample was unrepresentative of both the Dutch population, as well as that of Dutch train travellers compared to the NS standard, (2008). This does not affect the extrapolation of the results, as it seems unlikely that either a theoretical or practical education will affect toilet usage; this could be a subject for further research.

3.3.2 Train travel

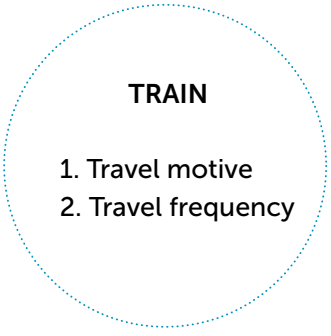


Figure 3.11 Variables of train travel representativity

By representativeness of the sample for train travel, we refer to people's travel motive (reasons people travel by train) and their travel frequency (how often the respondents travel by train). People have different motives for travelling by train, e.g., going to work or visiting family, see A.3.1, question 17 (in Dutch). In addition, in terms of travel frequency, hard-core train travellers are compared to those who travel occasionally. The data from two sources were matched: NS standard and Stated Preference research (NS 2008; Steer Davies Gleave 2010).

Travel motive

The questionnaire was not fully representative of Dutch train travellers for the main motive why people travel by train. Business travellers and people travelling to visit friends/family were over-represented in this study, and school children and students were under-represented. Nevertheless, in this sample, people who travel to work as their main motive (41%) matched the main motive of Dutch train travellers (42%) (NS standard: NS 2008).

Our research was more representative regarding the main motive of the train trip of Dutch train travellers than Stated Preference research. In the Stated Preference research, the opposite of representativeness occurred in comparison with our groups; people travelling for work and school children/students were over-represented, and passengers travelling for private purposes were under-represented (de Bruin and Loth 2013).

Travel frequency

Our study was also not fully representative of Dutch train travellers in terms of the frequency of train travel when compared to NS standard (NS 2008). Our research population showed that daily train travellers (4 times a week or more) were under-represented compared to the less frequent train travellers, in particular, the 'regular' train travellers who travel 1-3 times a month; 30%, 33% respectively (figure 3.12). This may be linked to the under-representation of the main motive of the journey and age: commuters are often younger people travelling to work, but they also travel more frequently by train.

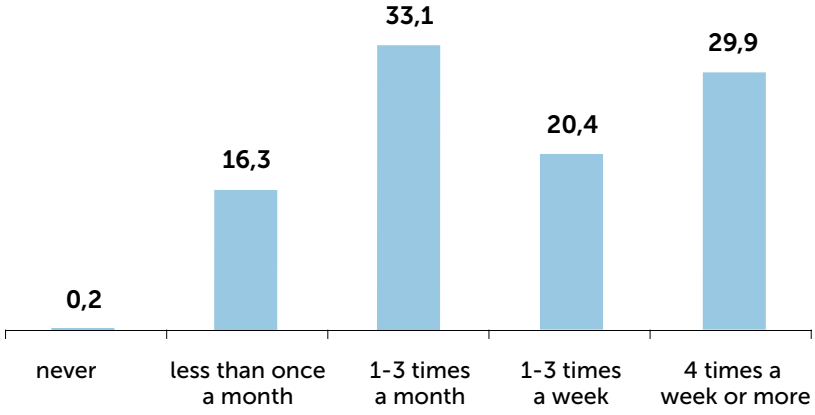


Figure 3.12 Travel frequency sample (in %, n=1267): never < 1 a month (NSnf: n=209); > 1-3 times a month (NS:n=1058)

Summary validity/representativity

In our survey, gender, and travel to work as a travel motive were representative of Dutch train travellers. For the other demographic variables, travellers were relatively older (58.6% aged 46-65+ compared to 41.4% aged 10-45), figure 3.10, and with a more theoretical type of education (66% compared to 34% with a practical education). Regarding the validity of train travel, regular travellers (1-3 times a month) participated more often in our survey than daily train travellers (4 times a week or more; 33.1% and 29.9%, respectively figure 3.12. The interdependency between age, motive, and frequency of travel is also reflected in this representativeness. Relatively older people travel less frequently, but more in off-peak hours when they visit friends or family (table appendix A.3.1)

3.4 Results

This section presents a summary of the results, according to the three Ts (Train-Toilet-Travellers) determinants. See appendix A.3.2 for extensive description of the results.

Results train travel

People who frequently travelled by train mostly did so during peak hours, whereas the off-peak travellers took the train less frequently. On average, off-peak travellers stayed longer on the train (mode: 30% more than 60 minutes) compared to peak-travellers (mode: 40% 20-40 min), and they also switched more often to a consecutive train (off-peak: 65% compared to peak 35%). Off-peak travellers more often experienced the train trip as 'relaxed', while peak-travellers perceived their journey more frequently as 'speed and control'. The average duration of the train trip-from home to destination was about 11% <30 minutes, 28% 30-60 minutes, 28% 60-90 minutes, and 34% > 90 minutes.

The need for a toilet depended on the period that people spent on the train, see figure 3.13.

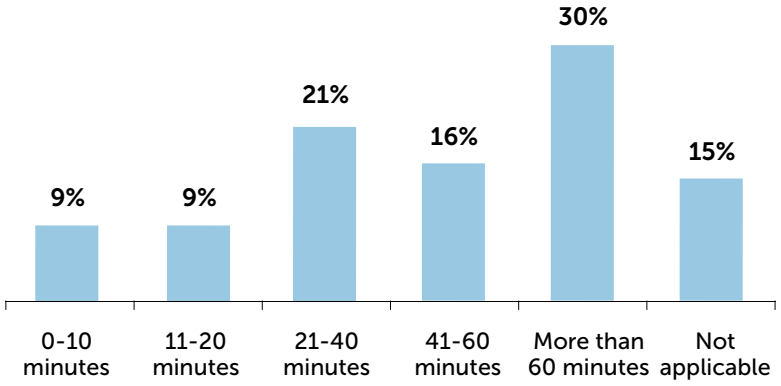


Figure 3.13 When would you like to use a train toilet (during the train journey)?

Results train toilet

Of the respondents, 17% (n=1058) indicated that they often use a toilet, 'wherever I am', and 19% considered a (train) toilet to be a fundamental right. A small percentage (10%, n=108) found the toilet so important that if there was no toilet, they would not take the train. Conversely, 13%, (n=164) thought the availability of a train toilet was unnecessary because they could use the toilet at home. Moreover, the issue of carrying hand luggage was also a reason given for a train toilet not being necessary.

In response to the question 'where do you use a toilet during your entire trip?' (question 23a, appendix A.3.1), figure 3.14 indicates that most respondents used the private toilet at home during their journey 62% (n=654), followed by the train toilet 48%, (n=505). In the third place, 44% (n=465) used the toilet at the arrival point, and finally 26% (n=276) mentioned the station toilet. Other possible toilet locations were mentioned considerably less: 5% (n=54) reported the toilet on the platform, 4% (n=40) another location, 4% (n=38) a public toilet, and finally, 2% (n=25) on the street/bushes, see figure 3.15.

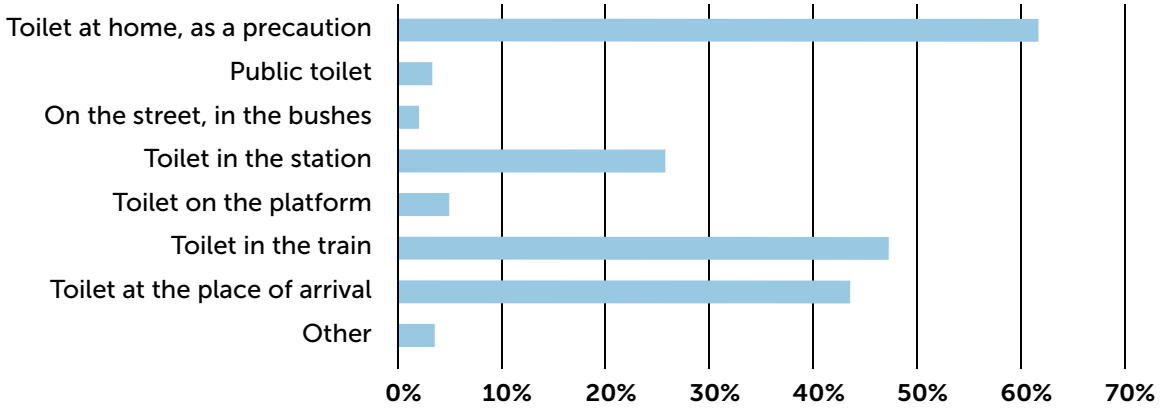


Figure 3.14 : Overview of toilet locations during the trip

Results train travellers

Men travelled by train more frequently than women. They also had fewer difficulties using the train toilet, while women avoided the train toilet more often. Older people gave more importance to the train toilet and used it more often than younger travellers, and the 56+ age group travelled more often during peak-off hours, while the 26-55 age group commuted more frequently during rush hours. The number of travellers with physical restrictions was representative of the Dutch (in general/world): 10%, see figure 3.15. Whereas this group proportionally preferred to travel during off-peak hours. Finally, a large minority compared to the Dutch population expressed their preference to travel by train with children.

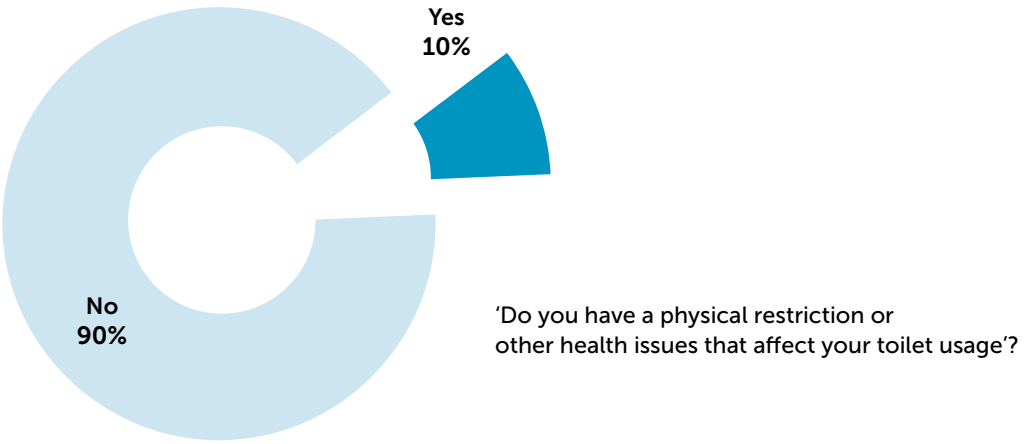


Figure 3.15 10% of the sample (n=1267) indicated to have physical restrictions that affected toilet usage

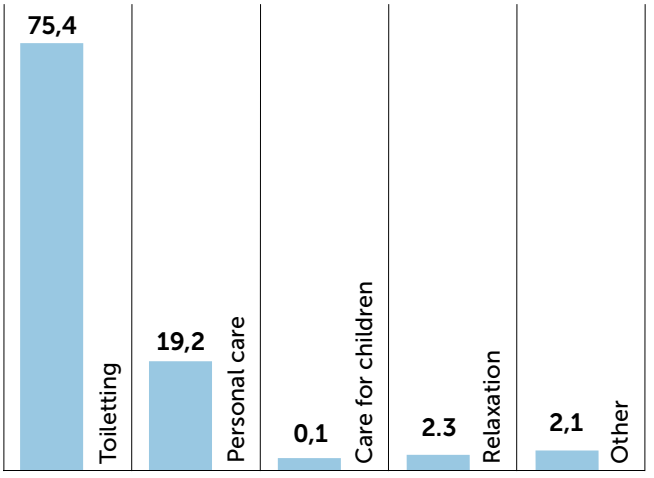


Figure 3.16 If you use the train toilet, what do you use it for?

Results toilet usage

The **top ten** of the most common actions that **travellers** (n=1058 'NS') perform in the train toilet, see figure 3.17:

1 flushing the toilet after urination (44%, n=466)
2 searching for support because of the train's movements (35%, n=351),
3 wiping after urination (27%, n=288),
4 urination while standing in front of the toilet (26%, n=279),
5 toilet flush after defecation (26%, n=277),
6 wiping with toilet paper (24%, n=258),
7 urination while hovering above the toilet (23%, n=241),
8 wiping after defecation (22%, n=235),
9 toilet seat up / down (19%, n=206), and
10 cleaning the toilet seat (18%, n=195).

Men and women differed in the actions they considered to be important.

The **top ten for men** (n=513 of all frequent male train travellers) was:

1 urination while standing in front of the toilet (54%, n=277),
2 flushing the toilet after urination (44%, n=227),
3 searching for support due to the unexpected movements of the train (35%, n=178),
4 toilet flush after defecation (34%, n=173),
5 toilet seat up / down (32%, n=162),
6 wiping after defecation (28%, n=144),
7 defecate while seated (23%, n=116),
8 wiping with toilet paper (20 %, n=102),
9 cleaning the toilet seat (18%, n=90),
10 wiping after urination (14%, n=72).

The **top ten for women** (n=545) was:

1 toilet flush after urination (44%, n=239),
2 urination in hovering position (42%, n=226),
3 wiping after urination (40%, n=216),
4 searching for support because of the unexpected movements of the train (32%, n=173),
5 wiping with toilet paper (29%, n=156),
6 urination while seated (21%, n=112),
7 cleaning the toilet seat (19%, n=105),
8 cover the toilet seat with toilet paper (19%, n=105),
9 toilet flush after defecation (19%, n=104),
10 wiping after defecation (17%, n=91).

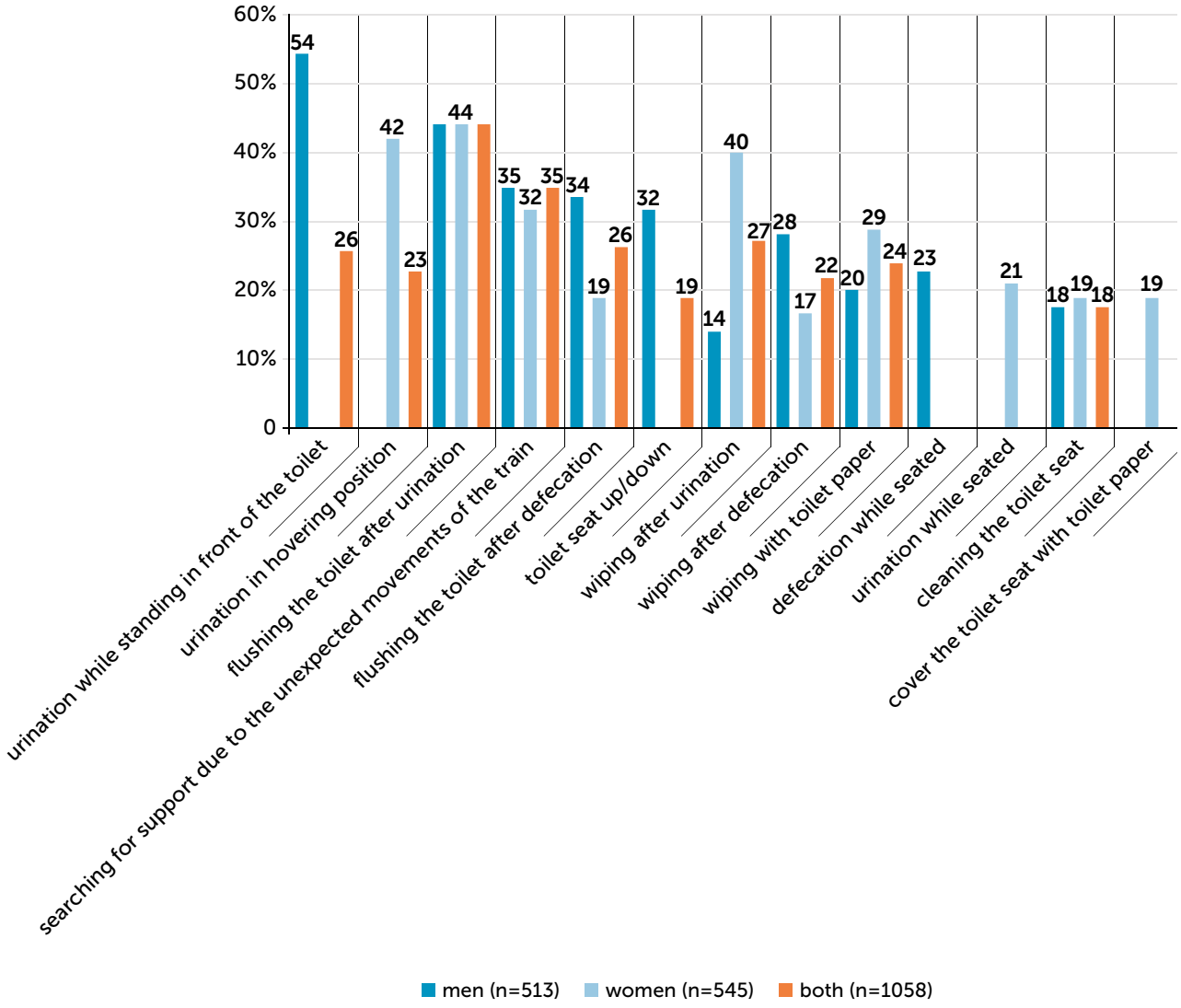


Figure 3.17 Top ten toilet actions to be important for male and female travellers (in %, note that n is different)

The respondents were then asked to assess to what extent -good, sufficient, or insufficient- the train toilet (toilet and space) suited their performing the main practices mentioned. Figure 3.18 gives an overview of 27 key actions based on an analysis of these answers.

More than 30% of the respondents who identified the relevant practice as important assessed the train toilet as *insufficient* for the following practices: Flushing the toilet after urination (n=142: 31% of n=466), searching for support as a result of unexpected movements of the train itself (n=142: 41% of n=351), wiping with toilet paper (n=77: 30% of n=258), urination while hovering above the toilet (n=102: 42% of n=241), toilet seat up/down (n=66: 32% of n=206), cleaning the toilet seat (n=129: 66% of n=195), drape toilet paper on the seat (n=71: 42% of n=170), seated defecation (n=54: 33% of n=166), hand washing (n=58: 48% of n=122) defecation while hovering above the toilet (n=36: 51% of n=71), toilet flush in advance (37% of n=65), flush toilet before urination (n=14: 40% of n=35), put toilet paper into the pot (n=5: 31% of n=16), changing a tampon (n=5: 33% of

n=15), helping my child with toilet use (n=10: 71% of n=14), cleaning the toilet/pot (n=11: 79% of n=14).

They regarded the train toilet to be *good* for doing the following practices: looking into the mirror (n=11: 34% of n=32), put toilet paper in the pot (n=5: 31% of n=16), blowing their nose (n=4: 50% of n=8), combing/re-arranging hair (n=3: 38% of n=8). Notably, these activities do not involve excreting actions.

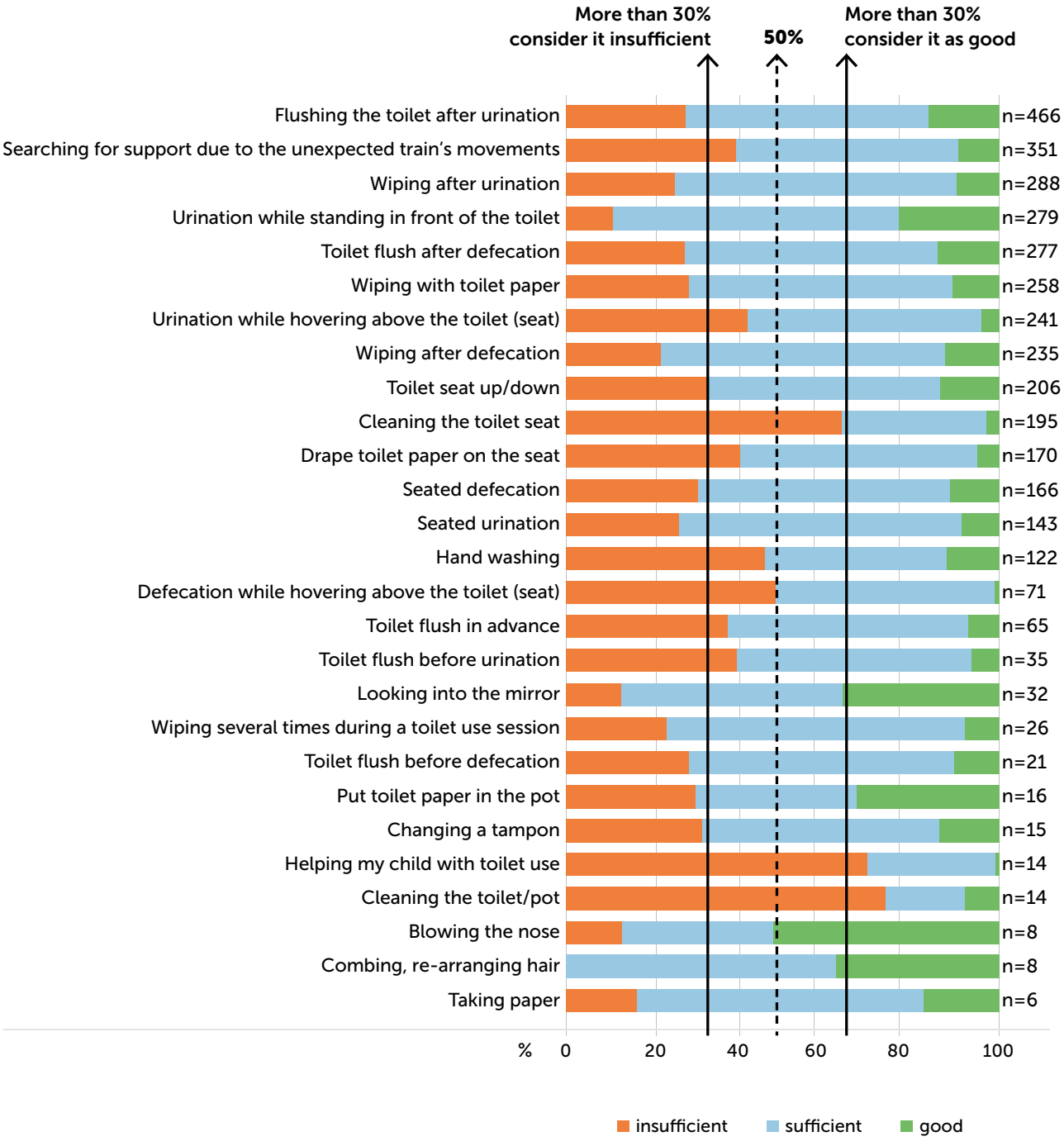


Figure 3.18 Overview to what extent a current train toilet meets travellers' main practices.

3.5 Discussion

Humans are very diverse, and so are their needs and usage of a toilet. In this study, we aimed to identify these different needs and uses, specifically in the context of train travel. The responses of 1267 NS panellists who responded to our email request to participate in this study formed a solid basis that eventually led to the design of a new NS toilet that will improve the hygiene of train toilets and, as a consequence, its use. In this section we discuss this study's main results and limitations.

3.5.1 Main results

The following characteristics of travellers that affect train toilet usage are discussed; gender, age, physical abilities and travelling with children.

Gender

More women than men participated in this survey, similar to the NS 2008 survey of train travellers in the Netherlands (NS 2008). Women perceive train toilets more negatively than men, which is probably why they are more reluctant to use them than men. They are more involved in toilet use than men as they have more physical contact with a toilet facility because of their anatomy. They adopt a sitting or hovering position, whereas men remain standing in front of the train toilet. As a consequence, they are probably also more negative about the hygienic quality of the toilet. This is in line with the findings of (Curtis, Aunger, and Rabie 2004, S132). They suggest that women respond "more sensitively specifically to disease threats" from, in our case, faeces than men because of their "evolutionary role in protecting the next generation".

Age

In terms of age, more travellers from an older age group (45-65) took part in the study (figure 3.10). Furthermore, more recreational travellers took part than commuters; recreational travellers also travelled less frequently by train. The factors are probably interrelated: an older age group includes more recreational travellers who travel by train less frequently.

Older people are probably more motivated to participate in a toilet study than younger people who are relatively less dependent on toilets (Greed 2003; Bichard, Hanson, and Greed 2005; Molenbroek, Mantas, and de Bruin 2011). Relatively more younger respondents participated In the Stated Preference survey than in our study. As a result, the need for a train toilet was less pronounced compared to our results (Steer Davies Gleave 2010). The Stated Preference study concluded that 30 minutes is the critical time before a toilet becomes necessary. This contrasts with our findings, where a percentage of 30% indicated that they would need a toilet within 30 minutes (figure 3.13).

Physical ability

About 10% of all respondents (n= 121 of 1267) replied that they had disabilities or other health reasons that affected their toileting (figure 3.15). This reflects a common distribution of people with disabilities in the Netherlands. However, we did not ask which kinds of restrictions they had.

Travelling with children

Relatively few respondents (n=24) expressed that they travelled by train together with children, while the proportion of children under the age of 10 in the Dutch population is larger: 10%) (CBS 2009). However, we did not ask a direct question about traveling with children, so that the actual number of passengers travelling with children could not be determined. Only those who reported using the train toilet for the care of children were counted. A separate direct question about travelling with children would probably have increased the number of respondents travelling with children.

Furthermore three other aspects are discussed; necessity of a train toilet, paying for a toilet, and the Needscope approach.

Necessity train toilet

Travellers consider the presence of a train toilet important. NS research shows different numbers of passengers using train toilets. According to study one (n=3095), 5% used the train toilet (NS 1 2007) (see table 1.1). Another study found 13% (of n=692) who used it (Hauwert 2008). Louts who conducted 29 hidden toilet observations, counted a number of 5- 6 travellers per hour who used the train toilet.

Paying for a toilet

The phenomenon of paying for a toilet is an ethical issue, as some people are dependent on a toilet. It seems unfair to pay for a facility given the natural need it meets, which some people need more than others. Moreover, paying with coins or without (such as contactless) also creates new usability problems, while natural access for a basic need is expected.

The willingness to pay for a toilet was evenly spread, a majority of 55% were unwilling to pay. Nevertheless, it could be an incentive for the operator to offer a clean(er) toilet. Paying for a toilet visit dates back to Vespasianus and Jennings' times, see section 2.4.1. It was an incentive to offer sufficient public toilet facilities (Parent 1987; George 2008; Lamarcq 2012). Finally, on the one hand, while payment raises a barrier to using a toilet, on the other it may also remove a barrier, because people expect it to be cleaner (77% of n=333, see A.3.2.3, and de Bruin and Loth 2013, 134-137). This ethical issue needs to be further discussed and researched.

Needscope

Although a psychological analysis was not the core of this study, a question was addressed to NS's Needscope approach, which categorises train travellers in six groups such as certainty seeker, functional planner, and four other groups, see A.3.2.2, figure A.3.3 (Jung 1959; van Hagen, Visser, and de Gier 2005; Boes 2007; van Hagen 2011; van Hagen and Exel 2012). A quarter (27%, n=280) could not choose a specific Needscope category as this study primarily addressed ergonomic aspects of toilet use. A conclusion from this questionnaire is that demographic variables such as age and gender, together with physical ability (somewhat dependent on age), are considered to have an impact on toilet usage. However, psychological aspects that could be important for the perception of toilets are minimally described.

3.5.2 Limitations of the questionnaire

Validity

This study's limitations are reflected in the representativeness of standard demographic human variables such as age and education, and in travel characteristics, such as travel motive and travel frequency. However, the sample is fairly representative for determinants affecting toilet usage: gender and physical ability. In addition, a relatively large number of older people completed the questionnaire, while their needs relate to many train travellers. Older people form a growing segment of Dutch (travellers) population whose needs and wishes are becoming increasingly prominent due to the 'ageing' of society (CBS 2009; Dutch Minister of Social Affairs and Employment 2017).

Moreover, to concentrate as a designer on this 'ageing' phenomenon, which is usually accompanied by physical deterioration and limitations that concern a smaller 'vulnerable' group, offers an opportunity that benefits the large 'healthy' majority. In other words, the design approach encompasses the 'inclusive design theory' (Greed 2003; Bichard, Hanson, and Greed 2005; Anthony and Dufresne 2007; Molenbroek and De Bruin 2011; University of Cambridge 2017; DTO 2018; BTA 2019; WTO 2019). It is thus relevant for NS, policymakers, and designers alike to anticipate the needs of a relatively older group of train travellers. In conclusion, the results can be considered valid and useful for humans and Dutch train travellers in general, although the results cannot be directly extrapolated to the Dutch train travel population due to some limitations in representativeness.

Train toilet

The representation of the train toilet in the questionnaire (figure 3.5) could have been interpreted as a 'dressed up' version, i.e., it looks spick and span, or unused. Although the image is not representative, respondents were not disturbed by the embellished image; it appears that they had a more realistic version of a train toilet in mind when answering

the questions. However, NS research shows that a train toilet receives a somewhat higher score (still considered insufficient) after people assess it immediately after usage. Therefore, the assessment of a train toilet is also based on a biased negative attitude that people in general have towards public toilets, including train toilets.

Motivated respondents

Approaching the respondents via the NS panel and the fact that NS would remove the train toilets from the Sprinter trains could have led to a select group of motivated train toilet users. In addition, the questionnaire may have been too long; some respondents may have taken at least 30 minutes to complete the questionnaire. However, they had the choice to make it longer than necessary. Nevertheless, this did not prevent them from sharing valuable information in the form of additional comments. The pilot of 7 participants completed the questionnaire in an average of 16 minutes, however they reported that they needed 20 minutes.

3.6 Conclusions and recommendations

3.6.1 Conclusions

Based on a questionnaire with 1267 respondents, the sub-research questions of this study were answered:

RQ 3.1: What are the characteristics of train travellers?

1. Humans are diverse, and so are train travellers. The characteristics of humans that affect toilet usage are their gender, age, and physical ability.
2. Carrying (hand)luggage, is a typical characteristic of train travellers.
3. Relatively few respondents expressed that they travel by train with children.
4. Relatively older people (45-65) completed the questionnaire.

RQ 3.2: How do they use the train toilet?

5. The train toilet is mainly used to urinate (7 indicated that they do not urinate (1%) versus 351 who do not defecate (44%), n=798)).
6. The majority of men (68%) stand while urinating, and 58% women hover and 29% remain seated.
   Approximately the same postures were adopted while defecating for women, although more women than men said that they do not defecate in the train toilet.
7. Train travellers are more likely to use the toilet sitting down because of the train's movements.
8. Respondents who do not sit while urinating or defecating would never sit down, even if it were hygienically possible (30% avoid sitting while urinating and 16% avoid sitting while defecating).

Finally, the answer to the research question posed in this chapter:

RQ A2: How does train travel affect train toilet users' needs and usage?

9. A train toilet fulfils an important public toilet function throughout the train journey (from door to door).
10. People are more inclined to travel by train if a clean train toilet is available, specifically older people.
11. The need for a toilet correlated with the period that people spent on the train.
12. Providing adequate storage space for hand luggage in the train toilet can remove a barrier to its use.
13. Travellers search for support in the train toilet for the (unexpected) movements of the train.
14. The train toilet needs to be made more accessible for children (and their guardians).

3.6.2 Recommendation

Based on the questionnaire results, the following aspects should be further researched: storage space, observational research, education type, the needs of older adults and children, and a tool for cleaning the train toilet. Lastly, the ethical issue of paying for a toilet also needs to be further addressed, as discussed in section 3.5.

More people with a theoretical education participated in the questionnaire. It is assumed that educational type does not affect toilet usage. However, this assumption could be further researched.

Older adults have less control over their toilet usage (bladder). Their needs are not always taken into account in public toilet design (Bauer and Huebner 2013; Greed 2003; Bichard, Hanson, and Greed 2005). Moreover, this group also carries items such as diapers, colostomy equipment, catheters, wheelchairs and walkers. This should be further examined in the context of train travel in general and, more specifically, on toilet use.

In addition to older adults' needs, the wishes of children aged under 12 who usually travel with attendants should be taken into account in the design concerning train travel and train toilets. Specifically, the toilet needs of babies and toddlers who are most in need of guidance during their toilet use requires further design, see Part C (Chapter, 7 and 8).

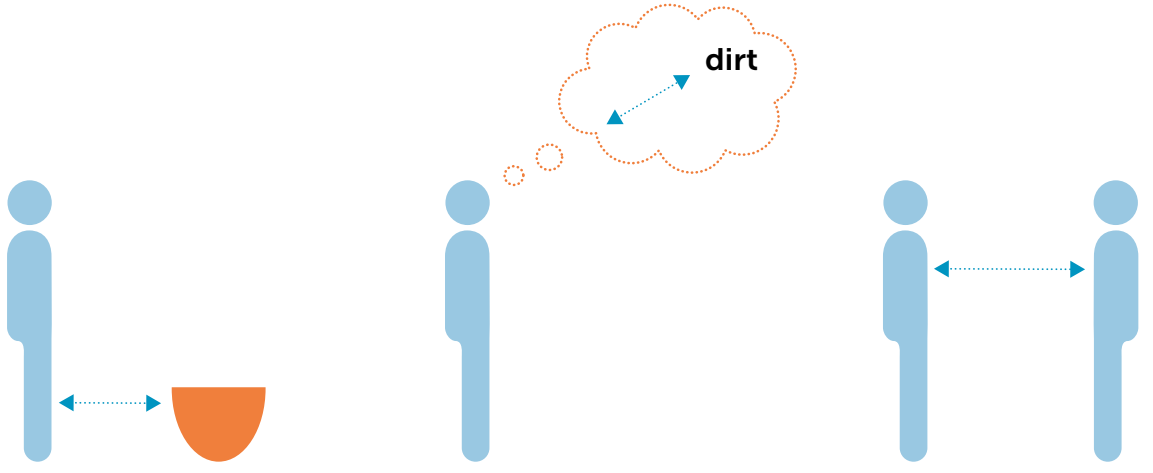
People indicated that they were willing to leave the toilet clean. Nevertheless, a facility to clean the train toilet is not available in the train toilet, such as a toilet brush. NS is reluctant to offer a toilet brush in the train toilet because of possible misuse. Further research is required to develop and design a facility for cleaning a train toilet for those who have just used it.

Part A:
literature and surveys

Recap

In Part A, we set out to answer the following research question: '**Why are train toilets perceived as being dirty?**'

In chapter 2, we reviewed the literature on sanitation and the history of personal hygiene as well as findings from regular NS surveys. We found that toilets and their sewers have played a leading role in improving hygiene conditions; clean toilets are a symbol of development and civilisation. Over the past four thousand years, the human approach towards personal hygiene has transformed from a communal activity to an individual matter.



a. Physical distance (P) to toilet

b. Mental distance (M) to dirt

c. Social distance (S) between train travellers

We introduce the concepts of Physical, Mental and Social distance. We noticed a Physical distance (P) between public/train toilets, including issues like carrying hand luggage in train toilets. People perceive a Mental distance '(M) between the human body and what we define as 'dirt': human dirt refers

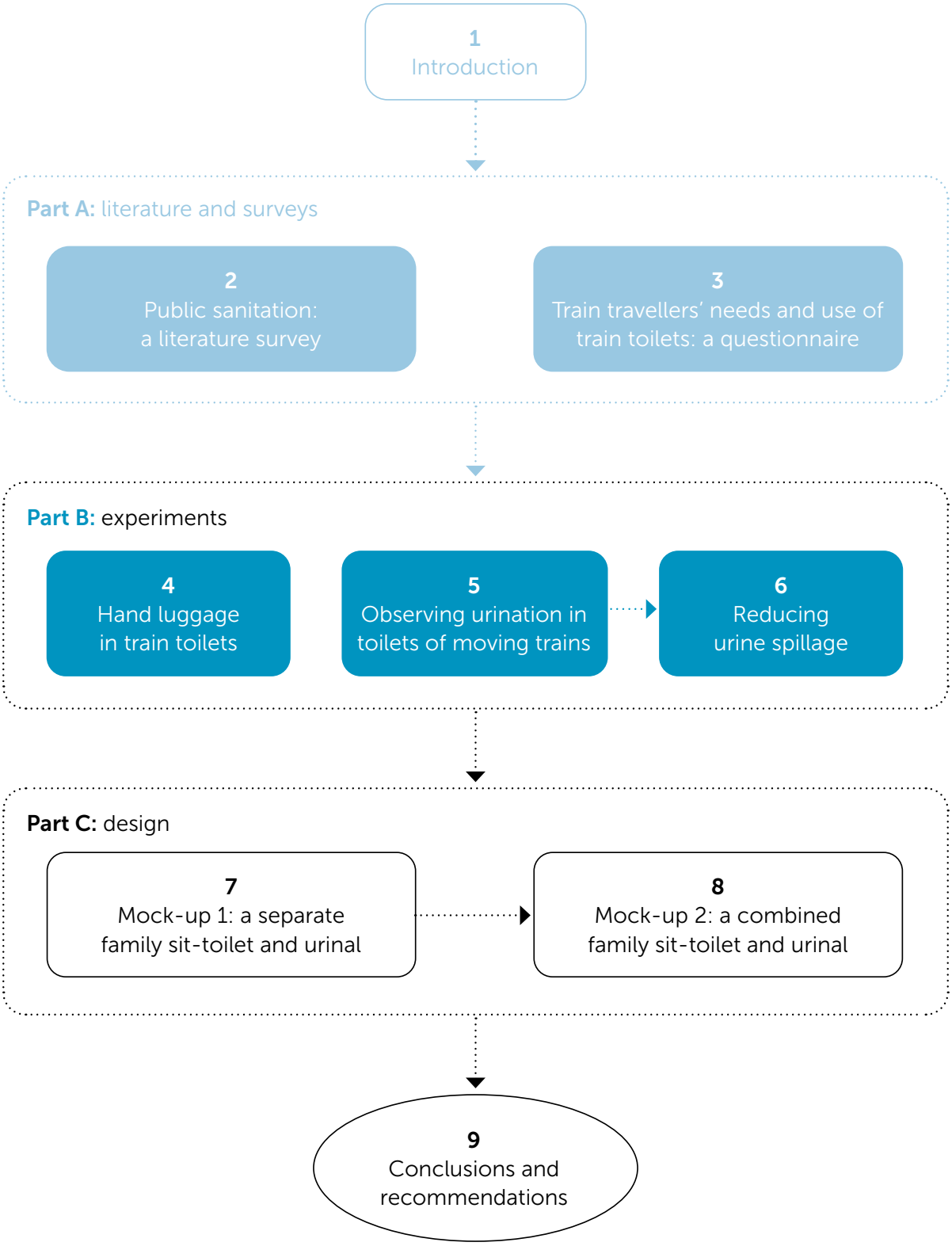
to toilets with materials like faeces, urine, blood and toilet paper that people perceive as being out of place. We discuss the Social distance (S) that occurs when the dirt belongs to unknown users, i.e., between whom there is a wide social distance.

In addition, we recommend improving the accessibility of train toilets for travellers, by addressing the project from an "inclusive design" perspective.

In chapter 3, we present the findings from a questionnaire developed together with the NS (Dutch Railways) in which we asked train travellers about their needs and usage of train toilets in the context of train travel.

Respondents stated that there is insufficient storage space for their hand luggage in the train toilet and that this forms a barrier to using the train toilet. Therefore, further research is needed on storing hand luggage in relation to their use of train toilets.

The train toilet is insufficiently assessed because travellers indicated that they are unable to perform some practices properly. Based on this, we recommend conducting observational research as a research method for the successive experiments of Part B to obtain a clear insight into train toilet usage as an alternative to the questionnaires.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Public sanitation:
a literature survey
3
Train travellers' needs and use of
train toilets: a questionnaire
Part B: experiments
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5
Observing urination in
toilets of moving trains
6
Reducing
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Part C: design
7
Mock-up 1: a separate
family sit-toilet and urinal
8
Mock-up 2: a combined
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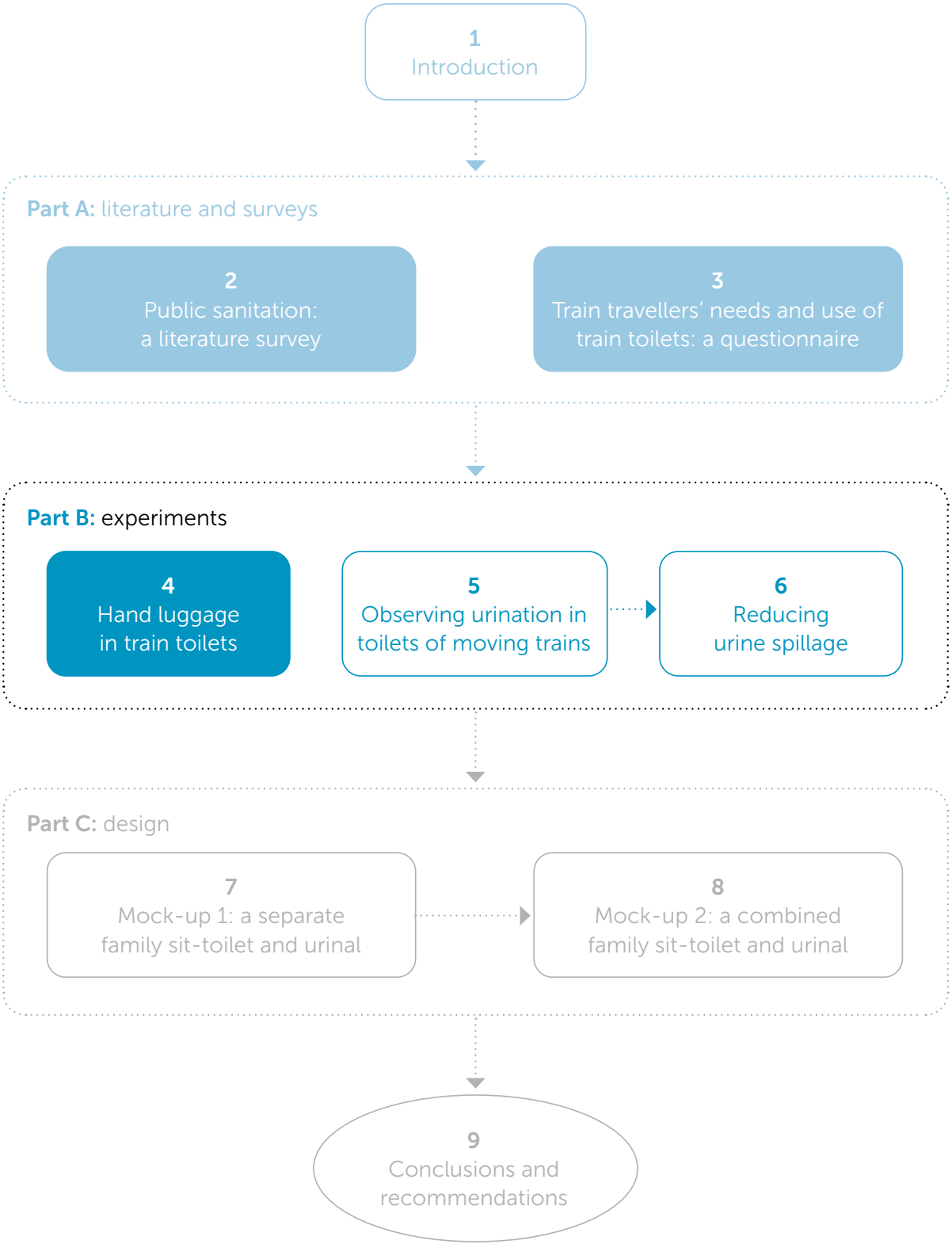
Part B: experiments

Introduction

In Part B, train toilet use was explored based on observational research experiments in moving trains.

In Part A, we described the (toilet) needs and the use of the various groups of passengers based on a review of the literature and a questionnaire sent to train travellers. Results showed a number of factors related to using train toilets: there are hygiene issues related to their main use, urination, and that access is affected by difficulties with luggage and the storage space.

The experiments in part B thus focus on the use of the train toilet with regard to hand luggage and urination, the themes of chapters 4 and 5 respectively. In chapter 6, we further investigate the issue of urine spillage observed in chapter 5.
Part B answers the main research question: **How does its usage affect train toilet hygiene?**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Chapter 4
Hand luggage in train toilets

4.1 Introduction

When answering the questionnaire (chapter 3), travellers reported that the lack of storage space forms a barrier to using the train toilet. Very little has been published on hand luggage in relation to public toilets; any literature found mainly refers to design solutions for storage, like luggage zones and shelves (Greed 2003; Anthony and Dufresne 2007; BSI Standards Publication 2012).

In this chapter, we dive into the issue of storing hand luggage in connection with the use of train toilets to answer research question **RQ B1: What travellers do with their hand luggage when using the train toilet?** Section 4.2 describes the questionnaire used to determine how participants dealt with their belongings in train toilets. Section 4.3 describes the observational research which forms the basis for the observations in the next chapter. Sections 4.4 and 4.5 address the results of the questions and observations related to hand luggage. In section 4.6, we discuss the results and reflect on the study's limitations. Subsequently, in section 4.7, we present our conclusions on the hand luggage issue, together with our recommendations.

Hand luggage characterises travellers; commuters commonly have some form of (hand) luggage with them; they carry "more than [just] a rolled-up" newspaper (Greed 2003, x) or mobile phone. In Dutch train compartments, various storage place are available including hooks to hang up a coat, overhead luggage racks, and spaces behind the seat for luggage storage. In all NS train toilets, however, only a hook is available for hanging up a bag and or coat. This leads to the focus of this chapter, in which we examine what travellers do with their hand luggage when using the train toilet.

Firstly, let us define what we mean by hand luggage: small luggage that can be handled and stored on the body, with an estimated weight of less than 5 kg, including coats and excluding suitcases and trolleys. We describe four commonly used bags based on size. The smallest of these is a handbag -a small handheld bag. A shoulder bag (figure 4.8a, section 4.3.3) is larger than a handbag, and, the largest type of hand luggage is a weekend/sports bag (figure 4.11c, section 4.5.1). These three bags are similar in that they have a strap attached so that they can be slung over the shoulder. The fourth type is a backpack/rucksack; a form of hand luggage with two wide straps designed to be carried on the back (figure 4.11b, section 4.5.1). However, many travellers also have plastic

shopping bags with them (figure 4.4, section 4.3.2), and some have medical aids such as a colostomy bag, catheters, walkers, and wheelchairs (Greed 2003).

4.2 Method questionnaire

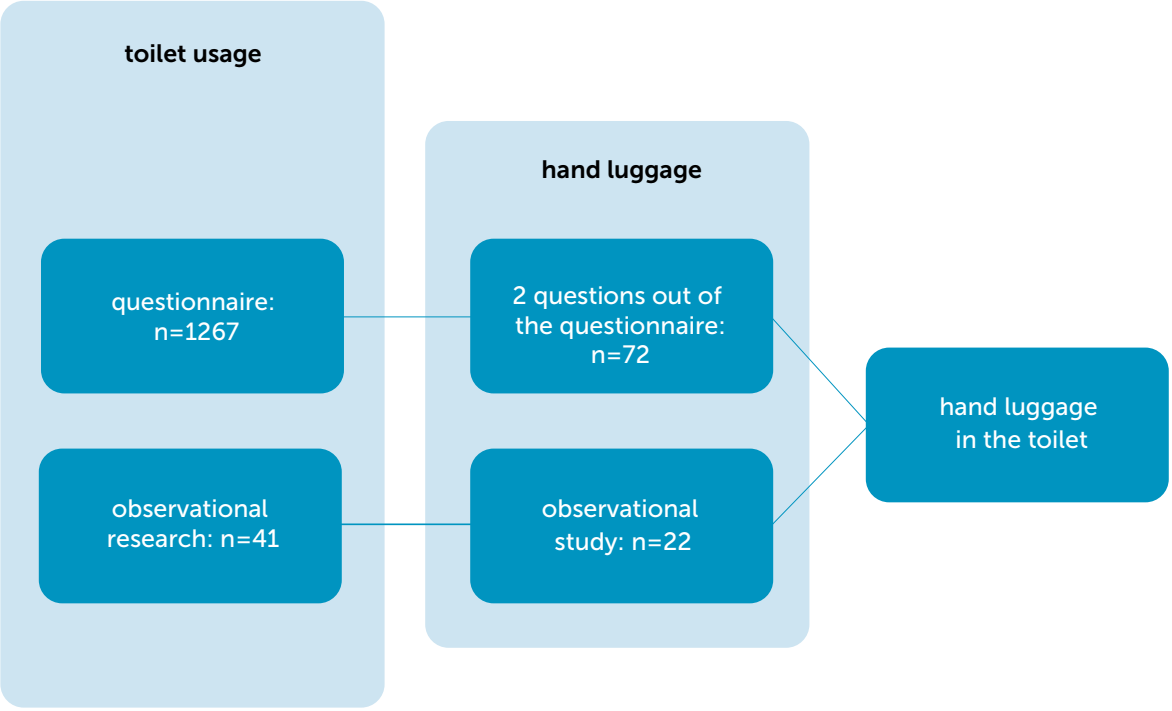


Figure 4.1 illustrates the research method of this chapter

First, the questionnaire, described in chapter 3, was developed to determine travellers' needs and use of the train toilet. It includes 75 mainly closed multiple-choice questions, and was completed by 1267 Dutch train travellers. 72 respondents completed the two questions specifically related to dealing with personal belongings in the train toilet. The first of these dealt with the dilemma of carrying hand luggage in the train toilet and the second, open question, was asked to gain insight into the types of hand luggage travellers carry with them on their trip:

1. I do not want to/cannot take my luggage into the toilet:
   1.1 because of a lack of storage.
   1.2 if I take my belongings with me I lose my seat.
2. Can you give a description of the hand luggage/personal belongings?

Secondly, in the observational study, the focus was on aspects of taking hand luggage into the train toilet, and what travellers did with it when using the train toilet. It forms part of an overarching observational research, which is described in the following section.

4.3 Method observational research

In this section, the method of the overarching observational research is described, which includes the method for both chapters 4 and 5.

In the observational research study, 41 participants visiting train toilets were audio-video-recorded in moving trains. These were conducted in the context of toilet usage and hygiene. This chapter includes an analysis of the observations of how 22 participants dealt with hand luggage in the train toilet.

4.3.1 Ethics, privacy and participants

Ethics and privacy

Research students (Master and Bachelor) audio-video recorded 41 male and female participants using the toilet in two standard moving NS trains, followed by interviews. The 'Human Research Ethics Committee' (HREC) at TU Delft approved this research in retrospect, see Appendix A.5.1. We met the consent form criteria in combination with making the participants unrecognisable in order to safeguard their privacy. The study took place in 2010 before HREC was established in 2012 (TU Delft, n.d.) as part of the Master's courses 'Design For Interaction', "Observational Research DFI 4225", as well as a Bachelor's elective course "Research Project IO 3080.

Initially, the participants were divided into six research groups; each group focusing on a certain aspect such as hand luggage or touching the door handle. All observations were combined, analysed, and coded using the Observer XT program. Several precautions were taken to preserve participants' privacy. First, the data (observations) were stored on a password-protected desktop computer only accessible to the author who coded the observations, and on an internal TUD server (as backup) which was only accessible to the lab manager and author. The research students had temporary (one quarter) access to the TUD server in a TU Delft lab under supervision of the lab manager.

Second, participant information (e.g., names) was replaced with numbers based on gender (1m, 2f, etc.; see table 4.1 hand luggage, section 4.5.1). Therefore, no recorded information could be connected to the participants by name. Lastly, to ensure that the participants were completely unrecognisable in publications, Fleur Derks drew outlines of their video recordings as representations of their (toilet) activities, as exemplified in all the figures where people were involved, such as 4.11-4.15, section 4.5.1.

Participants

Research students and the PhD team used their network of colleagues, friends, students, and family members to recruit a mixed group of participants. We strove to represent a diversity of train passengers in terms of age, gender physical capacities, profession, and

frequency of train travel. The 41 participants were aged between 5 - 60, with 10 females and 31 males. Four travellers had specific usage needs: a wheelchair user, a young child (female), a colostomy bag user, and one participant used crutches (see table 4.1 hand luggage, section 4.5.1). All participants had previous experience using train toilets.

The participants were directly approached and informed verbally about the purpose and nature of the study and that they would be audio-visually recorded using the toilet. Therefore, they were asked to provide informed consent, while the researchers guaranteed their privacy, see Appendix A.5.1.2. The young child's guardian provided informed consent on her behalf. In addition, the participants were compensated with a travel card for one day of unlimited first-class train travel (value around 80 EUR).

Although the participants represented a mix of professions, ages, genders, and specific usage needs, many healthy young male students were involved, referred to as "able-bodied men" (Williams 2009: p.12). The sample represents a convenience rather than a representative sample of all Dutch train users. However, students often travel by train in the Netherlands, as they receive a free public transport card for the duration of their studies ('Ov-Chipkaart' 2016). The research students themselves could not be involved as participants (one of the preconditions for ethical approval), because of their dependent or unequal relationship with the author (student-instructor). Research students might therefore be regarded as a vulnerable group of participants, which is also the case for young children. The young child who participated did not have any relationship to the author, and could therefore be involved as a participant after the child's guardian provided informed consent on her behalf.

4.3.2 Experiments

The NS facilitated this unique research opportunity by providing two double-decker VIRM Intercity trains in daily service ('Intercity [VIRM]' 2015) that we equipped with observation equipment. Both trains were occupied exclusively by people involved in the study, including the research students, participants, and support staff. The first experiment was held on 9 March 2010 and included 31 participants on the journey from the Hague to Amsterdam and back, a duration of approximately 120 minutes. As time was limited, the four groups took turns, and camera positions were changed to observe participants from different perspectives. This experiment resulted in 32 observations.

Two weeks later, on 23 March 2010, a second train was scheduled for a shorter journey from The Hague to Leiden and back; a journey of approximately 50 minutes. This second experiment resulted in 13 observations of 12 participants divided into two groups. Members of the press were invited to attract public attention to the joint project.

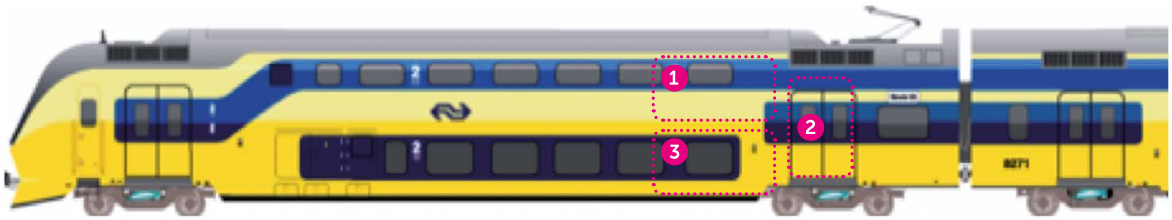


Figure 4.2 Routing of participants in Double Decker Intercity VIRM: 1 = waiting room with drinks and snacks, 2 = train toilet where observations took place, 3 = observation room with computer

Procedure

The procedures were similar for both experiments. The participants were asked to drink enough before entering the train so their bladders were full, maximising opportunities for toilet use. The participants and researchers met at 9:30 on the platform at The Hague Hollands Spoor station (Den Haag HS.) and boarded the double-decker train. Participants were directed to sit in the upper level of the train.

Preparations for the study, such as introduction to the research team, explaining the procedure, privacy and informed consent took place in the upper area. We emphasised that participants could exit the study at any time if they felt uncomfortable and/or disallow the use of any observations. This upper level also served as a waiting area with some drinks and snacks that could be freely consumed. The research students' main tasks included giving instructions, interviewing, and observing train toilet usage using audio-visual recordings of the participants. This took place in the lower level of the train.

Subsequently, the participants walked downstairs to the toilets, guided by a research student who gave participants a minimal instruction 'use the train toilet as usual' to create a situation in which they would naturally use the toilet. In addition, the students did not interfere with the participants when they were using the toilet. Figure 4.2 shows the research setup.

A research student inspected the train toilet environment after each use; consequently, it was sometimes cleaned in between. The criterion was that the train toilet environment reflected a 'normal' state, which meant it was neither completely clean nor dirty, and was kept in the same tidy condition as at the start of the study. An exception was formed by research group 1 (1m to 11m) who studied a clean train toilet scenario with half of the group and a dirty scenario with the other half, to examine whether the participants would behave less carefully in a dirty scenario. This group cleaned the train toilet before each participant used it, and dirtied it with chocolate spread for the dirty scenario.

In many cases, it took some time before the first participant needed to go to the toilet, so many observations took place sequentially resulting in shorter interviews in which

only a few questions were asked; in some cases, the interviews were skipped altogether. Only groups two (12f to 21m) and four (29m to 33m) reported all interviews (see appendix A.5.2). Groups four and six deviated from the standard procedure with regard to the interviews as they participated in the second research train with a shorter journey of 50 minutes. Therefore, group four held a brief interview with their five participants after the observations. Due to time pressure, group six participants' observations were given priority over interviews. After the interviews, or in cases where the interview was skipped (approximately half), the participants returned to their seats on the upper level of the train.

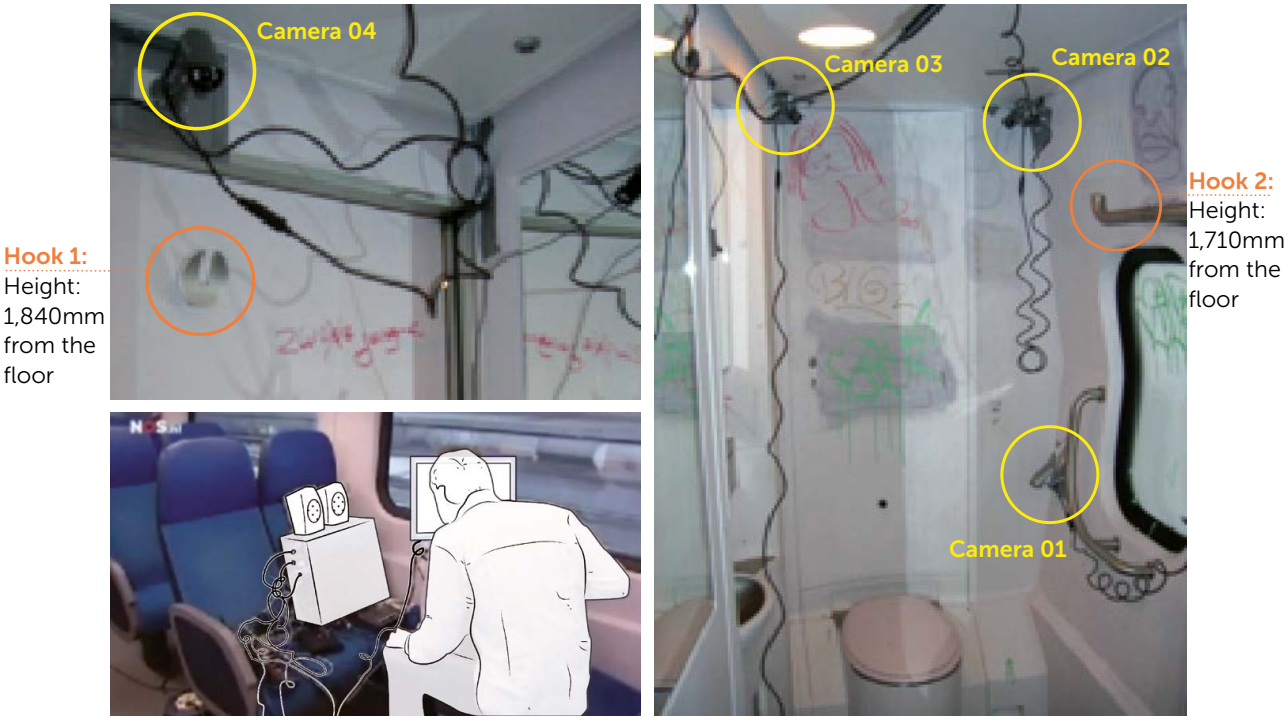


Figure 4.3. Impression of the context and installation of cameras (within blue circles) and positioning of hooks (within purple circles)

The train toilets were equipped with cameras (figure 4.3; within the blue circles), and further observation equipment was installed in the train compartment in the vicinity of the toilets. Figure 4.3 gives an impression of the context during a pilot test that took place before the actual observations (shown in figure 4.4) where the cables were made less noticeable with duct tape. However, they were less hidden in the pilot test (figure 4.3; the examined hooks 1 and 2 are within the purple circles).

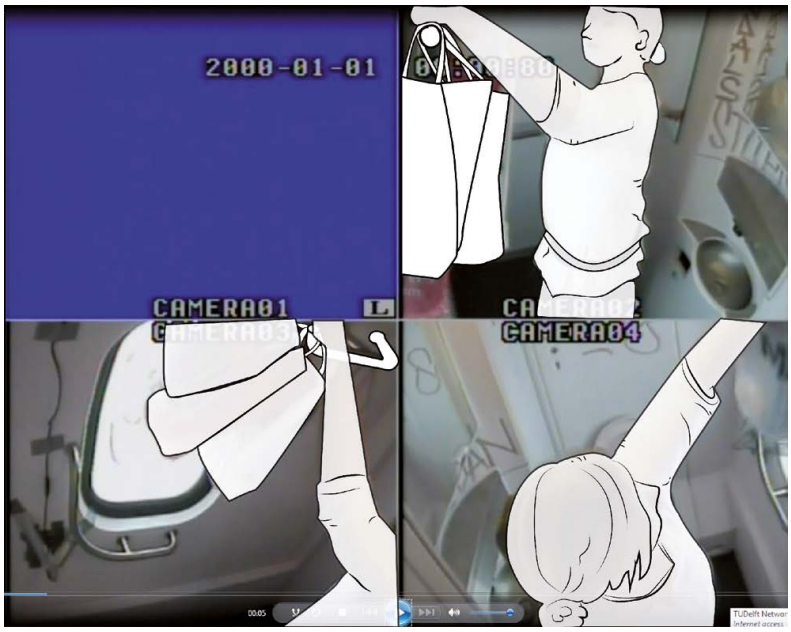


Figure 4.4. Plastic shopping bags in large train toilet, camera 01 was disconnected

Hand luggage intervention

The research group studying participants 12 - 21 focused on hand luggage, taking extra care to ensure the camera positions that recorded the handling of hand luggage while their participants used the train toilet. Moreover, they encouraged their participants to take hand luggage into the train toilet, where they could choose between plastic shopping bags or a weekend bag in addition to their own hand luggage such as a handbag and rucksack (Loth, Molenbroek, and van Eijk 2018). For reasons of discretion, one camera (01) was disconnected in order to ensure a less clear view of the female participant (figures 4.3 and 4.4).

4.3.3 Materials

Train toilets

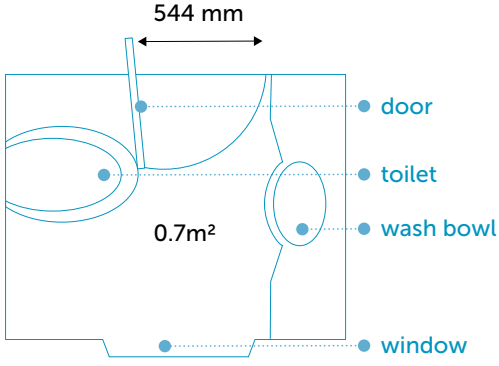


Figure 4.5a Small train toilet

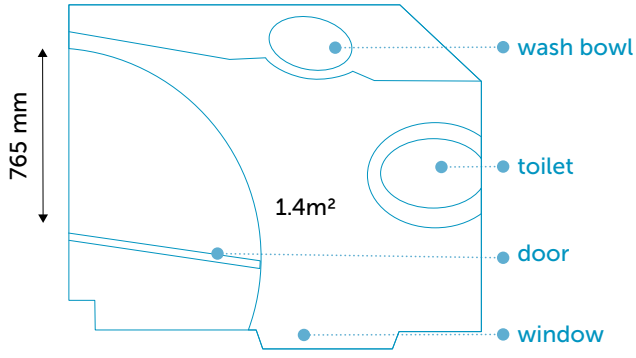
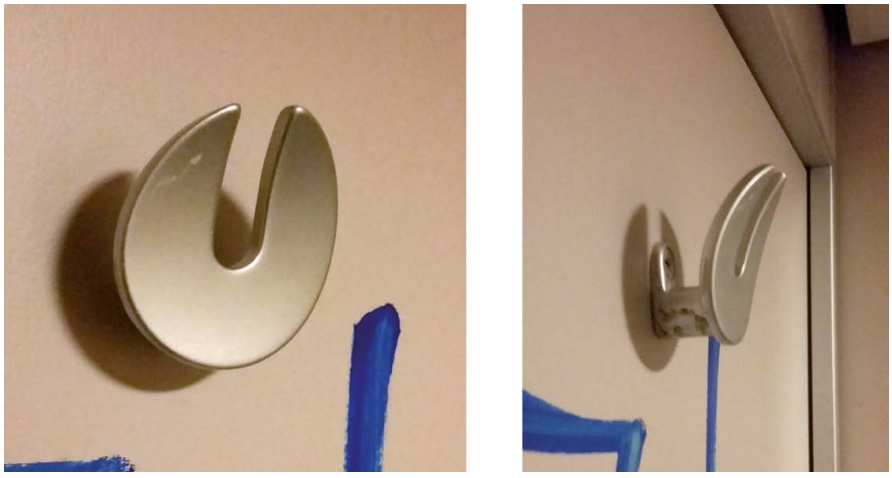


Figure 4.5b Large train toilet

Figure 4.5 Top views train toilets in VIRM trains

The VIRM research trains have two toilet sizes: a small toilet (0.7 m^2) in the front compartment (figure 4.5a), with a larger toilet (1.4 m2), designed especially for users with disabilities, situated at the rear (figure 4.5b). The main differences between the toilets are the interior dimensions, door size, and direction of door opening/closing figure 4.5. The toilet is a sit-toilet, as shown in figure 4.3. In the overarching study, 23 observations were recorded in the small toilet and 22 in the large one. With regard to hand luggage, 8 observations took place in the small toilet and 14 in the large toilet.

Hook 1



a *b*

Figure 4.6 a and b: Current hook in the train toilet.
Photo: Jantien Doolaard

The toilets have a specially-designed hook, the same as those in the train compartments, inside the train door at a height of 1840 mm from the floor, which, for example, can be used to hang a coat, figure 4.6a, b. It can carry a maximum weight of 30 kg (International Union of Railways 1990).

Hook 2

Figure 4.7 Hook 2: actually, designed for another purpose,.
Photo: Jantien Doolaard

In the toilets, an alternative hook (hook 2) was located at the far end of the support bar (see figures 4.3, 4.7 and 4.13, sections 4.3.2 and 4.5.1); 140 mm lower than hook 1 at the height of 1700 mm from the floor. The real purpose of this hook (contiguous with the support bar) was to hang up a triangle aid that would support users with disabilities to transfer themselves to and from the toilet. Because of frequent misuse of this triangle aid, the NS decided to remove it from the supporting bar (information provided by Dutch Railways, NS).

Cameras

Camera type CCD4Q Elro (PAL) was chosen due to its user-friendly and unobtrusive design. The cameras were installed in three steps. First, they were tested in a lab setting to determine strategic positions. A pilot test was held in a stationary train at a marshalling yard in The Hague to check the connection between the cameras and the computer, during which the research students acted as participants, see figure 4.3, section 4.3.1.

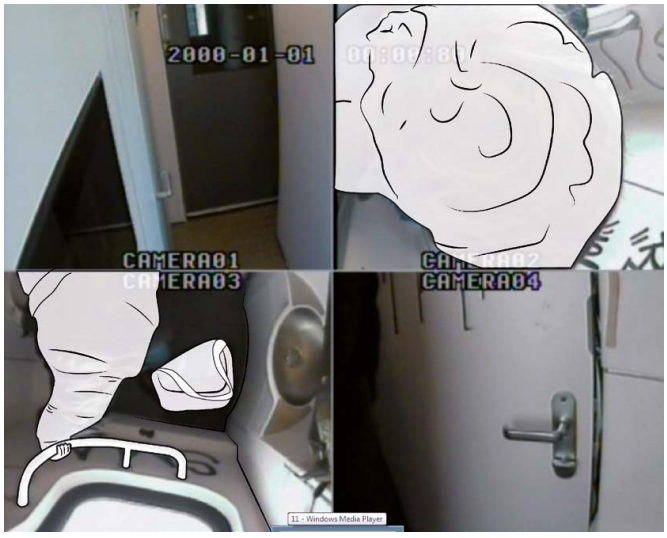


Figure 4.8a four camera viewpoints, and (shoulder) bag placed on the floor in the small train toilet

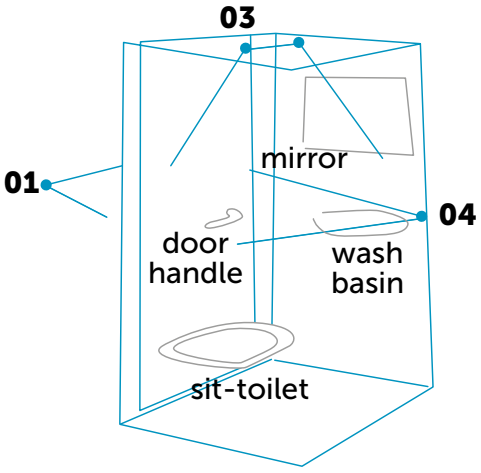


Figure 4.8b Overview camera positions

Figure 4.8 Camera positions

Finally, four cameras were installed in the train toilets to ensure that four viewpoints were visible on the computer screen (figure 4.8a). One camera was positioned for a complete overview, while a second focused on the washbasin to observe hand washing and drying. The other two cameras were positioned for each group according to the research questions being addressed. For example, for group three (22m to 28m), two cameras were positioned to film both the indoor as well as the exterior door handle (see figures 4.8a and b).

4.4 Results questionnaire

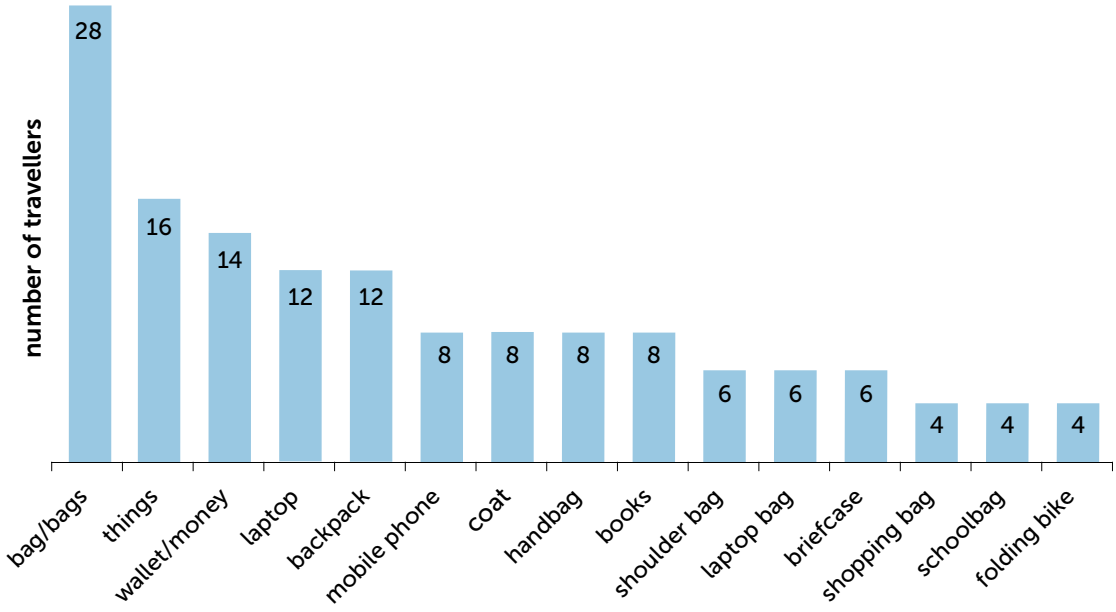


Figure 4.9 Description of the hand luggage of Dutch train travellers

72 respondents completed the questions related to hand luggage:

1.	**I do not want to/cannot take my luggage into the toilet:**	**n=72**
1.1	because of a lack of storage:	n=28
1.2	if I take my belongings with me I lose my seat:	n=22
1.3	both reasons (1.1 and 1.2):	n=22
2.	**Can you give a description of your luggage?**	**n=72**

In answer to question 1, approximately one third of the respondents (n=28) answered that there was no appropriate place to store their luggage, approximately one third (n=22) reported they were afraid of losing their seat, and about one third (n=22) gave both reasons.

In answer to question 2, the respondents (n=72) described their hand luggage, as noted in figure 4.9. The top 5 items of hand luggage travellers take on their journey are: (1) bag (s), (2) 'things', (3), wallet/money, shared (4): laptop and backpack, and shared (5): mobile phone, coat, handbag, and books.

'Things' are the second-most mentioned luggage items; however, the respondents did not explain what they meant by this. We deduct that this represents the 'small items' that passengers take with them, such as a phone, keys, and wallets; personal items that people "like to have stored close by" or that they carry "in their own pockets" (Alberda et al. 2015 p.659,662).

No respondents mentioned suitcases and trolleys as hand luggage so these were not included in the observational study.

4.5 Results observational research

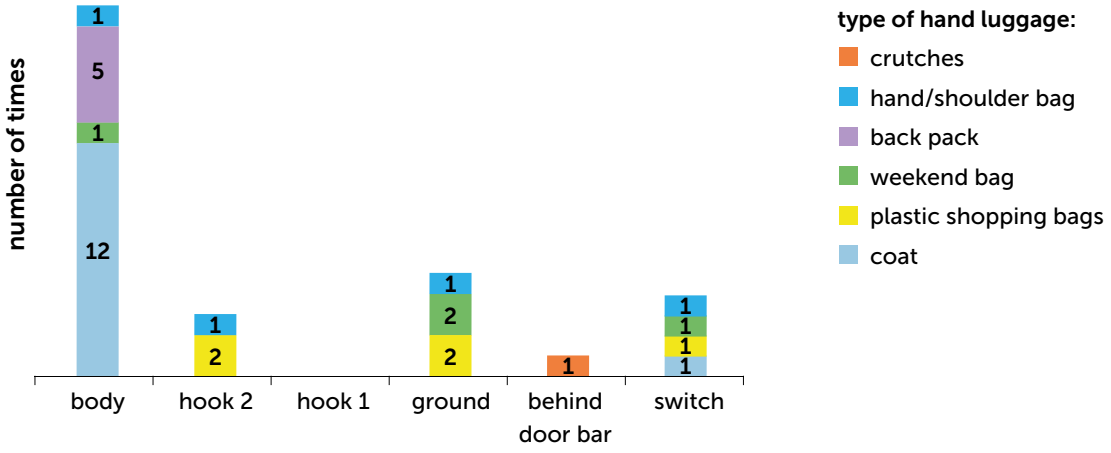


Figure 4.10 Places where the participants put their hand luggage in the train toilet

4.5.1 Places where participants kept their hand luggage

The observations showed that none of the participants used the hook 1 located inside the toilet door at the height of 1840 mm from the floor, (figures 4.3, section 4.3.2, and 4.6, section 4.3.3). However, they placed their hand luggage in the following places: (1) on their body (figures 4.11 a, b and c), (2) on the ground (figures 4.8a, section 4.3.3, and 4.12), (3) on hook 2 (figures 4.4, section 4.3.1, 4.13, and 4.14a), and (4) behind the door bar (figures 4.15a, c).

1. Body

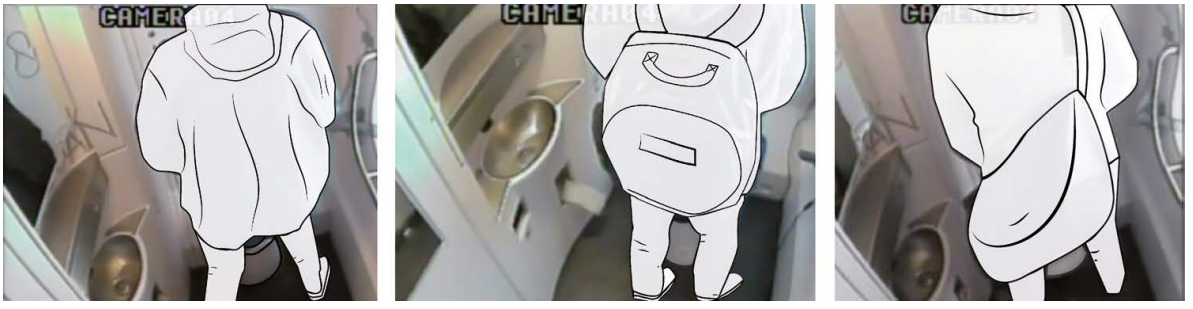


Figure 4.11a male participant keeps coat on while using the train toilet
Figure 4.11b a male participant wears rucksack on the back
Figure 4.11c male participant keeps weekend bag on the back while using train toilet

Figure 4.11 The body as storage place for hand luggage

By 'on their body', we refer to the item of hand luggage that participants kept somewhere on their bodies. Thus, on their backs, around their wrists, and/or keeping their coats

on. However, of the 22 participants, 9 left their coats on their seats before they embarked on the observation. The other participants kept their coats on (figure 4.11a) except one participant who directly hung up his coat on hook 2, but halfway through the observation he put on his coat again before washing his hands, (figure 4.14a,b; described below under switching). Five male participants kept their rucksacks on their backs (figure 4.11b); none of the women had a rucksack. One male participant held his weekend bag on the body (figure 4.11c). A female participant also did this initially, but as soon as she turned, she dropped the weekend bag in the corner (indicated as switching; figures 4.17, section 4.6.2.). In some cases, using the body as storage place led to difficulties, for example in one observation, it was clear that the male participant was looking for somewhere to store his plastic shopping bags, but he could not find a suitable place. As a result, he put the bags around his wrist, and this hampered him in his performance in the train toilet (figures 4.14 d, e, f).

2. Ground

Figure 4.12: A participant drops weekend bag in the corner on the ground

The corner of the toilet on the floor was a popular place to drop the bags (5 times) in the large train toilet, see figures 4.8a, section 4.3.3, 4.12, and 4.17c, section 4.6.2. One female participant directly put the plastic shopping bags in this corner on the floor, and after a short while, she dropped her handbag above the shopping bags in the same corner. So, in the large train toilet, participants dropped bags in the same spot, namely on the floor in the corner close to the door. In the small train toilet, the floor was used once to drop a bag (figure. 4.8a, section 4.3.3)

Figure 4.13 plastic shopping bags and shoulder bag on hook 2

3. Switching

Figure 4.14a 43m hangs up his coat on hook 2
Figure 4.14b 43m buttons up his coat, halfway
Figure 4.14c He keeps his coat on when washing the hands

Figure 4.14d 21m keeps plastic around his wrist 2
Figure 4.14e and he takes toilet paper
Figure 4.14f He drops plastic shopping bags on the floor between his legs when washing the hands

Figure 4.14 Switching with hand luggage

During the observations, five participants switched their hand luggage from one place to another, see figures 4.14, and 4.17, section 4.6.2. First, a male participant could not find a

place to keep the three plastic shopping bags, which he then put around his wrist (noted as body). In between, before washing his hands, he dropped the bags on the ground between his legs, see figures 4.14 d, e, f. Another switch action was a male participant who did the opposite in the small train toilet; he immediately dropped his bag on the floor and kept his coat on (figure 4.8a, section 4.3.3). Subsequently, he picked up his handbag from the floor and kept it on his body while washing his hands. The third case was the only participant who directly hung up his coat on hook 2, but halfway through the observation he switched: after sitting on the toilet and dealing with a colostomy bag, he put his coat back on, buttoned it up, and washed his hands (figures 4.14 a, b, c). Participant 15f kept the weekend bag on her back, but as soon as she turned her back to the wall, she placed the weekend bag in the corner, figures 4.17, section 4.6.2.

4. Behind door bar

a b c

Figure 4.15a and b 19m uses a crutch to raise the toilet seat
Figure 4.15c He puts the pair of crutches behind door bar

Figure 4.15 Using crutches

Participant 19m used crutches that he placed behind the door's support bar, figures 4.15.

Observation	Age group	Size of the train toilet	Type of luggage	Storage Place	Remarks	See figure:
6f	30-	small	coat	body		
9m	30-	small	coat	body		
12f	30-	large	plastic shopping bags	hook 2		*4.4*
13m	30-55	large	coat plastic shopping bags	body floor	in the corner	*4.11 a*
14 m	30-	large	rucksack	body		
15 f	30-	large	weekend bag weekend bag	body floor	while raising the toilet seat just before urinating	*4.17 a* *4.17 c*

16m	30-	large	weekend bag	body		*4.11 c*
17f	30-55	large	plastic shopping bags hand bag	hook 2 hook 2		*4.13*
18f	30-55	large	plastic shopping bags hand bag hand bag	floor	in the corner while closing the door above plastic shopping bags on the floor	
19m	30-	large	crutches	door bar		*4.15 a, b*
20m	30-	large	weekend bag	floor	in the corner	*4.12*
21m	30-	large	plastic shopping bags plastic shopping bags	body/ wrist ground	during urination during hand washing	*4.14 d, e* *4.14 f*
22m	30-	small	coat	body		
24m	30-	small	coat rucksack	body body		
26m	30-	small	coat shoulder bag shoulder bag	body floor body	during urination during hand washing	*4.8 a*
27m	30-	small	coat rucksack	body body		
28m	30-	small	coat rucksack	body body		
33m	30-	small	coat	body		
39m	30-	large	coat rucksack	body		*4.11 b*
40m	30-	large	coat weekend bag	body floor	in the corner	
41f	30-	large	coat	body		
43m	56+	large	coat coat	hook 2 body	during urination during hand washing	*4.14 a* *4.14 b, c*
Total:		**13**	**coats**			
n=22		**5**	**plastic shopping bags**			
male: n=16		**4**	**week-end bags**			
female: n= 6		**5**	**rucksacks**			
		4 **1**	**(hand/ shoulder) bags** **pair of crutches**			

Table 4.1 Hand luggage in the train toilet

4.6 Discussion

Hand luggage characterises travellers. The two questions about hand luggage revealed that issues of carrying belongings create a distance when deciding to visit the train toilet or not: the 72 respondents viewed the limited storage space in a train toilet as a problem and they were afraid of losing their seat. This prevented them from using the train toilet. They also gave an overview of their hand luggage when travelling by train (figure 4.9, section 4.4). The hand luggage observations, part of the overall observational research in chapter 5, showed where travellers left their hand luggage in a train toilet environment. In this section, we discuss the findings in the context of answering the following research question: 'What do passengers do with their hand luggage when using the train toilet?'

In general, people prefer to keep a close eye on their personal belongings in a train environment, as it is a relatively anonymous public place where a large social distance exists. As a consequence, they do not 'dare' leave their coats on their seats as they could be stolen and therefore, they take their personal belongings with them when visiting the train toilet. They reported both a lack of storage space and the risk of forfeiting their seat to another passenger.

However, if we compare a similar situation, it is likely that hand luggage issues are not the case in aircraft toilets where, like in train toilets, space is limited. In aircraft, the social distances between passengers are smaller compared to train travel in the Netherlands. Train travellers regularly board on and off, while in contrast, aircraft passengers board collectively prior to departure and on arrival, i.e. they spend the entire journey together. In addition, flight attendants are nearby. These factors make social distances smaller because there is more interaction and checks with fellow passengers, which means that flight environments are less anonymous and therefore the social distance is smaller.

Moreover, aircraft passengers do not lose their seat when visiting the toilet and they can also opt for an alternative to store their hand luggage, such as placing their coats in the closed overhead compartment. As a consequence, carrying hand luggage in aircraft toilets is less stressful. On the other hand, carrying and storage of personal medical belongings, such as colostomy bags, catheters, and diapers, both in aircraft toilets and in train toilets requires further research.

4.6.1 Storage places hand luggage

1. Body

The train participants' favourite place to store their hand luggage was their body, in particular, their coats and rucksacks (19 times, figures 4.10, and table 4.1 hand luggage in the train toilet, section 4.5.1, which is logical as both coats and rucksacks are designed to be worn. The other bags that participants kept on their bodies (a weekend bag, and shoulder bag) both had a suitable shoulder strap, although they could also have been

hung up on a hook. Male participants in particular preferred to use their body as a practical alternative for the storage hook.

2. Ground

The large train toilet for users with disabilities (door width 765 mm and floor area of 1.4 m2, figure 4.5b, section 4.3.3) offered enough space to drop hand luggage on the ground; this occurred five times exactly on the same spot, close to the door. In contrast, in the small train toilet, the floor space of 0.7 m2 is too limited to drop hand luggage, and the limited door width (544 mm) also hampers passengers with hand luggage (figure 4.5a, section 4.3.3). Additionally, when placing bags on the floor, the underside of the bag may pick up bacteria (Rawls 1988; Greed 2003), which in turn can be transferred to more sensitive (body) locations (Greed 2003).

3. Hook 1

The only 'designed' storage place available in the current train toilet is hook 1, which, for example, can be used to hang a coat. Although none of the participants used hook 1, three participants used the alternative hook 2, which is positioned slightly lower. The possible reason given for not using hook 1 was its location at 1840mm from the floor on the door, which is seen as being too high: it is above average eye-height (1563mm (F) and 1705mm (M), and even above the average height of both men and women (1817mm (M) and 1668mm (F) (TU Delft 1980). This location is thus outside the participants' reach envelope (TU Delft 1980; Molenbroek 1987).

4. Hook 2

Figure 4.16 "Hook being used for coats and bags" (Williams 2009: p.147]

The alternative hook 2, located 140 mm lower at 1700 mm from the floor, is within comfortable reach height. However, a height of 1250 is within the comfort area for those who can reach a restricted height such as children, people with mobility restrictions,

or those who use a wheelchair (TU Delft 1980; Molenbroek 1987). Moreover, hook 2 is more recognisable as a hook (figures 4.3, section 4.3.2, and 4.7, section 4.3.3) compared to the standard hook depicted in figure 4.16. It is worth noting that, hook 1 (figures 4.3, section 4.3.2 and 4.6, section 4.3.3) with a flat surface was specially designed for this type of train to reduce the chance that the hook could wound train passengers if they were thrown off balance by the train's movements and could hit the hook.

4.6.2 Differences between men and women

Figure 4.17a, 15f wears weekend bag on her back
Figure 4.17b, As soon as she turns,
Figure 4.17c, She drops the weekend bag on the floor in the corner

Figure 4.17 Gender and hand luggage

We evaluated the different storage places of the 6 female and 16 male observations with respect to the gender differences between participants. Gender is an important characteristic determining how people use a toilet, and impacted their dealings with hand luggage. The main findings from the questionnaire are presented in chapter 3, including details of respondents' background information of the questionnaire like gender, age, travel frequency, and length of train travel.

According to Rawls, "39% of the men" carry an item with them (Rawls 1988: p.44), while Kira reports that every woman carries "at least a handbag" (Kira 1976). In our 22 observations, five men wore rucksacks, while none of the women did. Furthermore, two women and two men carried their own bag into the train toilet: the men kept their bags on their body, while the women did not (one hung the bag on hook 2, and the other carefully placed her personal bag above the plastic shopping bags on the floor, protecting her handbag from the dirty floor.

It is thus likely, in the context of a public toilet, that the need for a storage place for women is more pressing than for men, as fewer men carry an item with them (Kira 1976; Rawls 1988). It was observed that it is easier for men to store hand luggage on their body, due to their position when using a toilet (face to the wall), so they have enough space left for hand luggage on their back, with a strap or rucksack. In contrast, women only have limited space on their bodies as they are in a hovering position or seated when using toilets with their back to the wall, (see figures 4.17 as an illustration).

4.6.3 Limitations of the study

The questionnaire

The indirect way the questions on luggage were asked may have influenced the number of respondents, which was relatively low: 72/1267=6%; their focus was on a question about why they found a train toilet unnecessary on trains, from which the hand luggage question arose. Before answering the specific questions on luggage (I do not want to/ cannot take my luggage into the toilet because of a lack of storage, if I take my belongings with me, I lose my seat), they had answered the following three multiple-choice options: - I do not use the train toilet, I already used the toilet at home, I use the toilet at the station and lastly they could choose the option: other reason.

Therefore, a total of 72 respondents commenting on personal belongings and hand luggage, although sufficient for analysis, is however, insufficient for drawing strong conclusions. A separate or more direct question on hand luggage would have probably increased the number of respondents.

The observational research

Of the 22 participants observed, nine left their coat on their seats before they embarked on the observation. On a more typical train journey, they may not have done this as they were seated together, which may have resulted in a more relaxed situation than would be normal in a train, i.e., the social distances between participants related to social perception was small instead of the usual large social distances between fellow travellers. Co-'travellers' and co-students were in the same position in the observational research; they had no concerns regarding the theft of hand luggage. On the other hand, this may be realistic, as they could have left their coat on the seat to claim it; in the questionnaire, 22 respondents mentioned losing their seats as being an issue. Based on the questionnaire and observations, we estimate that 30-40% of train travellers, depending on the social distance (S) in the train compartment, leave their hand luggage including coats, behind and thus claim their seats, when visiting the train toilet.

We took an explorative approach, using observational research. From the questionnaire, we learned that hand luggage is an issue for train travellers. The PhD team (author, co-promoter, and promoter) pooled the observations from the six different research

groups to code the observations in relation to the PhD research questions. As a result, for example with regard to the hand luggage observations, it was possible to almost double the number and variation of the luggage items involved, which also increased the number and variation of the participants concerned. Consequently, the validity of the generalisation of the findings was improved. However, the hand luggage sample size was too small to be conclusive, especially since there were noticeably fewer female observations (6) compared to male observations (16). Furthermore, the sample is only partially representative for train toilet use, as the participants were mainly healthy young students, termed by Williams (2009: p.12) as "able-bodied men". Other participants were older, the parents and friends of the students. We did not include a young child and wheelchair user in these luggage observations; their toilet usage is described in more detail in chapter 5. Nevertheless, the numbers of participants were sufficient to provide valuable direction for usage (Kanis and Arisz 2000).

4.7 Conclusions and recommendations

Conclusions

1. Travellers' maintained the largest possible physical distance between their hand luggage and dirty locations; they tried to store their hand luggage far away from the (dirty) toilet bowl, and the majority (14 of 22) did not place their luggage on the (dirty) floor.
2. Male toilet users used their body and mainly their backs as storage. In contrast, women, who have a greater need for a hand luggage storage facility, have limited space on their backs for hand luggage as they use toilets while seated or in hovering position, with their backs to the wall.
3. The currently available storage hook for coats and hand luggage in the train toilet remained underused. The form of a storage hook was less clear due to its flat design, moreover it was located too high, out of sight and reach.

Implications for design

4. The hook as storage place needs to be positioned lower at a maximum height of 1700 mm from the floor and a second hook at a height of 1250 mm needs to be added for people with a shorter (reach) comfort area such as children, wheelchair users, and people with mobility restrictions.
5. Designers of bags and coats need to take into account that travellers use their bodies to store these hand luggage items when using public toilets, including train toilets.

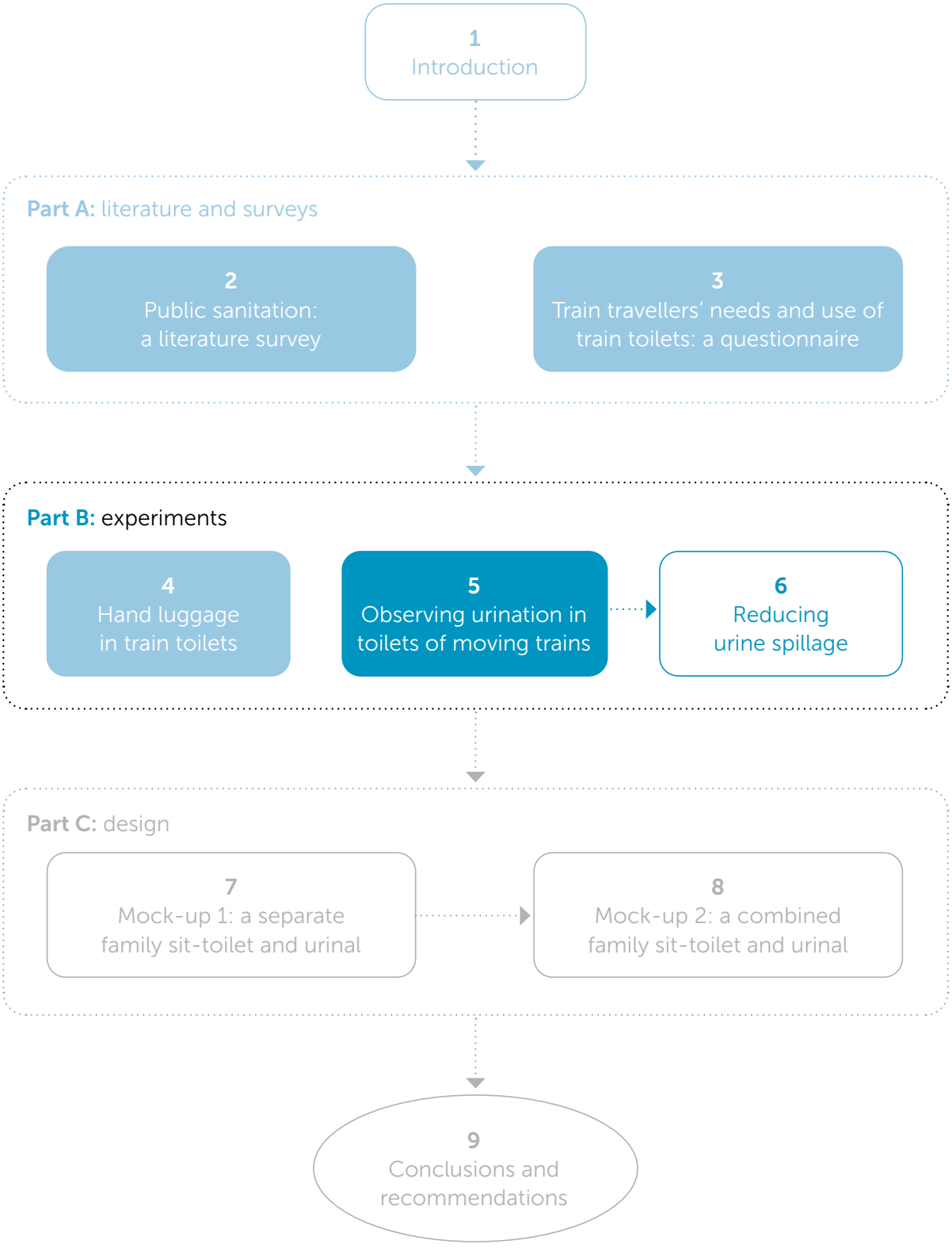
Recommendations

When designing adequate storage place in public toilets, including train toilets, designers need to account for both comfort and hygienic aspects. In terms of comfort, the storage facility needs to be easy to reach. In addition, with regard to hygiene, a transfer of bacteria that may be located on a shelf, for example, coming from the underside of a previously placed bag needs to be examined further. Therefore, a hook seems an ideal facility to

store hand luggage compared to a shelf, which in the UK for example is a requirement in toilets for people with disabilities (Greed 2003; BSI Standards Publication 2012). A shelf also appears to be a practical option for luggage storage (Anthony and Dufresne 2007; BSI Standards Publication 2012). Greed (2003, 219) mentions it "as an ideal, but as a minimum at least a hook for bags should be provided". Further research is needed regarding the hygienic aspects of shelves with regard to the transfer of bacteria from the underside of a bag. Literature shows that shelves are easy to clean (Rawls 1988; Greed 2003).

Secondly, storage space on the travellers' bodies is a practical alternative; this was noted several times in the observations. Designers of bags and coats need to take this into account.

Lastly, designers need to investigate how to provide an adequate storage place in public toilets, including train toilets, for other luggage items such as diapers, colostomy equipment, catheters, wheelchairs, walkers and strollers, as well as suitcases.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Chapter 5
Observing urination in toilets of moving trains

5.1 Introduction

In chapter 4, we reported on an important characteristic of train travellers: which hand luggage they take with them on their journey and how they deal with it when using the train toilet. In this chapter, we focus on a distinguishing characteristic of train travel, namely that the train toilet is situated in a moving environment. Furthermore, in part A, we approached the issues of hygiene and usage in theory by studying the literature and using a questionnaire. The conclusion was drawn to link train toilet usage to hygiene. In this chapter, the interaction of the three Ts (Travellers, Toilet and Train) with hygiene is further examined in practice (see figure 1.6). We conducted observational research as an umbrella for the experiments to determine how people use train toilets and how toilet usage affects hygiene (cleanliness).

Little research has been conducted on primary toilet use (i.e., urination and defecation) including related perineal (urinary and anal) cleansing (Kira 1976; Rawls 1988; Greed 2003; Möllring 2003; Buzink et al. 2006; Williams 2009; Molenbroek, Mantas, and de Bruin 2011). Even less research has been conducted using observational research, the method used in the present study.

Depending on culture, people use a toilet in squatting, sitting, hovering, and standing postures, and the perineal cleansing activities are water, toilet paper, or using hands to manipulate the penis after urination, respectively.

In the current study, observational research was conducted with a sample of 41 participants in moving trains to study toilet usage and to explore spillage likelihood in a shaky environment. Based on the conclusion of chapter 3 that train toilets are mainly used for urination, we concentrate on this aspect.

In order to answer **RQ B2 'How do train movements affect urination performance?'** this chapter focuses on the answers to the four research questions: 'What postures do people adopt while urinating in train toilets?', 'Which urinary hygiene actions (UH) are used?', 'Does urine spillage occur, and why?' and 'How do train movements affect urination performance?'. The findings of this study will be used to inform the new design of NS train toilets.

Section 5.2 describes the method, research questions and interventions in the observational method in relation to train toilet usage. The entire method has been described in chapter 4, however in relation to hand luggage use. In section 5.3, we report on the results from the observations, and in general, how travellers use train toilets and whether usage affects hygiene, which is mainly measured by urine spillage. Furthermore, we discuss the findings in section 5.4 and compare results with those of other researchers who have studied the same issues. We also discuss the study's limitations and implications for design. Section 5.5 concludes this chapter and provides recommendations for design.

5.2 Method

Observational research is the umbrella method we used to explore the interaction between users and train toilets in moving trains to capture real-life usage phenomena. The methodology has been described in chapter 4, however in relation to observations about storing hand luggage. In this chapter, we describe the method in relation to toilet usage, specifically that of urination, including the consecutive cleaning of the participant's body that we have defined as urinary hygiene (UH) practices.

The toilet studies by Kira (1976) and the 'friendly restroom' study by Molenbroek, Mantas & de Bruin (2011) guided our study design. Kira (1976) and Hurd et al. (2013) studied urine spillage in relation to toilet usage, particularly the backsplashes caused by standing male urination. However, the participants and the contexts of these earlier studies differed from the conditions of train travel; in Kira's observational studies, he and his wife were the only participants. The friendly restroom study by Molenbroek et al. (2011) conducted observations of people with disabilities and older adults who avoid travelling by train in the Netherlands due to difficulties in boarding caused by platform gaps (Steenbekkers and van Beijsterveldt 1998) or the risk of falls due to the train shaking (Buzink et al. 2004, 2005,2011). Furthermore, observations were gained from perineal cleansing studies, however these studies were performed in laboratory contexts following defecation, where participants kept their underwear on (Buzink et al. 2006; Dekker, Buzink, and Molenbroek 2011). The spillage study by Hurd (2013) was also carried out with a controlled artificial urine stream and, thus, did not use participants.

People are generally unaware of how they perform toilet practices. They are "second nature", characterised by a variety of routine actions and movements (Lea 2001, 193; Bichard, Hanson, and Greed 2005, 3). Our assumptions are as follows: men's preference for standing urination (in a public environment) stems from a deep mechanism, or first nature, of readiness to run and fight (hunt), which is faster from a standing position than from seated. Moreover, it is a natural position (Choudhury et al. 2010), which they see as contributing to their masculinity (Schwerma 2000; Barcan 2005). The first

nature of women is to squat while urinating, to adopt a protective position. Women then gradually adapted this squatting first nature posture to hovering and sitting urination postures, as a second nature. We define first nature as being original, and "second nature" (Lea 2001, 193; Bichard, Hanson, and Greed 2005, 3) as a derivative thereof, which has adapted to become an automatic habit.
In our observational studies, we recorded participants' activity in train toilets. The audio recordings provided recognisable sounds, such as liquid hitting the bowl during urination, and the video recordings included the ability to play back observations in slow motion. Other research methods, such as questionnaires, manikins, or drawings through which people can depict or describe their toilet usage (Molenbroek, Mantas, and de Bruin 2011, xi,69-79,187,202; Buzink et al. 2011), produce only indirect information. These methods rely on the participant's memory, which is less able to reproduce authentic toilet practices that are performed almost automatically.

As a brief summary of the methodology described in chapter 4, four cameras were installed in NS train toilets. NS train toilets are equipped with a sit-toilet with a toilet paper dispenser, support bars, a mirror with hand washing facilities underneath, and a toilet door that can be locked, (see figures 2.13, 3.5, and 4.3).

On some occasions, research students cleaned the toilet in between participant visits. The criterion was that the toilet would neither reflect a completely clean nor dirty toilet. It was kept in the same tidy condition as at the beginning of the experiments. However, for group one (participants 1m-11m) the toilets were cleaned for half of the participants before each use, and were dirtied for the other half with chocolate spread. This was due to the specific aim of group one: to study toilet performance in a clean versus dirty train toilet scenario.

We recorded the urination practices including the consecutive cleaning of the participant's body that we have defined as urinary hygiene (UH) practices of 41 train travellers (31 males and 10 females) after they provided informed consent as shown in the appendix A.5.1.2. The number of observations (45: 11 females, 34 males) was greater than the number of participants (41: 10 females, 31 males) as two participants used the toilet twice during the first experiment (observations 5m/10m and 38f/45f). In addition, two participants took part in both experiments (2m/31m and 8m/40m), see table 5.1 urination performance, section 5.3.5.

5.2.1 Research questions

We examined how travellers urinate in train toilets and whether usage affects hygiene, which is mainly measured by urine spillage. This chapter covers four research questions to answer RQ B2' How do people urinate in train toilets. We observed how people use train toilets by studying urination postures, including their post urinary UH actions and measuring the duration of urination and of UH actions to answer the first and second research questions.

RQ B2-1: What postures do people adopt while urinating in train toilets?
To inform the design of new toilets for NS, we examined whether the context of a shaky train affects the urination postures that men and women adopt, and to what extent posture affects urine spillage. The three main postures adopted by people in Western countries when using a sit-toilet are standing, hovering, and sitting (Kira 1976; Greed 2003; Williams 2009; Loth and Molenbroek 2011).

A good posture to prevent urine spillage is the seated position, as sitting keeps the seat dry. Moreover, a toilet seat is designed for comfortable seated use (McClelland and Ward 1982). Furthermore, seated urination can benefit people with urological problems to a certain extent (Moore et al. 1991; de Jong et al. 2014). The reasoning for this is that sitting reduces the amount of urine left in the female bladder, which helps to reduce the incidence of Urinary Tract Infection (UTI) (Kira 1976; Moore et al. 1991; Williams 2009). However, there is no strong evidence for this argument. In addition, for healthy men and women there is no reported medical benefit from urinating while sitting (Ünsal and Çimentepe 2004; Norg 2008; Choudhury et al. 2010).

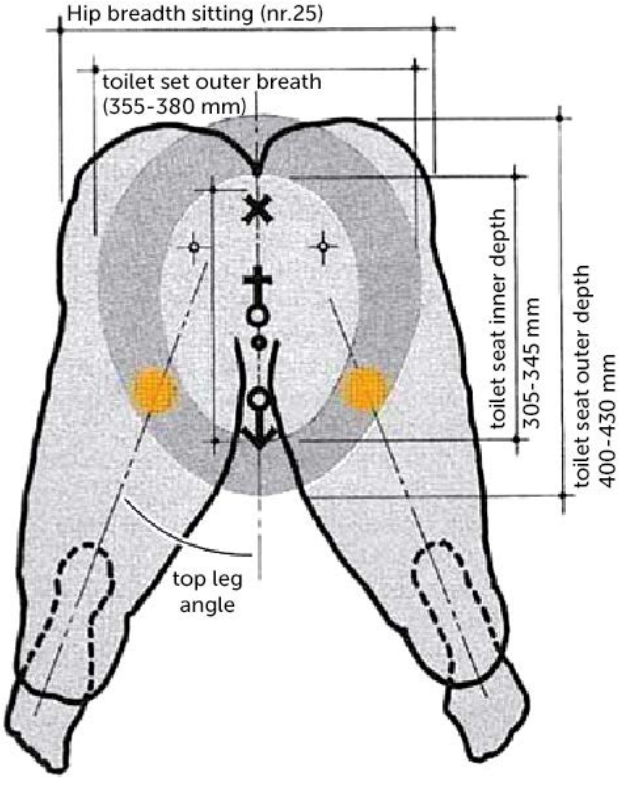


Figure 5.1 Body dimensions and seat dimensions. The penis touches the front of the toilet seat (Kira 1976 p. 126, van Dijk 2010 p.74)

Men usually avoid touching a toilet seat with their buttocks when they need to urinate; for the same reason, women often prefer to hover over a public toilet seat. This is

probably to prevent infections 'that can be caught from toilet seats', even though this is unlikely (Williams 2009; Trimarchi 2015). Moreover, the penis can touch the front of the toilet bowl when sitting, something men also want to prevent (Möllring 2003; Williams 2009; van Dijk 2010; Loth, van Eijk, and Molenbroek 2014), see figure 5.1. Therefore, men prefer to urinate in a standing posture which is enabled by clothing design and holding the penis. However, clothing design hinders women from urinating while standing. Women can also use disposable (paper) funnels to urinate in a standing posture (Kira 1976; Möllring 2003; Gaskell 2015), although this is an unnatural solution for an extremely natural practice. Thus, in public toilets, most men and women (85%) prefer to urinate in either standing or hovering positions (Moore et al. 1991; Misterpoll 2008).

Duration of urination, UH actions and total toilet visit

The duration of urination was standardly measured in all observations, as was the duration of the UH actions. The literature notes an average urination time of 25 seconds (K. Yang et al. 2010; Knip 2016), varying from 10 – 90 seconds depending on bladder capacity and habituation. Graus (1957) noted an average of 45 seconds in military situations (Kira 1976; Rawls 1988), while an average of 21 seconds has been calculated for large mammals, including human beings (P. J. Yang et al. 2014).

The duration of urination was measured as follows: the start time was set as soon as a stream became visible on the video, so from the moment the urine left the body or point of origin until the moment the stream stopped. For male participants this was directly observable, whereas for female participants the duration had to be estimated, as the stream was not visible. The estimation was interpreted based on body language, like changing body gestures of arms and legs, or the handling of the clothes, which sometimes happened to both male and female participants.

In addition to urination, we observed how participants managed their UH actions. The UH action was measured from the moment participants took toilet paper, and/or as soon as they started to manipulate the penis.

Furthermore, concerning the duration of a total toilet visit, a number of articles mention that women need approximately twice as much time for a toilet visit as men do because they perform additional activities, mainly due to their anatomy (Rawls 1988; Greed 2003; Anthony and Dufresne 2007). For example, women pull down more garments, use toilet paper, and sometimes deal with menstruation, whereas men remain standing, unzip and urinate. Based on these and other studies, extra facilities for women were added to public toilets in the United States, following 'Potty Parity' laws to reduce the disparity in (waiting) time between men and women (Anthony and Dufresne 2007). The duration of a total toilet visit was defined as follows: starting from opening the door and entering the toilet until closing the door after leaving.

RQ 2B-2: Which urinary hygiene actions (UH actions) are used?
In Western cultures, people are 'wipers' using toilet paper for perineal cleansing (Gallagher 2008; Demirbilek 2011). Public toilets are commonly a combination of sit-toilets in cubicles provided with a toilet paper dispenser, and male urinals without this facility (Rawls 1988). We have used the following terms to describe urinary hygiene actions: using toilet paper by wiping, blotting or dabbing; commonly used by women as methods of perineal cleansing. Wiping can either be from back to front (BTF) or front to back (FTB) (Persad et al. 2006) while blotting or dabbing describes touching the urinary region to get rid of the last drops of urine after urination. In the case of men, the terms squeezing and/or agitating are used when men manipulate the penis by hand to rid the penis of the last drops of urine. An internet survey reports that 76% of 331 males 'shake' several times to get rid of the last drops of urine, whereas the rest (24%) use their underwear to absorb the last drops (Misterpoll 2008).

Subsequently, we identified whether and why and to what extent spilling occurred to answer the third research question.

RQ 2B-3: Does urine spillage occur and why?
All people can encounter problems that cause wide variation in urine stream control. Therefore, both sexes can have difficulty controlling the urine stream due to many factors, such as health issues (e.g., prostate problems, weak bladder and/or pelvic floor muscles, urethra stricture), age, pregnancy and delivery, mental state, poor vision, protruding belly, poor lighting, unclear contrast of urine stream with background, unpredictable initial line of the urine stream (which also happens when the foreskin is not pulled back while urinating), dispersion of the urine stream, and urgency (Kira 1976; Greed 2003; Norg 2008; O'Farrell, Chung, and Weiss 2008; Bauer and Huebner 2013; de Jong, Pinckaers, ten Brinck, Nyeholt, et al. 2014).

Men who stand can oversee the urine stream and have more control when directing the urine stream using their hands. Women can, to a lesser extent, exercise control over the urine stream by tilting the pelvis when they hover; however, this prevents them from seeing the urine stream, as it is underneath them (Kira 1976; Möllring 2003; Williams 2009).

The male urine stream needs to bridge a large distance, resulting in backsplash (Kira 1976; Hurd et al. 2013). However, clothing prevents the male toilet user from sensing the spillage while urinating in standing position (Kira 1976). The backsplash is further examined in chapter 6. Women, on the other hand, can reduce the trajectory of the urine stream, and thus backsplash, by bending their knees (Loth 1998; Loth and Molenbroek 2011).

Based on the literature, it is expected that males urinating in a standing posture would spill urine outside the bowl. Likewise, it is predicted that women urinating in a hovering

position would also contribute to spillage, especially on the toilet seat (Kira 1976; Schwerma 2000; Möllring 2003; Williams 2009; Loth and Molenbroek 2011; Flores et al. 2011).

Lastly, the factors like postures, UH actions and spillage come together in the context of the shaky environment typical of train travel. This is addressed in the fourth research question:

RQ 2B-4: How do train movements affect urination performance?
To answer this fourth research question, we studied factors of postures, UH actions and the likelihood of spillage -which is defined as urination performance -in a non-stationary situation. The influence of train movements on urination performance was coded and described with regard to maintaining stability of posture (i.e., whether and where the participants used support actions) and the likelihood of spillage.

Interventions in urination

Three interventions took place in the observational research. The first research group of participants (1m to 11m) examined a clean versus dirty train toilet scenario, see table 5.1 urination performance, section 5.3.5. In the dirty scenario, chocolate spread was spread into the bowl, and yellow tea was spilled over the seat. In the clean condition, the surfaces of the toilet bowl and seat were cleaned and dried prior to use.

Secondly, two participants used a water bag to simulate urination (34f, 35m), and finally, a paper seat was used to detect the spillage of male urine, involving five participants (28m to 33m), see table 5.1 urination performance, section 5.3.5. One research student had difficulty with the intimacy of the observations and therefore asked her two participants (34f and 35m) to use a urine collection bag filled with water that was hidden around the participants' belly. A piece of tube connected to the water bag simulated the natural way that urine would leave the body from both male and female participants. They 'urinated' by using an on-off switch that activated the flow of water coming from the water sack.

Furthermore, in the second experiment that took place two weeks after the first, the idea arose to use a paper seat cover to detect the male urine spillage. Black paper was attached to the wall across from camera 1 to create a greater contrast between the urine stream and the background. Even though the earlier audio-visual recordings had not been analysed, it was noticeable that the expected urine spillage was not visible and was difficult to recognise on the video recordings. In addition, all male participants raised the seat before they urinated.

Figure 5.2 Paper covers placed on the floor and toilet rim under the raised seat and lid

In research group 4, observations (29m to 33m) covered the following scenario; see table 5.1 urination performance, section 5.3.5. The toilet rim was covered with paper after the seat and lid were raised (see figure 5.2), and more paper was placed on the floor. After each toilet visit, a picture was taken of the pieces of paper that were replaced (Loth and Molenbroek 2011).

5.3 Results

The observations of the different research groups were pooled for each research question. As a result, the number and variation of participants per research question increased, which benefits the validity of generalising the findings.

The details of the participants (gender, age, group), and other factors like the size of the train toilet are presented in table 5.1 urination performance, section 5.3.5. Furthermore, the table shows the urination performance including urination postures, UH actions: agitating, squeezing, and using paper to get rid of the last drops of urine, mean duration, the extent of urine spillage, and finally, the effect of the train's movements.

5.3.1 Results for RQ 2B-1: What postures do people adopt while urinating in train toilets?

Participants successfully urinated in the train toilet in 39 of the observations. In the other six observations, two participants (1 male and 1 female) simulated a toilet use session using a urine collection bag filled with water. Furthermore, four participants

(3 males and 1 female) intended but were unable to urinate which is termed 'blocked'. It is assumed that they felt they were under pressure (i.e. urinating 'on command', being observed), and this caused them to have difficulties urinating. Furthermore, two of the blocked participants were additionally restricted in their movements. One used crutches because of an injured foot and explained in the post-trial interview that he could not urinate because his leg hurt, and one participant was in a wheelchair. The fact that she did not urinate initially went unnoticed because she was seated when she used the toilet and sequentially wiped her body with toilet paper. But, when she stood up to flush, no urine (recognisable due to the amber colour or aerated surface) was visible in the toilet bowl. This contrasts with the three male participants for whom it was clearly visible that they were blocked while attempting to urinate; the urine stream did not appear.

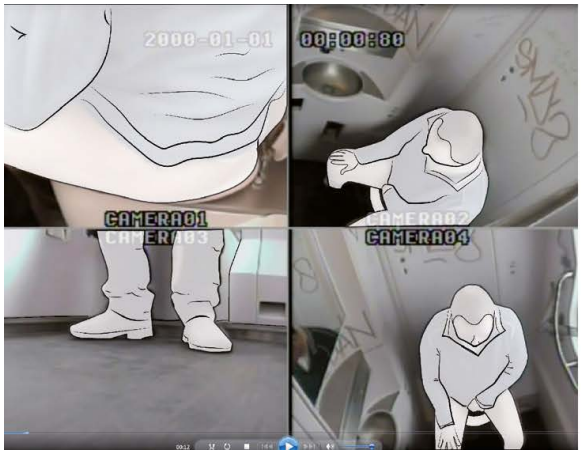


Figure 5.3a=seated male participant

Figure 5.3b=standing male participant

Figure 5.3c=seated female participant

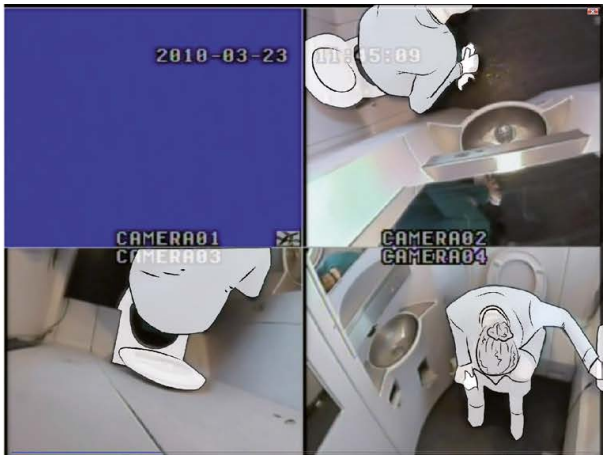


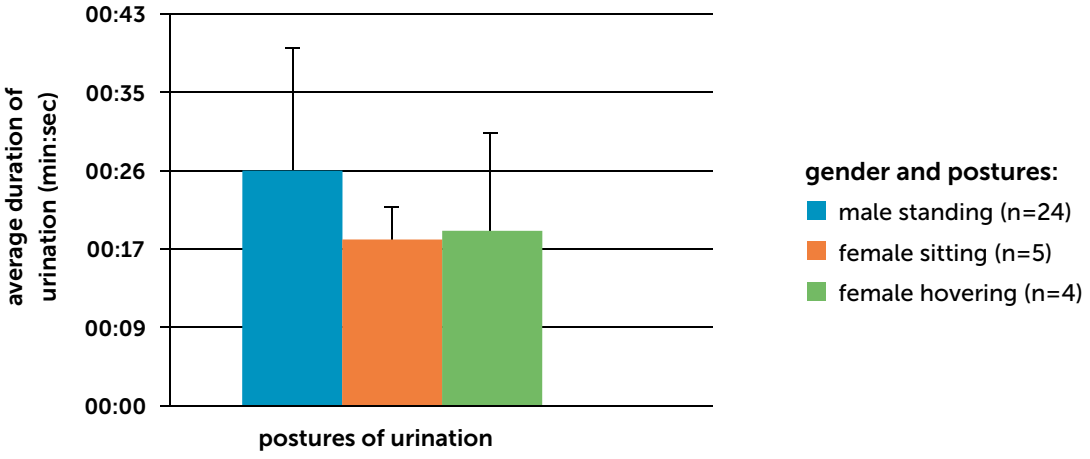
Figure 5.3d=hovering female participant

Figure 5.3 Urination postures

In our study, most male participants urinated while standing as shown in figure 5.3b (31/34 male observations), including the three who were blocked. The other three were seated, and pushed their penises downwards in the toilet bowl, as shown in figure 5.3a. Two of them explained in the post-trial interview that they had a specific reason for

urinating while seated: 36m urinated while sitting because he said that he was afraid to spill due to balance problems, and 43m had a colostomy bag and needed to sit to empty it. Participant 33m did not give feedback, however, it is assumed that he sat down because he was carrying several items such as a bag, which prevented him from having his hands free while urinating. Regarding the females, 6 of 11 female observations urinated in a seated position (figure 5.3c), including a female participant who did not urinate (42f). The others (in 5 of 11 observations) hovered while urinating (figure 5.3d), including a female participant who simulated a toilet urination session (34f), see table 5.1 urination performance, section 5.3.5.

5.3.2 How long does urination take compared to the total toilet visit time?

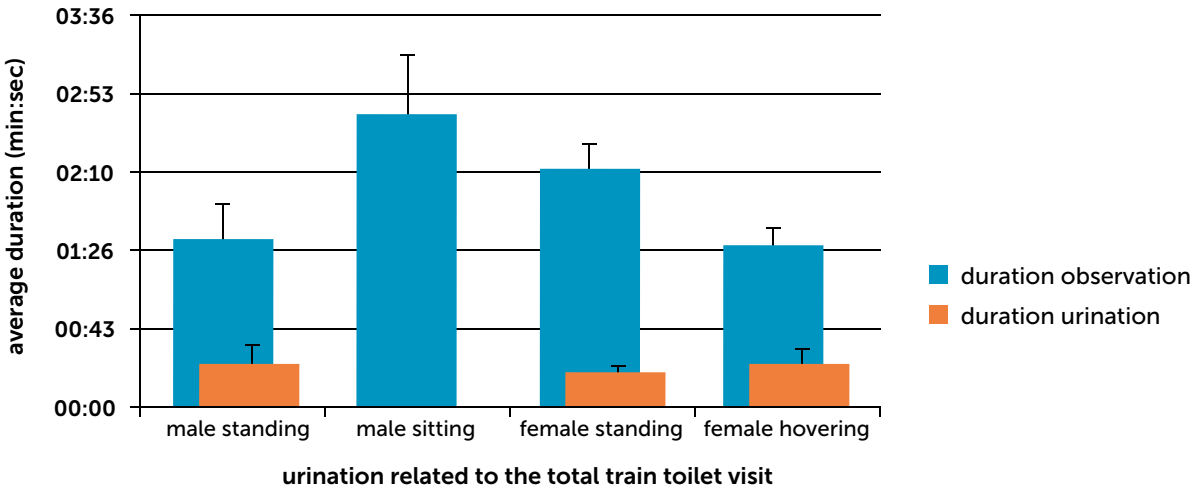


average duration of urination		mean	SD
gender posture	n	time (sec)	time (sec)
male standing	24	26	13
male sitting	3	m.v.*	m.v.*
female sitting	5	19	3
female hovering	4	20	10
total	**36**	**22**	**9**

*missing value

Figure 5.4 Average duration urination

The duration of urination was measured in 33 observations, and the duration of the total toilet visit time in 29 cases. The female participants (n=9; seated 5 and hovering 4) urinated for an average of 20 seconds, while the male participants averaged 26 seconds (standing: n=24), see figures 5.4, 5.5. The three seated male participants took much more time, and urination could not be observed, indicated as missing value (m.v.)



	Duration observation			Duration urination		
gender posture	n	**mean** time (sec)	**SD** time (sec)	n	**mean** time (sec)	**SD** time (sec)
male standing	16	94	20	24	26	13
male sitting	3	162	34	3	m.v.*	m.v.*
female sitting	6	131	15	5	19	3
female hovering	4	90	9	4	20	10
total	**29**	**119**	**20**	**36**	**22**	**9**

*missing value

Figure 5.5 Urination duration in relation to the average length of toilet visit

5.3.3 Results RQ 2B-2: What urinary hygiene (UH) actions are used?

For those participants whose urination time could be measured (n=33; 24 males and 9 females), the average duration was 22 seconds per participant. This is approximately 18% of the total toilet visit time of almost two minutes (119 sec, n=29) (figure 5.5). Time spent in the toilet is related to the urination posture; 4 females who used the toilet while hovering had the shortest visit times (90 seconds), followed by the 16 male participants who remained standing (94 seconds). Those who sat (6 females and 3 males) required on average 131 and 162 seconds, respectively. The 6 female participants who urinated while seated took on average 41 seconds (46%) longer than those who hovered. In comparison, the 3 seated male participants took much more time: 68 seconds (72%) longer than those who stood.

Figure 5.6 Male urinary hygiene (UH) action after urination

Male participants

We were able to analyse 38 of the observed UH actions (28 males and 10 females). In the 34 male participants, a number of UH actions were noted; the majority (18 of 28) used their hands to agitate and /or squeeze to rid themselves of the last drops of urine, see figure 5.6. In four cases, they did not touch their penis, but waited until the final drops fell (16m jumped a little, 21m, 37m, and 39m waited). In three cases, they used toilet paper; two while standing, after first squeezing or agitating, and the third who wiped the penis after emptying a stoma while seated. 21m dabbed his penis after taking approximately one meter of toilet paper (figure 4.14e) that he had folded in advance. In the case of 32m, the toilet paper was visible after he threw it in the toilet bowl.

In four cases, no UH action was taken; there was no urination (3 'blocked' male participants: and 1 conducted a simulation session). Lastly, one participant who urinated while seated did not use any form of UH action. Finally, in 6 cases the UH action was not visible nor was it interpretable through body language (assigned a missing value in table 5.1 urination performance, section 5.3.5).

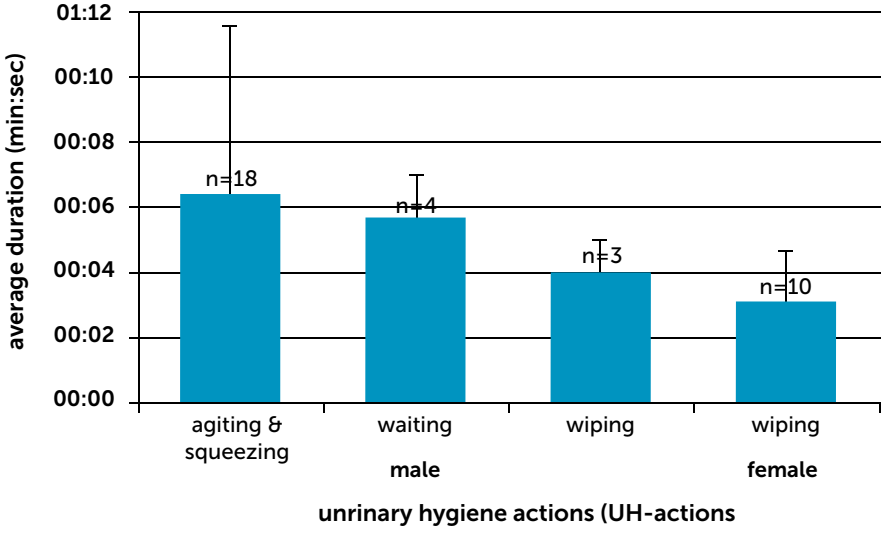
Female participants

Figure 5.7 Female urinary hygiene (UH) action after urination: wiping with toilet paper

Of the female participants, 10 (of 11) used toilet paper as a UH action. One female who did not wipe did a simulation urination session. Of the 10 UH actions, 5 approached the body from the front, and five from the rear (figure 5.7). Three females wiped from front to back (FTB), and one from back to front (BTF); the latter is considered improper, as in the female, the anus is close to the urethra (McClelland and Ward 1976). FTB wiping prevents bacteria from the anus (faeces) being brought forward to the genitalia and the urethra, reducing the development of urinary tract infection (Kira 1976; Persad et al. 2006). Two females dabbed or blotted the perineum area from the front with toilet paper they had crumpled up. Further, one participant seemed to have too little space to wipe, as her body completely covered the seat. She was sitting on one buttock and wiped from the rear, however she had not urinated.

The postures adopted while wiping with toilet paper were: sitting, hovering, or standing while bending forward. Five female participants continued seated, and one female continued while in her hovering posture. Three switched from hovering urination to a standing wiping posture, and one from sitting while urinating to a standing wiping posture, see table 5.1 urination performance, section 5.3.5. In two cases, the act of wiping was not visible because the body obstructed the view. Furthermore, 41f threw the toilet paper she used for wiping into the bin instead of into the toilet bowl. Finally, the toddler embraced the caregiver's legs to keep balance while the caregiver wiped her from the rear (table 5.1 urination performance, section 5.3.5).

Duration Urinary Hygiene (UH) actions



gender	practice	n	mean time (sec)	SD time (sec)
male	agiting & squeezing	18	6.37	4.83
male	waiting	4	5.82	1.15
male	wiping	3	4.01	0.97
female	wiping	10	3.12	1.32

Figure 5.8 Duration urinary hygiene (UH) actions

The duration of the UH actions of the 10 female participants using toilet paper did not differ greatly, ranging between 1.8 - 3.24 seconds, while the toddler girl who was wiped by a caregiver took longer (5.20 and 5.76 seconds). Male participant UH actions differed more in action and duration, taking on average 6 seconds (agitating, squeezing and waiting); almost twice as long as female participants. The three males who used toilet paper took an average of 4 seconds (2.96, 4.18 and 4.88 seconds) (figure 5.8).

5.3.4 Results for RQ 2B-3: Does urine spillage occur and why?

The observations regarding urine spillage of 24 of the 41 participants were included; for all other observations, it was impossible to observe spillage and these were indicated as missing values (M.V., see table 5.1 urination performance, section 5.3.5).

In the pre-trial interview of group two (12f-21m), three of seven participants answered that the toilet seat is, for them, the dirtiest spot in a train toilet area. All male participants in our observations first raised the toilet seat (assuming they wanted to keep it dry) using either toilet paper, a foot, or a crutch, before they started to urinate while they remained standing. Further, one female participant explained in the post-trial interview that she had washed her hands twice because she had touched the toilet seat.

Spillage was common but difficult to see with the naked eye. A thin sheet of paper as well as close-up camera recordings were necessary to measure this.

Figure 5.9 Spillage on toilet seat and floor using paper

Regarding the paper sessions, urine drops were found around the toilet on the floor, and on the toilet rim which was covered with a paper seat (figure 5.9). Floor spillage was only

visible in interventions where paper was used, and floor spillage happened once during hand washing that was observed after urination. In the remaining observations, spillage was visible on the toilet seat.

Of the five male participants who participated in the paper session observations, one was blocked and could not urinate, and one sat on the rim covered with the paper seat; in both cases, the paper remained dry. The other three who urinated while standing spilled urine on the paper seat and floor. In two observations, the pieces of paper, specifically those on the seat, slowly absorbed an almost invisible spray of urine, transforming into wet spots on the paper seat (figure 5.9). Observation of male participant 31m also showed these wet spots, but without the spray. There were large differences noted between the volume of urine and spillage; those with a small urine stream produced the least spillage, whilst the participant with the largest stream produced more spillage and spray (figure 5.9). It was also noted that participant 30m started with drop spillage on the front of the paper-covered toilet seat; 31m did the same, but with smaller drops. Their urine streams were directed straight down, without a bow. Participant 32m also started with drop spillage, but this was on the back of the paper covered toilet seat, as shown in figure 5.9.

Figure 5.10 Close-up recording of the toilet bowl, in which urine spillage (in pink circle) is visible. The urine stream appears in the yellow oval.

In addition, urine spillage could be (vaguely) seen without a paper sheet using close-up video recordings, such as those conducted for group one (1m to 11m). In the close-up video recordings (figure 5.10) used with group one, spilling on the rim was detected in 8 of 11 cases, including those in which the spray was barely visible. In two cases, tiny drops and/or a splash were noted from the start of urination (table 5.1 urination performance, section 5.3.5.). Furthermore, in the post-trial interview that specifically asked twelve male participants whether they spilled urine while using toilets, everyone in groups three and four admitted to it.

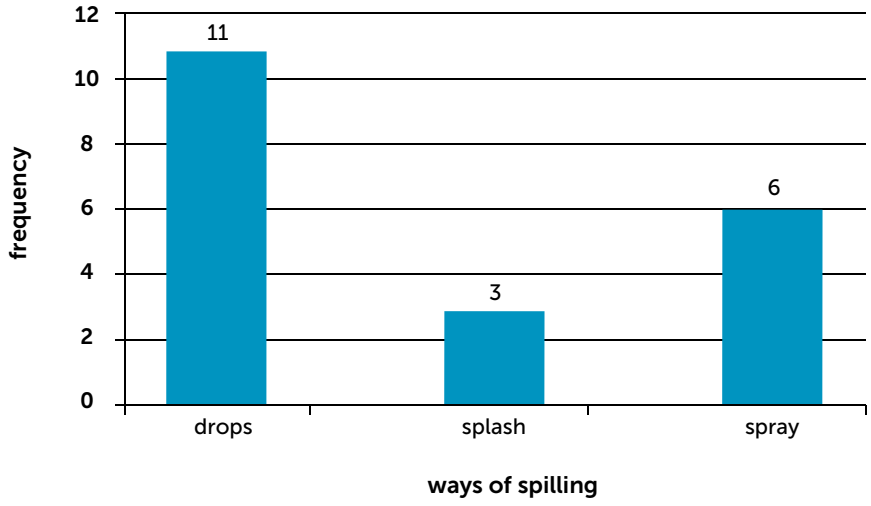


Figure 5.11 Different forms of spillage

Overall, serious spillage happened in five observations (2m, 8m, 30m to 32m). We observed three forms of spillage: spray, drops, and splashes (figure 5.11). These were commonly found on the floor in front of the bowl and on the toilet rim (figure 5.9). However, in eight cases in which 3 male participants urinated in standing position, and the other five participants were seated, it appeared that no urine was spilled.

The fine, nearly invisible spray appears constantly during urination and is caused by the backsplash of urine against the bowl, while spillage by splashes occurred unexpectedly: a sudden splash at the start when the direction of the stream is difficult to predict (Kira 1976), or at the end when urination had just started or ended. The drops were mostly visible afterwards.

5.3.5 Results for RQ 2B-4: How do train movements affect urination performance?

The influence of the train movements on urination performance is described with regard to maintaining stability of posture (i.e., whether the participant performed support actions), and the likelihood of spillage.

Train shaking affected all 41 participants, which was often clear due to the participants' movements. Group two (12f to 21m) included participants who hung items on a hook that started to move back and forth, making the train's movements visible. Further, the liquid that 'danced' in the toilet bowl reflected the train's movement (Loth, Molenbroek, and van Eijk 2018). In addition, the audio recordings of this group were usable, which made the shaking audible due to the recognisable sound of the squeaking rails.

Many participants also had problems maintaining balance due to sudden train movements. In total, 13 participants performed support actions because of train shaking, and two participants supported themselves regardless of the movements of the train.

Six males used the wall behind the toilet during standing urination, and two males and two females used the available support option next to the train toilet while urinating in standing and hovering position (see figure 5.3d, section 5.3.1).

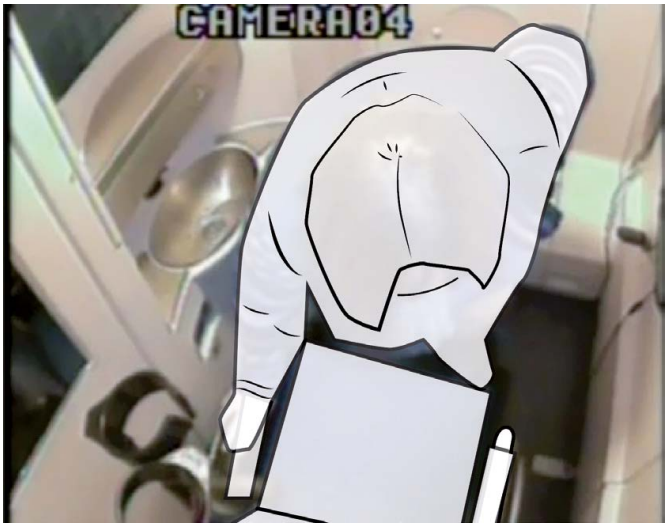


Figure 5.12 A participant tumbles forward and grabs the armrest of the wheelchair for support.

Two female participants grasped the wall close to the washbasin when they were standing just before urinating, from which one needed support on six occasions during the observation. She used the support option next to the sit-toilet when she entered while sitting in a wheelchair. When she stood up from her wheelchair and turned, she used the wall behind the toilet twice, the wall close to the washbowl, and the armrest of her wheelchair, which she also grabbed for support when she tumbled forward as she stood up after using the toilet, (see figure 5.12). The young girl embraced the legs of her guardian when she was wiped after urination, as she could not reach the floor with her feet when sitting on the toilet seat. In five cases, participants were thrown off balance, although they quickly regained their positions; three participants grasped the wall, two participants wobbled, and a participant grasped the armrest of her wheelchair (figure 5.12). Three male participants anticipated the shaking of the train by spreading their legs more widely to maintain balance (see table 5.1 urination performance, section 5.3.5).

Not all stability issues were observed, because in the post-trial interview four participants commented that they had difficulty with stability. However, one of these participants was observed to have used an available support bar, while in the other three observations, no stability issues were observed.

Furthermore, one participant plainly spilled urine due to a lateral jerk of the train, and he needed additional support as his body moved considerably while his feet remained on the floor. In four observations, it seemed impossible for the participants to properly urinate into the bowl. Two participants were thrown off balance, and all four wobbled. Nevertheless, the spillage was not observable on the video recordings.

In brief, participants had difficulties balancing due to train shaking. In total, it was observed that 13 used support actions, and five were thrown off balance. The wall behind the toilet and - to a lesser extent - the wall close to the washbasin were used as support options when people were standing. The available support next to the toilet was also used several times when people were in standing, sitting, and hovering postures (figure 5.3d, section 5.3.1); see table 5.1 Urination performance.

TRAVELLERS								
	TOILETTING PERFORMANCE							
			Urination		Urinary Hygiene (UH) actions			
Obser-vation	**Age group**	**Toilet visit Duration (downwards)**	Posture	Duration	Agitating Duration	Squeezing Duration	Wiping/ blotting Duration	Wiping/ blotting Posture
	years	**min:s,ms**		**min:s,ms**	**s,ms**	**s,ms**	**s,ms**	
1m	30-	1:47,00	Standing	1:00,16	02,08	01,64		
2m	30-55	1:09,60	Standing	0:25,16	02,24	03,77		
3m	30-	2:29,40	Standing	0:55,08	02,24*			
4m	30-	1:53,40	Standing	0:38,24	04,16	07,65		
5m	30-55	1:24,40*	Standing	0:14,72	04,00			
6f	30-	2:18,12*	Sitting	0:23:32*			03,24	Sitting
7m	30-	1:01,80	Standing	0:15,17	13,31*			
8m	30-	1:11,20	Standing	0:18,08	06,01*			
9m	30-	1:42,64	Standing	0:38,28	02,12*			
10m	30-55	1:21,80	Standing	0:16,36	03,36			
11m	30-55	1:09,04	Standing	Blocked	n.a.	n.a.	n.a.	
12f	30-	1:20,44	Hovering	0:14,68*			03,08	Hovering
13m	30-55	1:35,52	Standing	0:24,20	M.v	M.v		
14m	30-	1:55,68	Standing	0:30,12	07,04*			M.v.
15f	30-	1:34,48	Hovering	0:09,44*			02,60	Standing
16m	30-	1:17,88	Standing	0:21,16	05,60*W			M.v.
17f	30-55	2:16,08	Sitting	0:14,64*			02,60	Standing
18f	30-55	1:53,56*	Sitting	0:19,28*			02,48	Sitting
19m[1]	30-	2:04,44	Standing	Blocked	n.a.	n.a.	n.a.	
20m	30-	1:35,21*	Standing	0:12,52	11,24*	09,28*		
21m	30-	2:24,08*	Standing	0:09,00	07,00*W		02,96	
22m	30-	2:06,40*	Standing	M.v.	M.v	M.v		
23m	30-	1:25,00*	Standing	0:16,68	01,88			
24m	30-	1:02,29	Standing	0:21,01*	M.v.	M.v		
25m	30-	1:11,32*	Standing	0:21,04	6,36			

TOILET			TRAIN		
TRAIN MOVEMENTS					
	Spillage and Support				
	Urine spillage	Support		Train toilet	Research group	Train
		what	**support where**	**Size**	**no**	**A or B**
	Yes, drops	Support	Wall behind sit-toilet	Small	1	A
	Yes, splash drops and spray			Small	1	A
	Yes, drops and spray			Small	1	A
	No			Small	1	A
	No			Small	1	A
	No			Small	1	A
	Yes, drops			Small	1	A
	Yes, splash, drops and spray			Small	1	A
	Yes, drops	Support option next to sit-toilet		Small	1	A
	Yes, spray			Small	1	A
	n.a.			Small	1	A
	M.v.	Support in urination posture	Support option next to sit-toilet	Large	2	A
	M.v.	Anticipating by spreading legs		Large	2	A
				Large	2	A
	M.v.			Large	2	A
				Large	2	A
	M.v.	Thrown off balance before urination	Wall close to wash bowl	Large	2	A
	M.v.			Large	2	A
	n.a.			Large	2	A
	Yes, drops. Anticipating, using wall behind toilet as support			Large	2	A
	No Assumed spillage. Thrown off balance			Large	2	A
	M.v.			Small	3	A
	M.v.			Small	3	A
	M.v. Assumed spillage			Small	3	A
	M.v.			Small	3	A

26m	30-	2:10,60*	Standing	M.v.	2,20*			
27m	30-	1:48,00	Standing	0:18,32	M.v	M.v		
28m	30-	1:06,23*	Standing	M.v.	M.v	M.v		
29m	30-	1:11,00*	Standing	Blocked	n.a.	n.a.	n.a.	
30m	30-	1:33,20*	Standing	0:19,36	M.v	M.v		
31m	30-55	1:20,44	Standing	0:29,44	08,92*			
32m	30-	1:42,00*	Standing	0:37,62	04,72*			
33m	30-	2:03,32*	Sitting	0:39,92*	2,84			
34f	30-	1:19,80	Hovering	Simulation				
35m	30-55	1:27,44	Standing	Simulation				
36m	30-55	3:07,00	Sitting	01:45,00*				
37m	30-	1:30,80	Standing	0:37,40	4,32*W			
38f[2]	5 and 30-55	2:00,60*	Sitting	0:20,24*			05,20	Sitting
39m	30-	1:56,00	Standing	0:13,16	6,36*W			
40m	30-	1:29,32	Standing	0:24,99		7,60		
41f	30-	1:39,85*	Hovering	0:31,88*			01,80	Standing
42f[3]	56+	2:34,80	Sitting				02,32	Sitting
43m[4]	56+	2:54,68	Sitting	01:03,64*			04,88	Sitting
44f	30-55	1:24,36	Hovering	0:23,48			02,12	Standing
45f[2]	5 and 30-55	2:03,00	Sitting	0:18,76*			05,76	Sitting

Legenda of symbols, numbers, abbreviations, (colour of) letters (grey or black)			
m: male f: female [1] used crutches [2] young child [3] wheelchair user [4] colostomy bag user	00 complete observation 00* almost complete observation 00 incomplete observation	M.v. Missing value Interpretation by body language n.a. not applicable W Waiting	Size traintoilet Small: 0,7 m² Large: 1,4 m²

Table 5.1 Urination performance

M.v. Support option next to sit-toilet			Small	3	A
M.v. Assumed spillage Support Thrown off balance behind sit-toilet, wobbling		Grasped wall	Small	3	A
M.v. Assumed spillage			Small	3	A
n.a.			Small	4	B
Yes, spillage of drops and spray	Spillage of drops, wobbling, support	Wall behind sit-toilet	Small	4	B
Yes, spillage of drops			Small	4	B
Yes, spillage of splash, drops and spray	Anticipating by spreading legs		Small	4	B
No			Small	4	B
M.v.			Large	5	A
M.v.			Large	5	A
No			Large	5	A
Yes, spillage of drops Constantly	Support flushing	Wall behind sit-toilet	Large	5	A
No	Support	Hands of guardian	Large	6	A
M.v.	Anticipating by spreading legs, support by wall behind sit-toilet		Large	6	B
M.v.			Large	6	B
M.v.	Thrown off balance, support	Support option next to sit-toilet	Large	6	B
n.a.	Thrown off balance Needed support on six occasions	Support option next and wall behind sit-toilet, wall close to washbowl, armrest wheelchair	Large	6	B
No			Large	6	B
M.v.			Large	6	B
M.v.			Large	6	A

Research group > Intervention 1. Clean versus dirty > Making toilet clean or dirty with chocolate spread 2. Hand luggage > Request to bring hand luggage into train toilet 3. Door handle, focus camera on holding door handle 4. Urine spillage > Detection spillage by paper on toilet seat and floor 5. Movements of the train, focus camera on legs 6. Specific train toilet user: young child, wheelchair user, and colostomy bag user	Trains Train A: Duration 120 minutes Train B: Duration 50 minutes

5.4 Discussion

We explored the effect of train shaking on urination performance by observing 11 female and 34 male toilet actions in moving trains. This section summarizes the main findings, the study limitations, and includes design implications.

Initially we had 51 observations, but in order to obtain post-study ethical approval, the Human Research Ethical Committee of TU Delft requested the deletion of the data of five participants (3 women and 2 men), one of whom had also used the toilet twice. As a result, we removed a total of six observations (3 female and 3 male observations) from research students in a subordinate position to the author at the time the data were collected (see appendix A.5.1.1).

5.4.1 Findings

Urination and spillage

The observations and the post-trial interviews demonstrated that the toilet seat is perceived as one of the dirtiest parts of the train toilet. As a result, people maintain a large physical distance (P) between the toilet seat, i.e., they avoid touching the toilet seat by adopting standing and hovering toilet positions because it is likely that they realise that urine is spilled there.

In our observations, spillage was typically not visible to users, but also difficult to observe with the cameras; close-up camera views and a paper seat were necessary to notice spillage. We conclude that spillage happens inevitably when people keep a large physical distance (P) between the toilet bowl when urinating.

Male participants preferred to urinate while standing (n=31) which for them is a 'first nature' or natural position (Choudhury et al. 2010). They see this as contributing to their masculinity (Kira 1976; Schwerma 2000; Barcan 2005). Therefore, triggering a man to sit in a *public* toilet environment is a fundamental issue, although it would reduce urine spillage drastically (Loth and Molenbroek 2011; Hurd et al. 2013).

Multiple factors are involved in spillage, of which the distance that the urine stream needs to bridge is a main spillage concern that can be reduced through design. Furthermore, it was difficult to observe urine spillage as a result of the train's shaking. For example, In the post-trial interview, one participant from group three (22m to 28m) said that he had spilled and that he could not prevent it because of the train's movements. It could not be observed and it was reported as a missing value; see table 5.1 urination performance, section 5.3.5.

Women were more likely to sit on the toilet seat due to the train's movements. A number of articles have reported a stronger distinction between women who hover and sit in

public toilets (Rawls 1988; Moore et al. 1991; Loth 1998; Greed 2003; Williams 2009; K. Yang et al. 2010).

We observed that 4 participants (3 males and 1 female) of the 41 felt that they were somehow under pressure (presence of the press, urinating 'on command', being observed) and that this caused them to have difficulties with urination. This could be seen as an intervention in their first or second nature. Furthermore, it seemed that two of these 'blocked' participants had additional difficulties while trying to use the train toilet because they were restricted in their movements; one male participant used crutches due to an injured foot, and one female with a wheelchair lost her balance and needed support on six occasions.

Duration toilet visit

The average time spent in the toilet (2 min, n=29) depends on the urination posture; Women who sat took on average 39% longer; the three seated men took 78% longer than those who stood while urinating (94 sec).

As women are more likely to urinate seated compared to men, we conclude that this could be a reason that a majority of women use the toilet for twice as long as men, supporting findings by Rawls. In addition, a number of women have to cope with menstruation actions; this also takes extra time, unlike men who only have to (un) zip and urinate (Rawls 1988; Anthony and Dufresne 2007). However, a drawback with regard to determining the total duration of the train toilet visit is that performing menstruation actions was not observed in any of the women. Further, the number of female participant observations (n=11) and male participants who urinated while seated (n=3) was relatively small, therefore their total toilet visit time in relation to (seated) toilet usage may only be indicative rather than conclusive.

It is assumed that the amount that the participants drank did not significantly influence the study as this affects the frequency of toilet visits rather than the duration of urination. The participants were asked to drink enough before boarding the train so that their bladders were full, thus maximising the possibilities for toilet use. All participants were offered drinks under the same conditions that they were free to consume. We tried to create a 'normal' situation, thus not forcing the participants to drink more than they were used to. It is assumed that participants visited the toilet as soon as they had to urinate naturally. Two participants (see table 5.1 urination performance, section 5.3.5) used the toilet twice for this purpose.

Urinary Hygiene (UH) actions

Of the 11 women, 10 used toilet paper as UH action to remove the last drops, as did 3 of the 26 men. However, the only female participant who did not use toilet paper did a simulation urination session making wiping with toilet paper unnecessary. One female

wiped with toilet paper although it was unnecessary as she had not urinated. It is likely that using toilet paper as UH action is a second nature action for women, and thus automatic (Bichard, Hanson, and Greed 2005). According to Kira, the fact that men do not use toilet paper to get rid of the last drops of urine "represents the most curious anomaly of personal hygiene practices"; using paper is something that "men would do well to copy" (Kira 1976). This needs to be explored further.

5.4.2 Study Limitations

Number of female participants
The study is not gender balanced; the number of female participant observations (n=11) was relatively small compared to those of the male participants (n=34). It is likely that women are more reluctant to participate than men due to the intimate nature of the research in which they are more exposed than men because they have to take more garments off. However, we were satisfied with this minimal number of female participants that Kanis and Arisz (2000) defend as enough to give insights into a general direction of use.

Interventions
One of the research students experienced discomfort regarding the intimacy of the observations and asked two participants to conduct a simulated urination session. It is assumed that the simulation session did not influence which posture both participants adopted with respect to hovering and standing, nor the duration of the toilet visit. It appeared that the researchers were more concerned about the privacy issues than the participants themselves, this resulted in poor camera angles in which spillage was not visible in 21 observations. Furthermore, due to privacy concerns, it was decided that only one author would code the participants' urination practices; the author triple-checked the coding instead of applying a reliability assessment to avoid involving an extra observer.

Cameras and additional audio and close-up settings
The different study approaches taken by the six research groups involved in both trains resulted in a range of camera settings. In the end, some parts of the toilet use sequence were difficult to view or were not even recorded. This was particularly true in group one (1m to 11m), where recording started later or stopped earlier, such as before hand washing started, because the research students in this group assumed that they had obtained enough information.

5.4.3 Recommendations for further research

Despite the fact that the study used privacy sensitive observations effectively, we recommend that future studies allow a second observer to do a reliability assessment so that the results are less dependent on one coder.

Overall, for future observational research, we recommend applying more method standardisation with regard to camera and time settings, as well as questions in the interview. Only groups two (12f to 21m) and four (29m to 33m) reported all interviews, see appendix A.5.2. Therefore, we recommend installing the four cameras in the same position for all observations and audio-video recording the observations at the same defined start and end moments. Another recommendation is that the same general questions should be asked to all participants, such as gender, age, profession, and train travel frequency in the pre-trial interview, even if different research themes were addressed in the pre-trial and post-trial interviews. This would have saved time determining results and reduced missing values. It is worth observing that the research approach conducted by six different research groups addressing six different themes was exploratory.

5.4.4 Implications for design

We observed that the usability of train toilets containing only sit-toilets was inadequate. Furthermore, the movements of the train sometimes threw the participants off balance and often caused them to use support actions to maintain posture stability. Therefore, we recommend that, in order to improve hygiene by reducing spillage, the NS adapt their train toilets to include both a sit-toilet for hovering and sitting postures, and a urinal for the standing posture.

Therefore, a urinal should be added that is placed in a higher position and thus requires a shorter distance for the urine stream to reach the toilet. This will give the user greater control over the flow of urine and reduce backsplash that leads to spillage in the environment; this is examined further in chapter 6. Moreover, having men use the urinal can persuade female users to use the sit-toilet while seated, a urination posture that also provides stability. Furthermore, support bars should be positioned in the vicinity of the sit-toilet and urinal and close to the washbowl, to provide users with posture stability. To support children, we advised NS to integrate child platforms into the confined space. Chapters 7 and 8 describe the train toilet designs and research with participants.

5.5 Conclusions

The research question 2B 'How do train movements affect urination performance?' was answered as follows:

RQ 2B-1: What postures do people adopt while urinating in train toilets?
Most men stood while urinating, and women hovered or remained seated in equal numbers. This corresponds to males' first nature; they are reluctant to adopt seated usage. In contrast, sitting is women's second nature, gradually adapted from a first nature of squatting.

RQ 2B-2: Which Urinary Hygiene (UH) actions are used?
Most male participants use agitating and squeezing as UH action whereas women use toilet paper as UH action, reflecting first and second nature, respectively.

RQ 2B-3: Does urine spillage occur and why?
Urine spillage was common; however, a thin sheet of paper was necessary to measure the spillage resulting from fine sprays of urine. Spillage was strongly related to the standing urination posture of male participants. The urine stream needs to bridge a long distance until it reaches the toilet bowl, resulting in a backsplash that ends in spray outside the bowl, such as on the toilet seat, which is perceived as dirty.

RQ 2B-4: How do train movements affect urination performance?
Support actions were commonly performed to achieve posture stability and to counterbalance the train's shaking movements. Spillage directly linked to the train's movements happened in several observations.

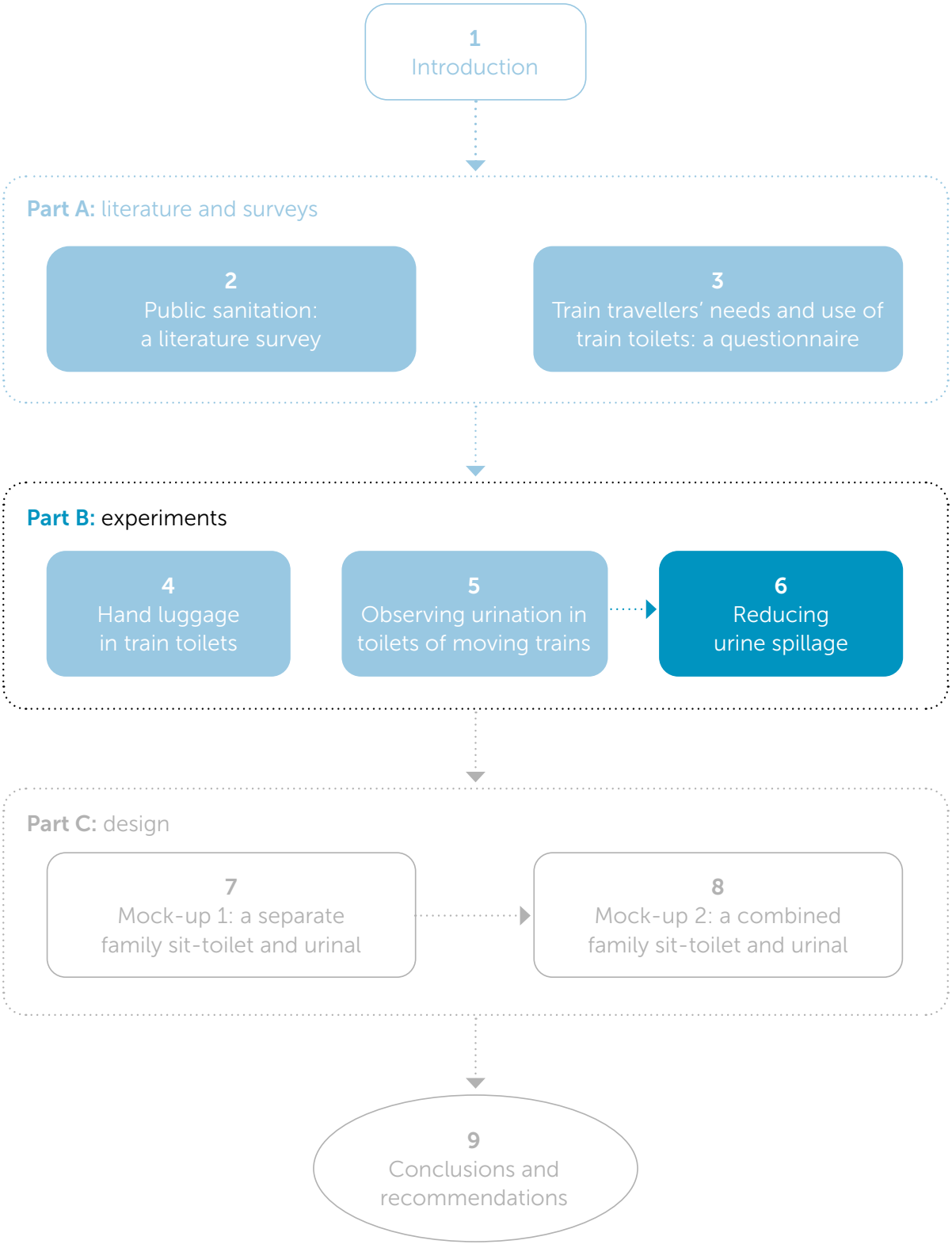
Implications for design
In summary, a urinal combined with a sit-toilet, with additional support options for hands, including horizontal and vertical support bars, and support platforms for children's feet, need to be integrated into train toilets to reduce urine spillage and improve hygiene and usability.

5.6 Acknowledgements

This study would not have been possible without the support of the Dutch National Railways (NS), in particular, Mirjam Meier and engine driver Lex Veldhuis, who made it possible for us to conduct this research in moving trains.

Furthermore, we would like to acknowledge the devotion of the research students who carried out the observational study: Ainhoa Ostolaza, Karla Rosales, Radoslav Gulekov, David Serras Marques, Samad Khatibi, Flip van Haaren, Loek Canton, Simone Hoogendoorn, Robert Star, Veerle van 't Hullenaar, Stefanie Mink, Renée van Boheemen, Isabel Hoefnagels, Mingus Vogel, Jasper de Vreede, Aniek Vliegen, Michel Sperling, and Tommy Louts.

In addition, we also would like to thank the dedication of the TU Delft staff: Noriko Sudo, Bertus Naagen, and Annelise de Jong.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Chapter 6
Reducing urine spillage

In chapter 5, we demonstrated that sit-toilets are not suitable for standing urination, as noted by Kira almost 50 years ago: urine spillage is strongly related to a standing posture. The urine stream has to bridge a long distance to the toilet bowl, resulting in backsplash that then sprays outside the bowl, especially on the toilet seat. Another issue specifically related to train toilet use was that the sudden shaking of the train threw some participants off balance. These train movements also contributed to the spilling of urine outside the toilet bowl.

Urinals are a familiar construct; they have existed since Roman times; see section 2.4.1. Urinals have enabled men to urinate standing up in public toilets for many decades (Kira 1976; Möllring 2003; Williams 2009). Airports and train stations are equipped with urinals, however they cannot be found in airplanes and trains, nor at homes, probably because they occupy (too) much scarce space at these locations (Kira 1976). However, high-speed trains in Japan and regular trains in Austria are exceptions, they both have urinals in train toilets exclusively for men (Central Japan Railway Company n.d.; ORF Salzburg Heute 2011; Sommerer 2018).

As an implication for design, we recommended that NS integrate a urinal in their train toilets to improve hygiene, as urinals reduce urine spillage. Urinals are placed in a higher position; therefore, the urine stream requires a shorter distance until it reaches the toilet (urinal). In this way, the urine stream is intercepted before it disintegrates into droplets, reducing any backsplash (Kira 1976; Hurd et al. 2013).

To demonstrate that a urinal could be a solution for reducing urine spillage in train toilets, we conducted three experiments to examine the urine stream in order to design a new train toilet. In the first two experiments, the researchers elaborated on the distance to be bridged by the urine stream, i.e., the distance (P) between the human body and the toilet; their findings are reported in sections 6.1-6.12. Lastly, in the third experiment we zoomed in on the stability of the standing urination posture while simulating the movements of the train; this is described in sections 6.13-6.17.

The underlying purpose of this chapter is to inform design for part C of this thesis and to answer the research question **RQ B3: 'How can urine spillage be reduced when using a urinal?'**

6.1 Introduction backsplash experiment 1

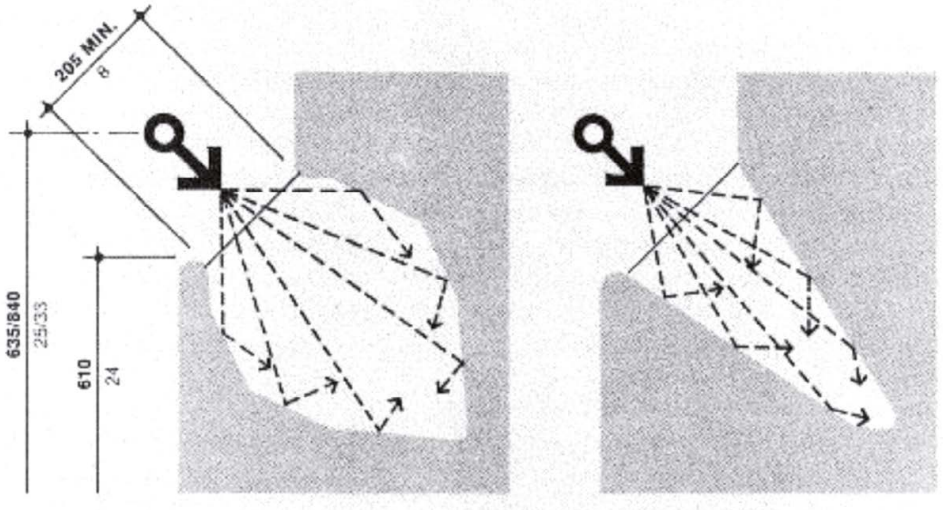


Figure 6.1a dome shape *Figure 6.1b cone shape*

Figure 6.1 Influence of contour of the urinal on the stream (Kira 1976, 144).

Backsplash occurs when the urine stream rebounds from a hard surface of any container. The first experiment focused on urine spillage as a result of backsplash via the inside of the urinal. This type of spillage ends up in the environment, such as on the trousers, the toilet seat, and the floor. Trousers also ensure that a man does not notice the backsplash, and is therefore unaware of this issue. According to Kira (1976), sit-toilets have the wrong configuration to prevent backsplash.

In chapter 5, we demonstrated that backsplash was a fine, almost invisible spray that ended up on a paper-covered toilet seat and became visible through this paper seat. Backsplash depends on three factors, namely the force of the urine stream, the shape of the inner bowl, and finally, the angle at which the stream hits the surface (Kira 1976).

It is to be expected that when using train toilets, the force of the urine stream will be strong as travellers indicated in both the chapter 3 questionnaire and in the chapter 5 observational study that they postponed their use of train toilets until they had an urgent need. As a result, they generally use train toilets with a full bladder which increases the force of the urine stream that hits the inner toilet bowl (Kira 1976).

When designing a new hygienic train toilet, the underlying intention is that travellers no longer postpone visiting the toilet; the urine stream force and associated backsplash will therefore decrease indirectly thanks to their having a less full bladder.

Design can also contribute to reducing backsplash as Kira noted, the inner contour of the urinal can minimise backsplash by enclosing it, see figure 6.1.

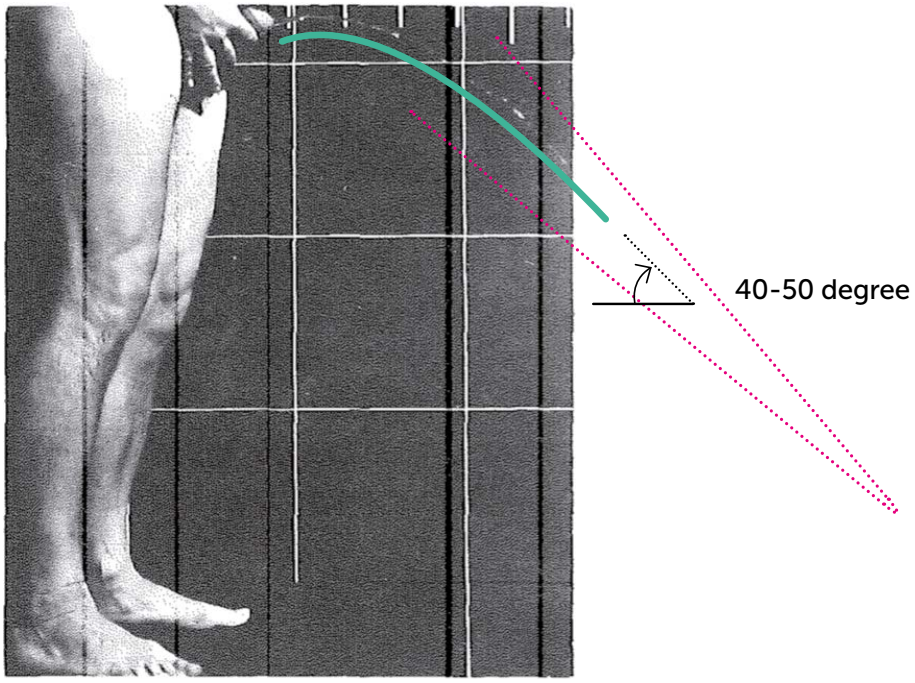


Figure 6.2 The direction of the urine stream (in green) falls between 40-50 degree angle (Kira 1976, 144)

The impact angle (angle between the stream and the impact surface) should be as small as possible (Kira 1976; Hurd et al. 2013; BBC 2013). Therefore, the urinal should preferably be dome or cone shaped. The axes, i.e., the angles at which the inside of the urinal is placed, should lie between 40-50 degrees, see figures 6.1 and 6.2 (Kira 1976). Consequently, the positioning of the inside of the urinal follows the direction of the urine stream. Van den Meiracker (2011) also used both concave forms in the back and bottom of the urinal so that the urine bounces away from the user when it hits the inner urinal basin, see figure 6.3.

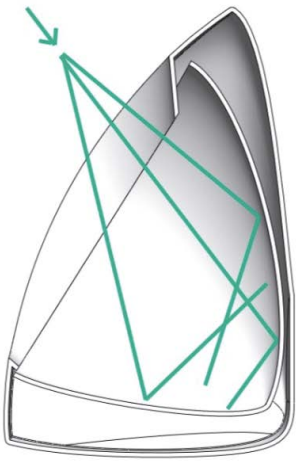


Figure 6.3a urine stream enters at high position

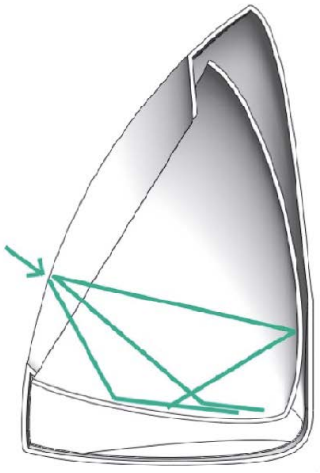


Figure 6.3b urine stream enters at low position

Figure 6.3 Concave forms in the back and bottom of the urinal, urine stream at higher (a) and lower impact positions (b) (van den Meiracker 2011a, 54,55)

Apart from Kira's study, very little has been published about urine spillage in relation to urinal usage. Both Kira and Williams argue that many urinals are poorly designed and do not prevent backsplash. Hurd and Kira agree that the impact angle significantly affects backsplash, which should be as narrow as possible; "aiming downwards at a low angle of impact" (Kira 1976; Hurd et al. 2013; BBC 2013: p.2). In this study, we further examined the backsplash of the urine stream to inform the design of urinals.

6.2 Method backsplash experiment 1

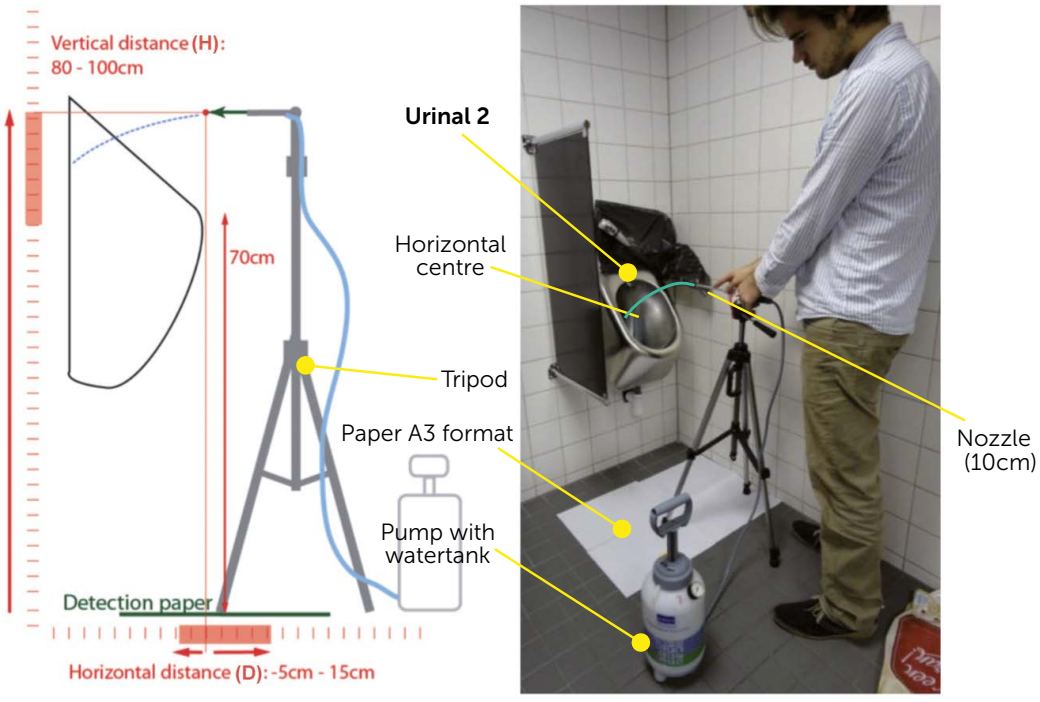


Figure 6.4a Schematic test setup experiment 1 *Figure 6.4b Test setup experiment 1*

Figure 6.4 Test setup experiment 1 (stream in green b aimed on a horizontal centre). The amount of backsplash is measured on the floor using A3 paper

Experiment 1 evaluated the hygienic performance of two forms of urinals, measured by the amount of backsplash detected on the floor. In this section, we briefly describe which urinals were tested and how experiment 1 was conducted. For more information on the variables and urinals that were tested and the procedure, see appendix A.6.1.

Physical distance (P)

We used an artificial test setup to determine how the physical distance (P) between the human body and the urinal affects the backsplash. This contrasts to the methods described in chapter 5, where spillage was recorded through observational research with participants in moving trains, where human and train variables, e,g. bladder content or movements of the train respectively, influenced the results of the backsplash.

Thus, we excluded human and train factors so that the physical distance (P) could be independently evaluated and varied in a controlled, artificial way. The physical distance (P) was divided into horizontal (D) and vertical distances (H), from the beginning of the stream to the urinal (D), and to the floor (H) respectively. The urination height (H) varied between 80-100 cm (to the floor), and the horizontal distance (D) between -5-15 cm (to the urinal), see figure 6.4a. For each measurement, the stream was directed towards a horizontal centre of the urinal, thus avoiding a difference in vertical distance, see figure 6.4b. Details on the experiment 1 variables that affect backsplash are presented in appendix A.6.1.1, figure A.6.1.

6.2.1 Urinals

Figure 6.5a Urinal 1

Figure 6.5b Urinal 2

Figure 6.5 Two test urinals with dimensions in mm

We chose two stainless steel urinals of different geometries, see figure 6.5; b x l x d. Urinal 1 and urinal 2 both had a variable depth to a maximum of 250 mm and were selected based on various shapes and the material, see appendix A.6.1.2, figure A.6.2. The NS uses stainless steel for its train toilets because of the hygienic perception, as they assume that traces of urine and faeces are less noticeable against a grey background than white porcelain. Moreover, stainless steel is a more vandal-proof material (Williams 2009). For these experiments, both stainless steel and vitreous ceramic materials were expected to behave in the same way with respect to backsplash (Williams 2009).

The urinals' inner sides followed a contour of 40-50 degrees and were dome shaped, following Kira's recommendation, see figures 6.1 and 6.2. The heights of both urinals were already set about 10 cm higher compared to Kira's 61.1 cm (measured at the lowest point of the urinal bowl, see figure 6.1).
This predetermined higher position of 70 cm was set to gain distance above the breakup of the urine stream and therefore reduce backsplash (Kira 1976; Hurd et al. 2013). In this way, we accounted for the length of Dutch male users and the related higher urination/crotch height (NASA 1978; TUDelft 1980; Loth and Molenbroek 2011).

Figure 6.6 Test setup in male lavatory.
The two outside urinals are the (stainless steel) test urinals

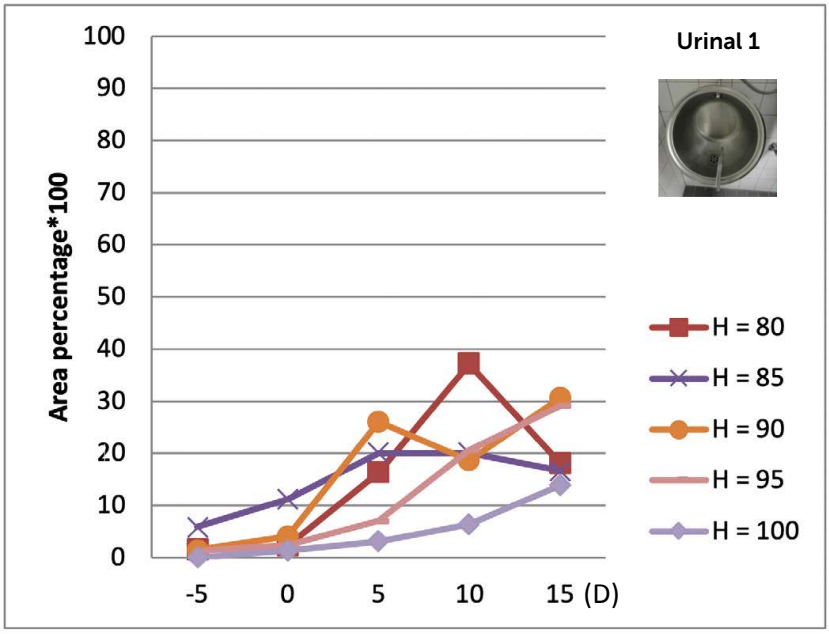
The study was conducted in a male toilet with four ceramic urinals at the Faculty of Industrial Design Engineering, Delft University of Technology. Two ceramic urinals were replaced by the stainless-steel test urinals, see figure 6.6.

6.2.2 Procedure backsplash experiment 1

The procedure is summarised in this section; for a more detailed version, see appendix A.6.1.3, figure A.6.3. The floor was first cleaned to remove any unevenness that could lead to a distortion of the result. Then, for each test, four A3-sized sheets were laid on the floor to catch the spillage that would lead to the scattering marks (figure 6.8). Blue feed colour was added to the water in the tanks to make the results of the backsplash visible on the paper, which would ease the analysis of the lost droplets. Subsequently, the blue scattering spots were provided with a higher contrast and, as a result, re-coloured with black markers, see appendix A.6.1.3, figure A.6.4.

The penis/urethra and its urine stream were imitated using a 10 cm long tubular nozzle connected to a human-powered water pump. This nozzle was mounted on a height-adjustable camera tripod with an on/off trigger to switch the 'urine' flow. Before the start of each measurement, the pressure was kept constant manually.

6.3 Result backsplash experiment 1



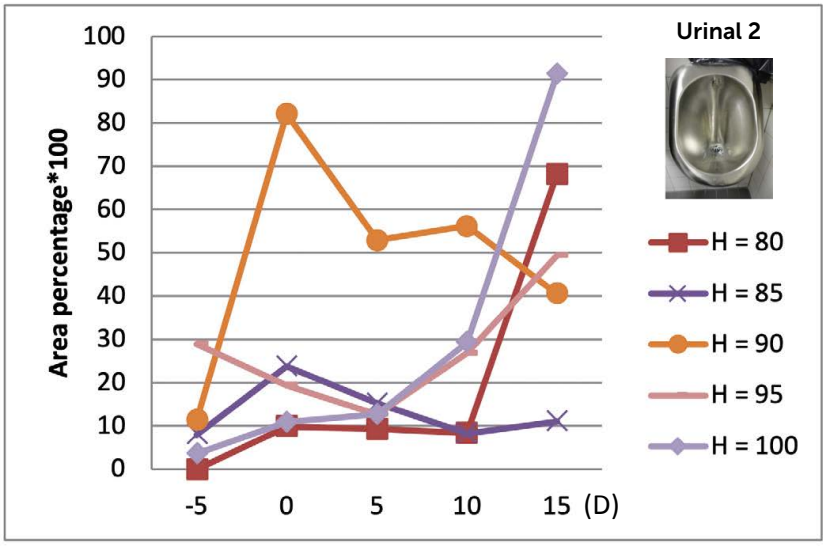


Figure 6.7. Soiled area (Y-axis) versus horizontal distance (D) from the urinal (X-axis) for different heights (vertical distance H)

Graphs were plotted for each urinal. The Y-axis shows the soiling percentage expressed using the covered area and scaled by a factor of 100 for ease of interpretation, see appendix A.6.1.3. The X-axis refers to the horizontal distance to the (nozzle) opening of the front part of the urinal. The different coloured contours represent the values obtained for selected heights H (vertical distance to the floor), see figure 6.4 section 6.2.

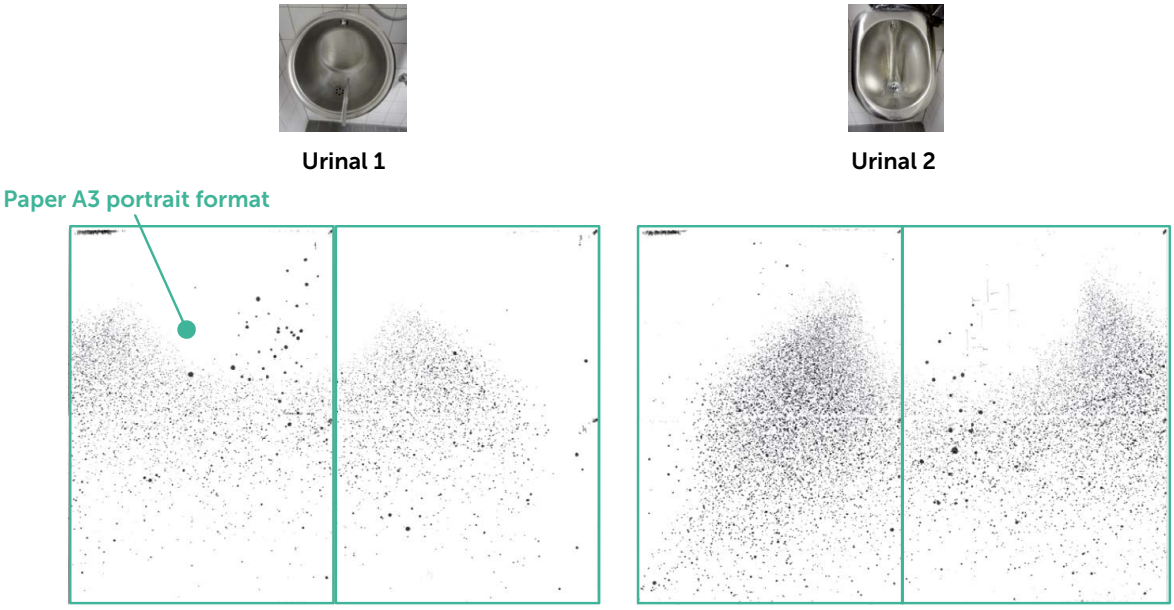


Figure 6.8a backsplash pattern on the floor under urinal 1

Figure 6.8b backsplash pattern on the floor under urinal 2

Figure 6.8 Combined scattering pattern of the backsplash collected on the two A3 papers on the floor under urinal 1 (a) and urinal 2 (b), according to Figure 6.8b. Urinal 2 (b) creates more backsplash than urinal 1 (a).

Subsequently, for each sample test, a set of 4 A3-sized paper was placed on the floor to catch the drops, which was converted into scatter plots. The 25 plots per urinal were combined using imaging software to represent the total scatter pattern per urinal, see figure 6.8.

We also observed the soiling of the dividing walls due to the backsplash. Soiling only occurred on the partition wall in the case of urinal 2 and not on the partition wall of urinal 1. The distance between each urinal (in the z-direction) and the partition wall was the same. In addition to a more concentrated backsplash on the floor, the urinal 2 scatterplot showed a point-like nature directed more towards the wall (figure 6.8b) compared to the flatter, diffuse pattern observed in the case of urinal 1 (figure 6.8a).

6.4 Discussion backsplash experiment 1

The following aspects of the backsplash experiment are discussed: the method, the limitations and finally implications for design.

Both urinals followed a general trend with respect to the backsplash soiling, i.e., more soiling occurred when the horizontal distance from the urinals increased. Furthermore, urinal 2 demonstrated more soiling on the floor and divider wall due to backsplash. The effect of the variable height (vertical distance from the floor) was inconclusive for this

study, which means we found no relation between a change in height and the soiling of the floor as a result of backsplash.

In summary, both the inner curvature of the urinals and the horizontal distance that the stream bridges to the urinals have the most impact on spillage caused by backsplash. This supports findings by Hurd et al. (2013), who also simulated a male urine stream using coloured water and recommended the user to stand as close to the urinal as possible to avoid backsplash (BBC 2013). Kira (1976) concluded similarly that the container needs to be close to the point of origin, although he made no distinction between horizontal and vertical distances.

Figure 6.9a Inside shape urinal 1

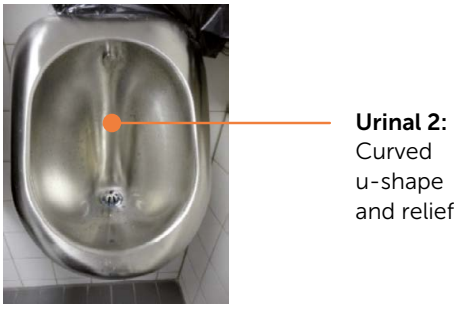


Figure 6.9b Inside shape urinal 2

Figure 6.9. Inner shapes of both urinals

In experiment 1, we also studied the impact of the urinal shapes that received the incoming artificial stream. We note that the back and, indirectly, the side contours of the inner surfaces of the two urinals contributed to the backsplash effect. Figure 6.9 shows the different inner sides of both urinals. Urinal 2 resulted in more intensive soiling on the floor and partition wall as a result of the backsplash, see figure 6.8.

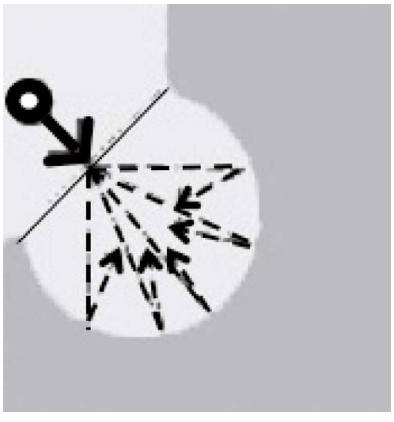


Figure 6.10. The circular inner shape of urinal 1 absorbs the backsplash (Kira 1976, 416)

Kira (1976) states that there is no ideal configuration of a urinal, nevertheless urinal 1 meets the basic criteria of a dome/cone shape placed at an angle of 40-50 degrees, while the backsplash is absorbed through the circular perimeter of the urinal, see figures

6.1a and 6.10. It was expected that urinal 1 would show more backsplash as its back has a flat surface that hits the stream of urine at a perpendicular angle, contrary to recommendations by Kira and Hurd et al. (2013). They concluded that the stream should approach the surface at a very narrow angle to avoid backsplash. However, the stream with backsplash in urinal 1 is redirected through the circular inner shape, which resulted in less widespread backsplash, see figures 6.9a and 6.10. Urinal 2, on the other hand, with a less curved u-shaped contour, had a relief that was probably meant to prevent the backsplash. We showed that the relief in urinal 2 was contra-productive, as it resulted in more backsplash (figure 6.9b).

This experiment confirms how shape, i.e., the contour of the back and the sidewall, affects the soiling outside the urinal. Williams (2009) noted that due to the variety of urinal shapes, it is difficult for each design to catch the urine accurately.

6.4.1 Discussion method backsplash experiment 1

The urinals were installed at the height of 70 cm, as determined by prior examination (Loth and Molenbroek 2011), nearly 10 cm higher than Kira's suggestion (in figure 6.1, section 6.1). We accounted for an increased urination/crotch height as Dutch men are generally tall (Schonbeck 2015). We set the lower limit of the vertical distance 10 cm higher, i.e., at 80 cm (figure 6.4a, section 6.2). A height of 75 cm (h=75 cm) was not possible due to a limitation in the equipment, i.e., the minimum height of the tripod used.

We also tested another detection method for measuring soiled areas using UV lighting. However, this was rejected because the study had to be conducted in the dark, which was difficult and unpleasant. In addition, the UV light detected everything in the environment, including water and dust, making the results overwhelming. Moreover, it seemed impossible to distinguish the types of soiling (e.g., urine versus water) using UV light.

The experiments were designed technically, so as to exclude human factors such as the length of the urethra and the urine stream velocity. For example, a nozzle was used with a fixed length of 10 cm and a water pump. The advantages of this technical approach were that empirical data could be obtained for quantitative evaluation. Moreover, it gave the freedom to modify the impact of each factor, focusing only on geometric aspects independent of human factors.

6.4.2 Limitations backsplash experiment 1

Even though the variables were artificially isolated and controlled, and thus the results were independent of human factors, the outcomes may have been subject to human influence. For example, the contour obtained for urinal 2 at a height of h=90 cm (figure 6.7) deviated from the observed trend. The reason for this anomaly was unclear, but

may be attributed to possible human error(s) during the tests. For example, the pressure that generated the velocity of the fluid stream leaving the nozzle affected the amount of backsplash. In addition, the amount of fluid in the tank influenced the pressure. Between the tests, the amount of fluid in the tank changed, and thus the pressure. More pressure was generated by pumping during the tests to keep the pressure meter at the same level. Since this was done manually, it may be a reason for the inaccuracy and outlier in the results.

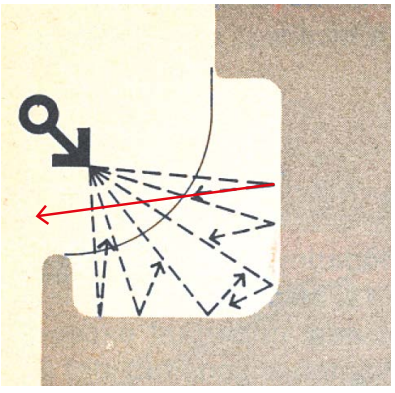


Figure 6.11a. The stream of urine (red arrow) causes backsplash on the wall (Kira 1976, 416)

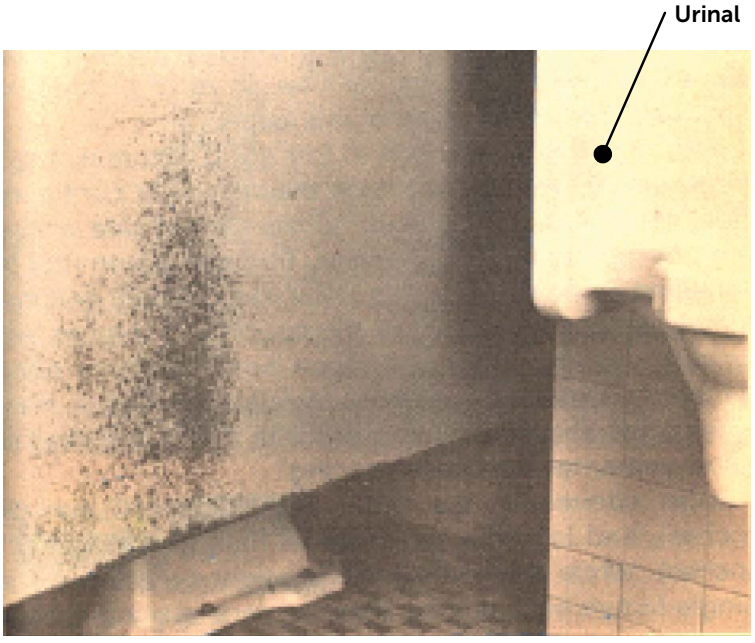


Figure 6.11b Backsplash on the wall from urinal (Kira 1976, 417)

Figure 6.11 Backsplash from urinal

The drops on the floor were evaluated by applying scatter plots to measure the amount of backsplash. However, spots of backsplash were also observed on the partition walls near the urinals. This is consistent with Kira's findings, who also showed the effect of backsplash on the environment (figure 6.11b). Therefore, the papers used to detect backsplash should have been placed everywhere, including the urinal wall. We only measured the backsplash on the floor. The toilet walls and partition walls contribute to people's hygienic perception and should therefore be included in future backsplash studies of urinals.

6.5 Implication for design to reduce backsplash

In this section, we discuss other (design) factors relevant to the design of a reduced-backsplash urinal, in addition to the impact of the inside of the back and the side surface, i.e., material, opening, angle and target.

6.5.1 Material

Backsplash occurs when the urine stream hits a hard surface of a container. Stainless steel or vitreous ceramics are both hard materials and commonly used in urinal manufacture. Therefore, they are easy to clean, but prone to inducing backsplash. It is not evident which material (stainless steel or vitreous ceramics) is better in terms of hygiene and backsplash. However, ceramics offer more options for adjusting the (surface) design in the production process using casting moulds (Williams 2009).

6.5.2 Opening

The urinal opening initially receives the stream of urine. Its size can affect the distance a user stands from the urinal and the angle and direction of the penis. Kira recommends a minimum opening dimension of 205 by 205 mm at a urinal height of 610 mm.

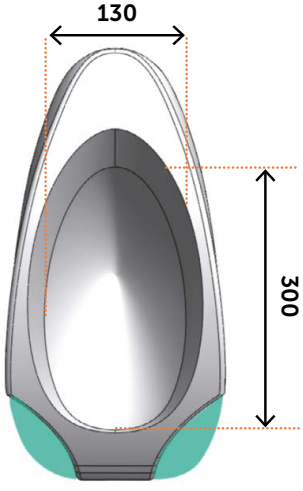


Figure 6.12b Top view

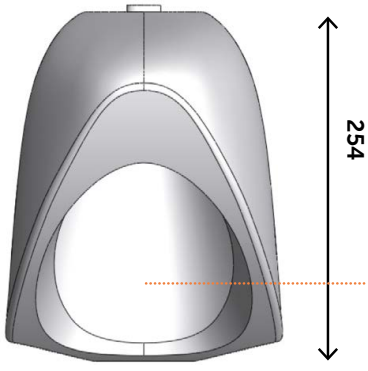


Figure 6.12a Front view

Figure 6.12 Narrow opening urinal of 130 x 300 mm, and depth of 225 mm (van den Meiracker 2011b; p.55)

Van den Meiracker (2011) designed a narrow opening of 130 mm to invite the user to stand closer to the urinal and concentrate on directing the urine stream (figure 6.12) versus the tendency to casually urinate in a large opening. The length of this 300 mm opening allows for different urination/urethra heights for different lengths of males, see figure 6.3, section 6.1.

Loth (1998) arrived at similar conclusions when designing a female urinal (lady p) that might encourage women to get closer to the urinal. Initially, she expected that a narrow opening in the female urinal would cause spillage, but this did not occur in the experiments. An additional reason for this narrow opening was to communicate that this urinal is intended for urine instead of faeces; a large opening could convey a toilet meant for defecation. As a result, lady p's design has a narrow opening of 115 mm and a length of 240 mm. Nevertheless, women can move the point of origin closer to the opening when they hover by bending their knees, which is unnatural for a man as they generally remain upright without bending their knees. Men can primarily reduce the horizontal distance by standing nearer the urinal.

Urinals with narrow openings may be a better solution in stationary environments than in a moving train. Moving environments sometimes throw people off balance thus altering the direction of the urine stream, as some observations in chapter 5 showed. A larger opening could better compensate for irregularities in the urine stream during movements. However, van den Meiracker (2011) examined and improved the stability of the standing urination posture by placing the urinal at an angle of 60 degrees to the direction of the train. He based this on snowboarding posture, where lateral forces are compensated by standing diagonally. This 60-degree approach could indirectly reduce the irregularity of the urine stream during the movements of the train, see section 6.13.

6.5.3 Angle and target

The angle at which the stream hits the surface is a factor that can be adjusted through design. Hurd et al. (2013) claim that altering the "angle of attack", i.e. aiming downwards at a narrow angle, helps to reduce backsplash.

Figure 6.13a A fly,
(van den Meiracker 2011b, 56)

Figure 6.13b A bee as target in the urinal
(Lambton 1995, 75)

Figure 6.13c A goal for men to aim at to 'avoid' backsplash? Photo: Pieter Jan Stappers

Figure 6.13 Targets in urinals

The permanent addition in urinals of a neutral insect such as a fly (figure 6.13a), or a bee (in Latin: apis; 'a piss' that was intended as a joke in the Victorian taboo era of 1900 (see figure 2.6, section 2.3.1), (figure 6.13 b), has been reported to be an effective solution to reduce spillage (Lambton 1995; Work 2013). This so-called "nudge" needs to be etched at a "sweet" spot where the porcelain's curvature reduces the backsplash (Vicente 2003, 79,80; Subich n.d.), see figure 6.13. Kira (1976) recommends providing a target in the critical area of the urinal with a ridge. However, urinal 2 used a ridge that proved to be counterproductive (figure 6.9b, section 6.4). The same is shown in figure 6.13; this 'goal' is also considered counterproductive because it creates additional surfaces for urine backsplash (figure 6.13c).

Figure 6.14 Switching light dot concept as target in the urinal (van den Meiracker 2011b, 58)

Van den Meiracker (2011) did a creative session with five participants using gamification to find an attractive way of improving urination aim. They searched for the elements of surprise and interaction through a dynamic rather than a static aim, so that it would remain appealing while using the urinal. They designed a switching light dot concept, see figure 6.14. However, a simple target without technology is preferred, as it saves energy and is not vulnerable to vandalism.

To conclude, the atmosphere around a urinal should be inductive to helping a man concentrate on the difficult task of urinating without spilling while standing upright. Simple targets in urinals can prevent nonchalance during urination and trigger users to get closer to the urinal, which helps reduce backsplash.

6.6 Conclusion backsplash experiment 1

1. Urinal 1 with a flat surface in the back and a circular inner shape caused less backsplash than urinal 2 that had interior relief, see figure 6.8.

Implication for design

2. The user should be encouraged to stand as close to the urinal as possible to avoid backsplash. A clean urinal, and to a lesser extent, narrow urinal openings and simple targets like a fly in urinals are design implications that contribute to men standing closer to the urinal.
3. The inner bowl should enclose the urine flow together with its backsplash so that the urine stream is confined by the surface curvature and depth of the basin.

Recommendation

A general recommendation is that more research needs to be conducted in the field of toilets and urinals. The design of male urinals needs improving to reduce its soiling, as confirmed in this study. Research in this field should include participants to account for the human factors affecting backsplash.

6.7 Introduction dispersion experiment 2

In experiment 1, we studied soiling on the floor caused by backsplash of an artificially generated urine stream via the inside of two different urinals. The outcome confirmed Hurd et al.'s (2013) conclusion that the closer a person stands to the urinal, the less the soiling. Furthermore, the experiment showed that the configuration of the inner bowl of the urinal also affected the urine spillage on the floor.

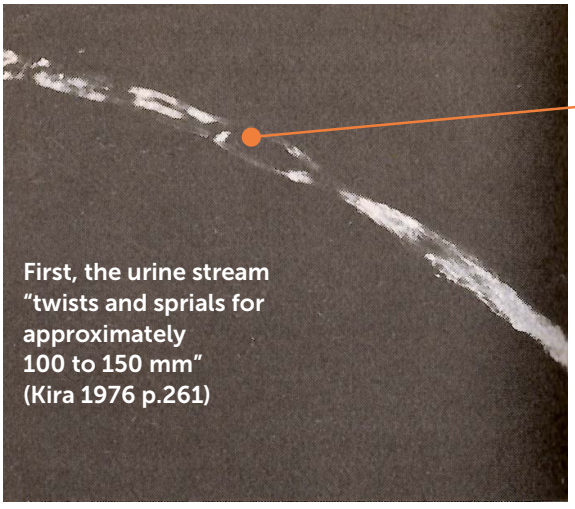


Figure 6.15a First twisting part of the urine stream

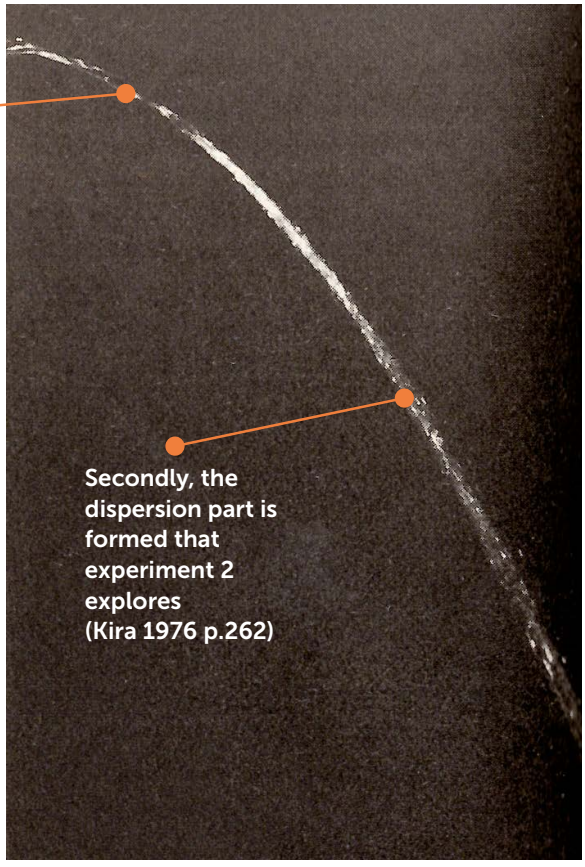


Figure 6.15b Second spread part of the urine stream

Figure 6.15 Male urine stream (Kira 1976, 261-263)

In experiment 2, we analysed the final, dispersed part of the urine stream and the related spillage that lands in or outside a toilet or urinal. According to Kira (1976) and confirmed by Hurd et al. (2013), this dispersed path, caused by the centrifugal effect on the urine stream (figure 6.15b), contributes to a significant proportion of soiling outside a toilet bowl.

We start by introducing the two-part urine stream:

1. First, a thin stream of 100 to 150 mm that "twists and spirals" and starts at the slit-like shaped urethral orifice (figure 6.15a).
2. Subsequently, it disintegrates into a centrifugal spray where the increment depends on the velocity of the stream; this varies between 9.5 and 50 mm. According to Hurd et al. (2013), the stream of urine breaks at a distance between 152 and 178 mm measured from the urethra.

Figure 6.16 The stream of one participant split into two streams and ended in a wide dispersion

3. In our observations we mainly observed the falling part of the urine flow. The urine flow of one participant (20m; table 5.1, section 5.3.5) was an exception because it split into two streams, with about 10 cm between them, see figure 6.16. Thereafter, the stream spread out into a wider dispersion of about 70 mm than shown in figure 6.15b.

Kira and Hurd et al., note that this second part of the urine stream contributes most to the soiling of the environment (Kira 1976; Hurd et al. 2013; BBC 2013) (figure 6.15b). In experiment 2, we explore this further.

Building on experiment 1, an artificial test setup was created to eliminate human factors that influence urine stream dispersion. In addition, we excluded 'urinal factors' that also affect the soiling in the environment. Therefore, both a high slot and three separate slots were used instead of a urinal to 'urinate' through, using a simulated urine stream, see appendix A.6.2.4.

In this chapter, we set out to answer the following research question: "how to reduce urine spillage when using a urinal?" To achieve this, in experiment 2 we focused on the dispersion part of the urine stream and the expected related spillage outside a toilet/urinal. The following factors were examined: the height from which the urine comes(urination/urethral height); the angle of the urethra/penis, and two different (bladder) pressures, namely 0.2 bar and 1 bar. Appendix A.6.2.1 and figure A.6.5 give a detailed explanation of the factors examined.

6.8 Method dispersion experiment 2

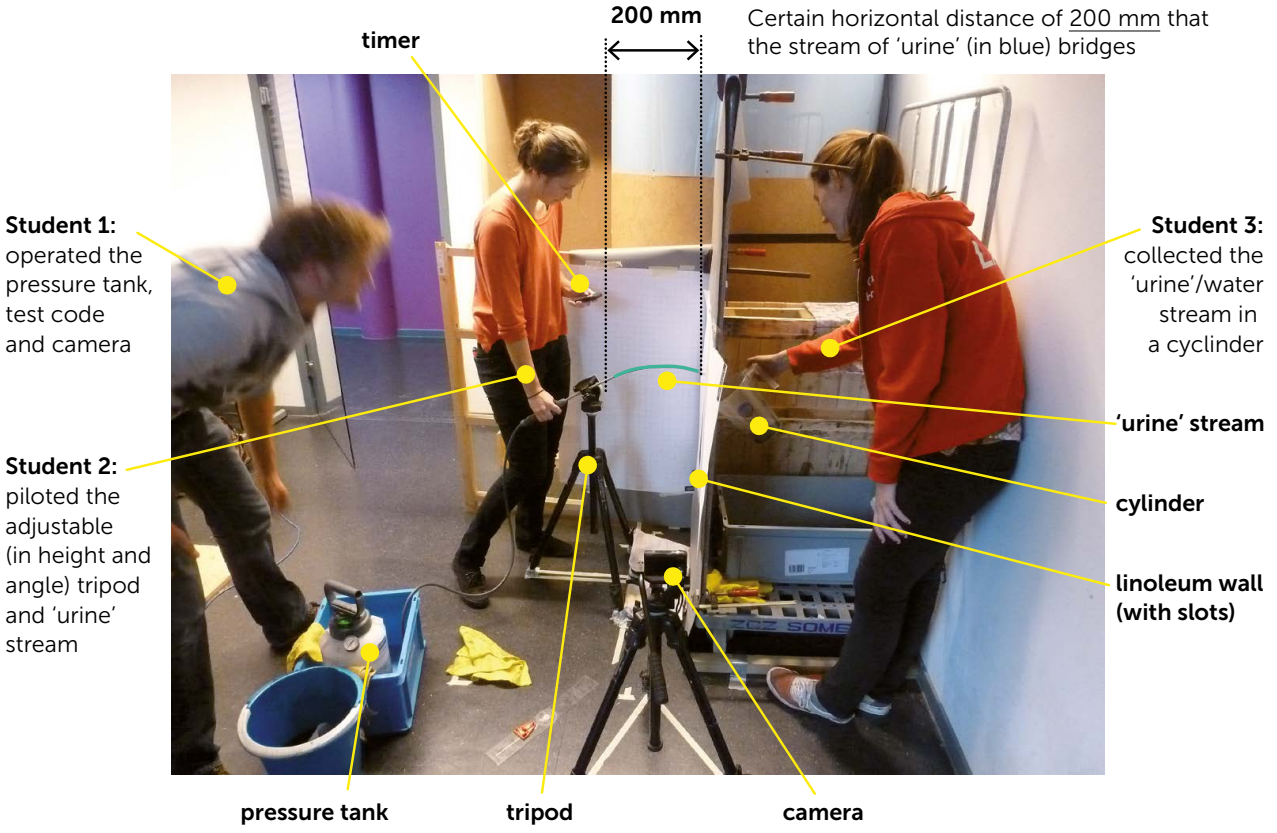


Figure 6.17 Test setup experiment 2

A pilot test set up was built in the laboratory to explore the dispersion of male urine flow (see Appendix 6.2.3, figure A.6.9 and 6.17). In this section, we describe the materials used and how the experiment was performed. Regarding the materials, a pressure pump in combination with a height-adjustable tripod was used to simulate a urinating man (as in experiment 1, see section 6.1). A hole or slot was created for urination at different heights, (see Appendix A.6.2.4, and figure A.6.12). The angles of the nozzle varied, at two pressures of 0.2 or 1 bar. The horizontal distance between the nozzle and the wall was set at 200 mm, see figure 6.17. This distance appeared to be adequate for the visibility of the dispersion on the papers on the wall. We accounted for the initial (100-150 mm) twisting of the urine stream, see figure 6.15a and Appendix A.6.2.3 under urination height-adjustable tripod.

Research student 1 filled the pressure tank with coloured water to improve the visibility of the urine stream. Subsequently, the air pressure was increased to either 0.2 or 1 bar and the camera was started. In the 0.2 bar test, the film started first, and the pressure of ± 0.2 bar was achieved.

Research student 2 stood next to the nozzle with a timer and started and stopped the flow of urine, see Appendix, figure A.6.9. A third research student (3) stood behind the

linoleum wall and captured the simulated urine stream that fell through the slot(s) with a cylinder, see figure 6.17. Different slots were used, depending on the pressures, serving as the target point of the 'urine' stream. In this way the same vertical distance of the urine under the different pressures could be compared, see Appendix A.6.2.4, dimensions of the slots. In both cases, the same amount of liquid was voided. In the 1 bar test, the urine stream stopped after 6 seconds. In the 0.2 bar test, urination started immediately and continued for 16 seconds; see appendix A.6.2.3 for more details of the materials.

6.9 Result dispersion experiment 2

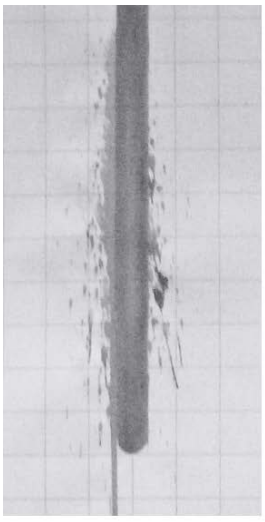
In experiment 2, we aimed to determine the effect of the dispersion of a 'urine' stream. This falling part of the 'urine' stream causes, in addition to the backsplash examined in experiment 1, soiling of the toilet environment (Kira 1976; Hurd et al. 2013).

Urination/Crotch height (mm)	Aim height (mm)	Angle	Pressure (bar)	Slot dimensions (mm)
P05 =785 mm	A = Aim 850 mm	0 = 0°	0,2 = 0,2 bar	Width = 20mm
P50 =870 mm	B = Aim 765 mm	1 = 12° (downwards)		Height = 475 mm
P95 = 955 mm	C = Aim 680 mm	2 = 21° (downwards)		1 Slot
		3 = 12° (upwards)		See figure A.6.12a
P05 =785 mm	A = Aim 925 mm	0 = 0°	1=1 bar	Width = 20mm
P50 = 870 mm	B = Aim 840 mm	1 = 14° (downwards)		Height = 50mm
P95 = 955 mm	C = Aim 755 mm	2 = 24° (downwards)		3 Slots
		3 = 12° (upwards)		See figure A.6.12b
		4 = 23° (upwards)		

Table 6.1 The examined factors differ in relation to the pressure

We focused on three aspects that can affect the dispersion of the urine stream and the related soiling: the difference in crotch/urination height, the angle of the penis, and the bladder pressure. The vertical distance of the urine stream between the height of the nozzle and the target point had to be the same for both pressures. However, the urine stream showed an irregular drop for both pressures. Therefore, the aiming heights, angles, and slots differed from each other for the two pressures, see table 6.1.

6.9.1 Results 0.2 and 1 bar tests



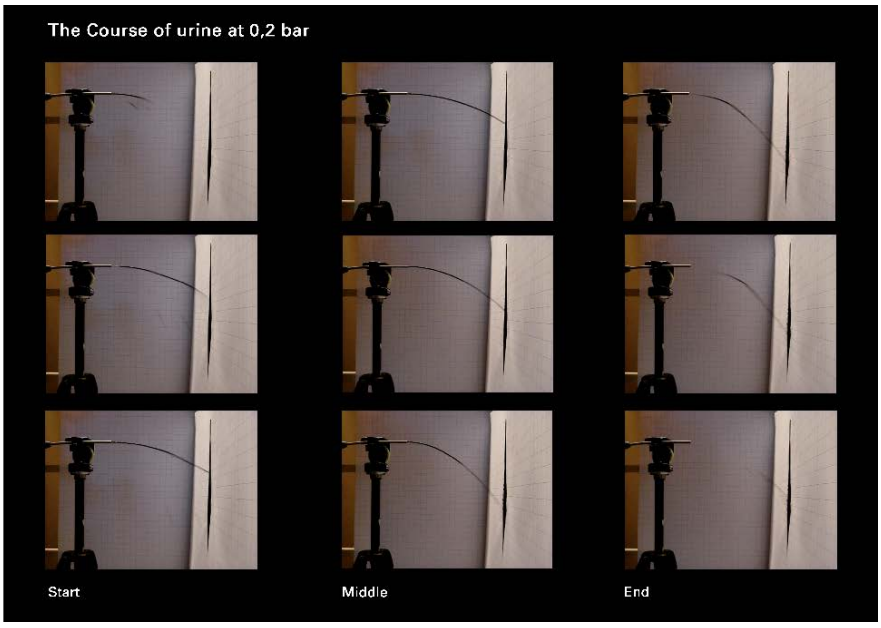
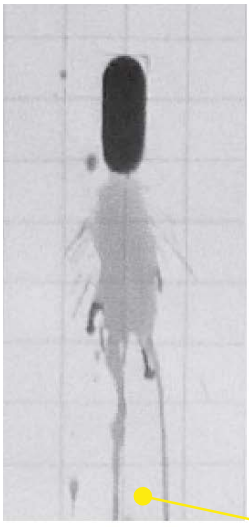


Figure 6.18a Front view soiling by dispersion around the slot of 0,2 bar test

Figure 6.18b Side view dispersion test 0,2 bar



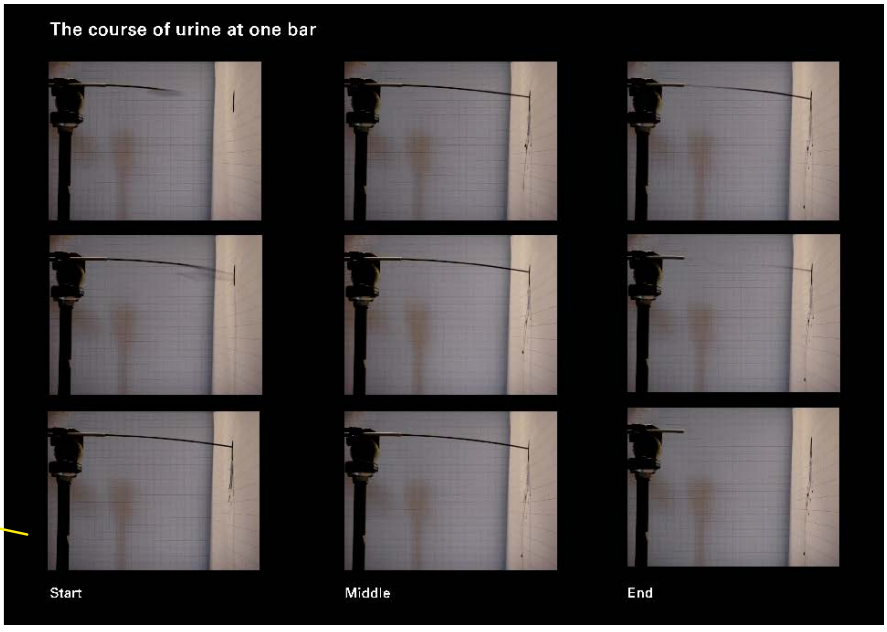


Figure 6.18c Front view soiling by backsplash under the slot of 1 bar test

Figure 6.18d Side view dispersion test 1 bar

The course of dispersion is shown in 9 camera shots, divided into 3 at the Start, 3 in the Middle and 3 at the End.

In the 0.2 bar test, the streams all started at the aiming point, but eventually, dropped ±120 mm due to loss of pressure (see figure 6.18b). As a result, the soiling caused by the dispersion of the urine stream was formed over a length of 150 mm around the slot, see figure 6.18a. This contrast with the 1 bar test where the stream fells by 30 mm (see figure 6.18d) and appendix A.6.2.4 for more information on the slots used for the different pressures.

In brief, the 0.2 bar test used a high slot only, and the 1 bar test used 3 separate slots. The soiling occurred at the bottom of the slot in the 1 bar test, caused by the stream start-up which was not a direct stream hitting the target point and subsequently caused dispersion, but the stream directly hit the paper, causing backsplash under the slot, figure 6.18c. Thus, in the case of the 1 bar pressure test, soiling occurred under the slot from backsplash and not from the dispersion of the urine stream.

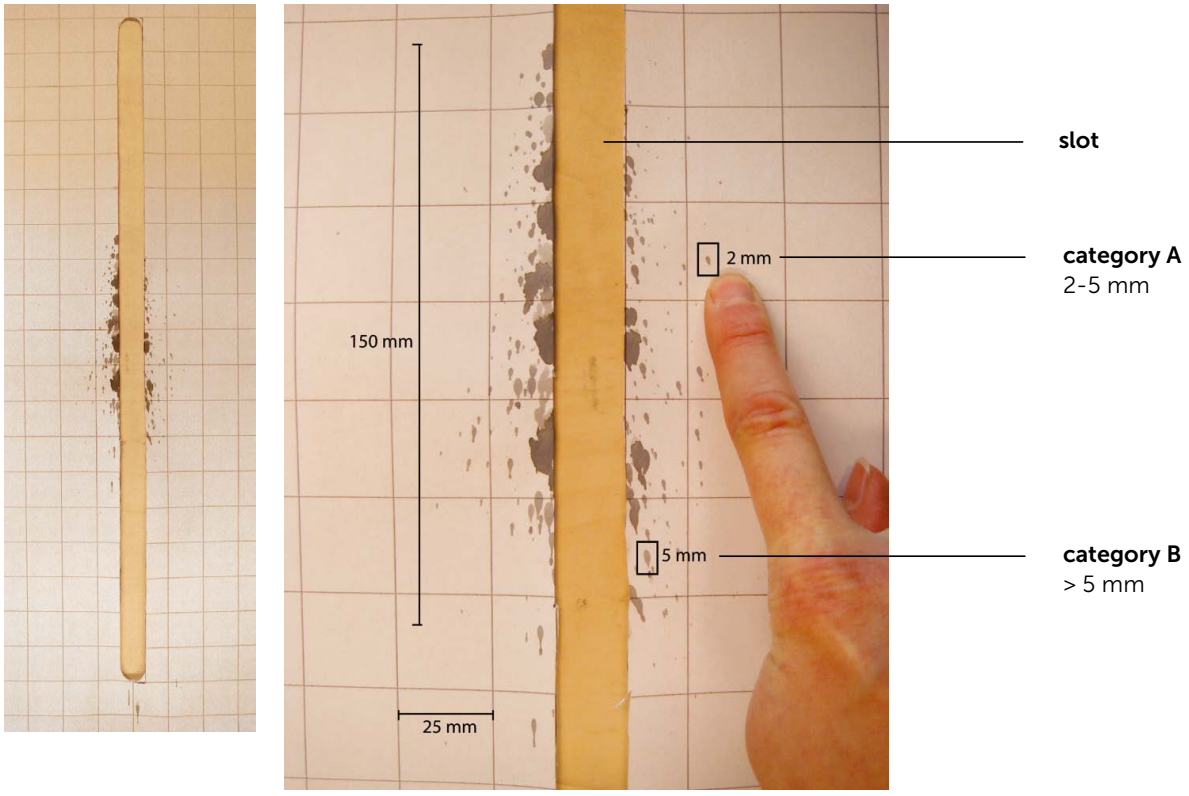


Figure 6.19 Two types of soiling by dispersion is measured in the 0,2 bar test

In the 0.2 bar test, we distinguished two types of soling due to dispersion. Category A, based on the smallest drops (< 5 mm with a minimum height between 2 and 5 mm). Some smaller drops were found at some distance from the slot and may have been caused by other factors. The second type of soiling, category B (>5 mm), formed a massive stain around the slot, see figure 6.19.

Both types of soiling were represented graphically, i.e., category A; droplets < 5 mm due to the dispersion of the urine stream further away from the slot, and B droplets > 5 mm near the slot, see figure 6.19 and appendix A.6.15a and 6.15b.

Test 0.2 bar

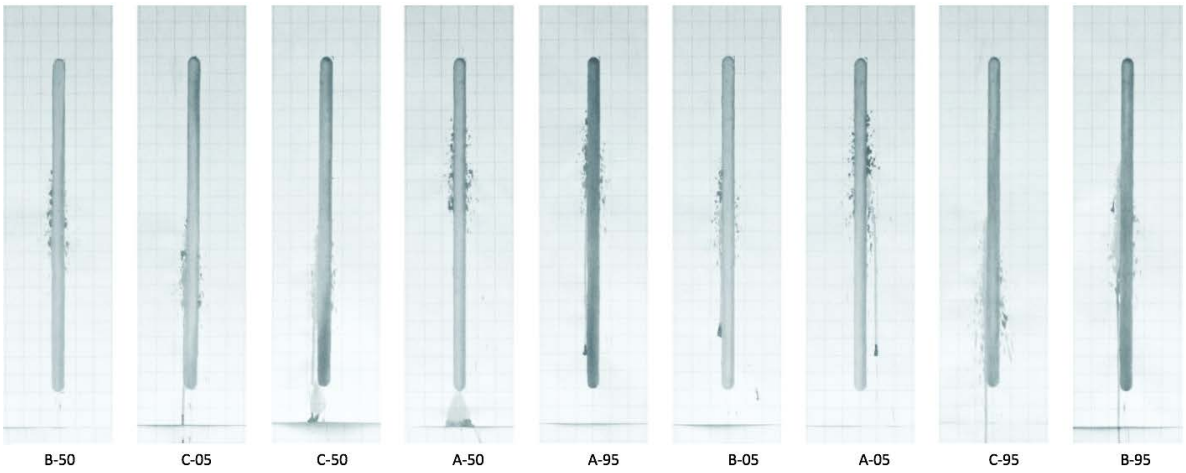


Figure 6.20 Row from least (left) to most dispersion (right)

Figure 6.20 shows the rows from the least to the most dispersions. These are the combinations B50, C05 versus C95, B95 respectively. This means that the stream coming from the middle crotch height to the middle aiming point, and the stream coming from the lowest crotch height to the lowest aiming point, caused the least dispersion. The nozzle was in a horizontal position in these two combinations of crotch heights and aiming points. Conversely, the stream from the highest crotch height to the middle and lowest aiming point, respectively, created most soiling due to dispersion.

Test 1 bar
The 'urine' stream did not show the dispersion effect at a ('bladder') pressure of 1 bar. It showed soiling from backsplash under the slot during the start-up of the stream which hit the paper directly, causing the stream to bounce back (backsplash). Subsequently, the flow slowly bent upwards towards the aiming point, while dispersion did not occur.

Conclusion 0.2 bar and 1 bar tests
In the 0.2 bar test, the stream demonstrated dispersion over a length of 150 mm around the slot. However, only small differences between the least and most soiling of category A and B droplets due to dispersion were found, leading to the conclusion that the effect of dispersion soiling is less relevant than expected. This is discussed in greater detail in appendix, A.6.2.5 for the 0.2 bar test only, as soiling due to dispersion did not occur in the 1 bar test.

6.10 Discussion dispersion experiment 2

In this part of the study, we examined to what extent the factors, crotch height/urination height, bladder pressure, and angle of the penis/nozzle affected the dispersion of the urine stream. The approach taken for both experiments 1 and 2 was technical in order to isolate factors that influence each other, thereby excluding interrelated human factors.

Although the simulation was designed to be as close as possible to the reality of human urination, it had some shortcomings which are discussed below.

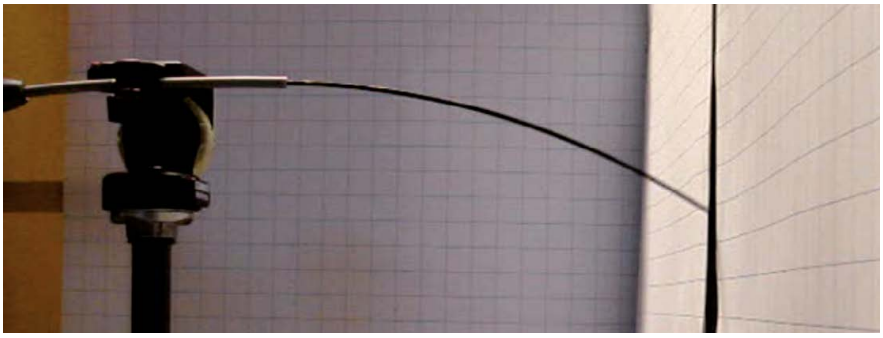


Figure 6.21 Twisting and turning of the stream did not occur

Urine stream

The urine stream did not start by twisting and turning (figure 6.21 compared to figure 6.15, section 6.7) which could have affected the dispersion. The stream started from a circular instead of a slit-like narrow aperture of the urethra. For further research, we recommend testing with a more detailed representation of the male urethra, and therefore repeat the test with a slit-shaped nozzle orifice approximately 6mm long and bordered on both sides by two small labia (Gray 1918) instead of an open round thin tube of 5 mm diameter.

Furthermore, the first drops came out of the nozzle unexpectedly. These drops caused soiling at a different location, lower than where the urine flow was spread. The last drops in the tests did not cause any soiling other than that caused by the dispersion. These droplets were caused by a small amount of water remaining in the nozzle.

Bladder pressure

The results of this dispersion experiment 2 contradict Kira's assumption of less dispersion at low bladder pressure than at higher bladder pressure. In the 0.2 bar pressure tests that represented the actual bladder pressure better than the 1 bar tests, the main source of spillage was the dispersion of liquid, but this was limited. The dispersion of the urine jet also caused some backsplash, see figure 6.18. In contrast, in the 1 bar pressure test the stream remained integrated; dispersion did not occur on the paper. Although the 1 bar pressure was unnaturally high, it gave insights into the effect of the pressure difference on urination: that low pressure increased dispersion instead of high pressure, as Kira (1976) asserted.

Moreover, according to the calculation (see Appendix A.6.2.3 and figure A.6.11), a pressure of 0.1 bar corresponds to a human urinal flow of 20 ml/s, see appendix figure A.6.8. However, the device was not accurate enough to spray continuously at this low pressure. Therefore, the lower limit of the pressure apparatus was set at 0.2 bar.

Furthermore, the start of urination and the pressure generated by the water pump did not fully correspond to human urination because the simulation immediately started under the high pressure. During urination, the pressure fluctuates, starting with a lower pressure, which increases at the end and then decreases again, see appendix figure A.6.8.

Another improvement would be to work with a more controllable device to simulate the bladder pressure. However, in chapter 5, we observed that the urine stream of two participants (30m and 31m, section 5.3.4) did not make a full arc, but fell directly onto the seat, which could also indicate that their bladder pressure dropped, as happened when using the pressure pump.

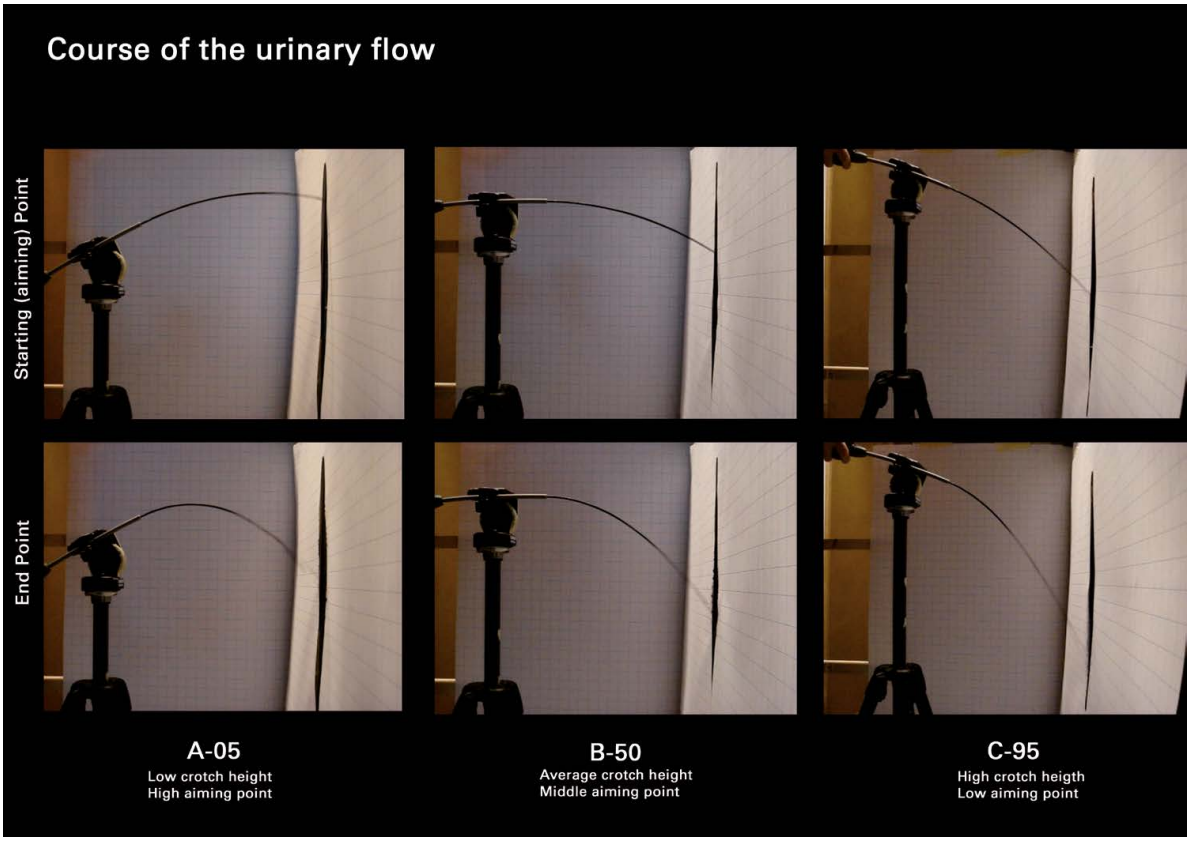


Figure 6.22 Course of the urine stream at different angles of the nozzle

Angle of the nozzle/penis

The upward angle of the nozzle and thus of the penis at the combination of A05 seemed unrealistic in retrospect: 'urine' from the lowest urination/crotch height of 785 mm which aimed at the highest aiming point of 850 mm, see figure 6.22. This A05 combination also caused a greater amount of soiling from dispersion (see figure 6.20) due to gravity, resulting in a disintegrated stream. Urinals that are placed at a height of 610 to 700 mm generally lead the direction of the penis downwards or horizontally. However, the test showed that holding the nozzle in the most extreme upward position caused less dispersion than holding the nozzle in the most extreme downward position, see figure 6.20. The combination C95 (highest crotch height aiming at lowest aiming

point (680 mm) caused a great amount of dispersion, see figure 6.20. Whether the penis is (regularly) directed in an upward direction during urination is not reported in the literature.

In summary, the angle of aiming the penis/nozzle affected the dispersion of the urine stream. The most extreme nozzle angles caused more dispersion than those approaching a horizontal position, see figures 6.20 and 6.22.

6.11 Implication for design to reduce dispersion

In this section, we describe implications for the design of a urinal which aims to achieve a reduction of spillage by dispersion of the urine stream. Accordingly, the urinal should meet the following minimum dimensions, as shown in figure 6.23.

Firstly, the height of the urinal was determined in a previous study at 700 mm (Y-axis) from the top of the front of the urinal (Loth and Molenbroek 2011). We confirmed this in our experiment. As an indication, 680 mm is the height of the lowest aiming point falling within the proposed yellow implication area, (see table 6.1, section 6.9).

Secondly, the urinal must have an inner horizontal dimension of 200 mm (Z-axis), approximately the distance between the end of the urethra (point of origin) and the back of the inner surface of the urinal.

Thirdly, to avoid soiling outside the urinal due to dispersion, the width of the urinal should be at least 80 mm (60 mm + 20 mm, including the width of the slot) in X-axis. We show that most soiling by dispersion occurred with a crotch height-aiming point combination of B-95, resulting in a spillage width of 60 mm, see figure 6.20, and figure appendix A.6.15a

Fourthly, due to bladder pressure, while the penis is held in one position, the stream of urine first rises and then bends over a vertical distance of about 120 mm. Therefore, the vertical distance that the inner shape of the urinal needs to bridge (including 30 mm margin) is about 150 mm (Y-axis).

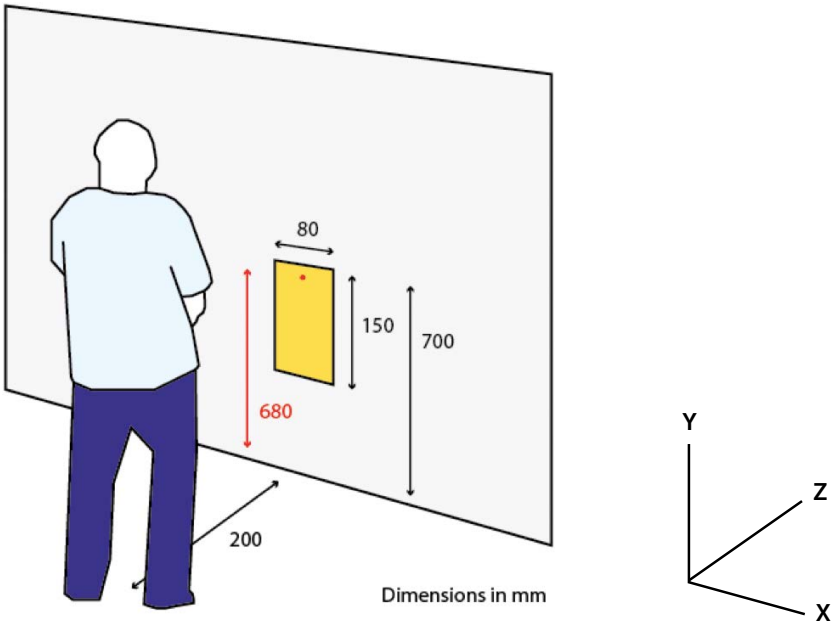


Figure 6.23 Implications for urinal dimensions to achieve a minimum spillage by dispersion.

6.12 Conclusion dispersion experiment 2

1. The amount of dispersion depends on the bladder pressure. The lower the bladder pressure, the more dispersion occurred. However, the effect on spillage due to dispersion was small at both low (0.2 bar) and high (1 bar) bladder pressure.

2. The crotch-aiming combination of B-95 caused the most dispersion soiling, with a width of 60 mm.

3. Experiment 2 showed that no soiling appeared on the floor under the stream caused by dispersion.

4. When the 'penis' was held horizontally, thus, parallel to the floor, the least dispersion occurred.

5. The dispersion of the urine stream did not have the expected effect on the spillage. We conclude that the backsplash is the main cause of urine spillage.

Implication for design

6. The inner dimension of the urinal should be 200 mm (Z-axis) with a width of at least 80 mm (X-axis). The height of the urinal should at least be 150 mm (Y-axis) and the height at which the urinal is placed should be 700 mm from the top of the front of the urinal to the floor.

6.13 A moving environment experiment 3

We close chapter 6 by describing experiment 3. In this experiment, we factor in train movements and test how men can retain a more stable posture and therefore more accurately direct the urine stream under shaking conditions. In chapter 5, observations showed that in five cases the movements of the train threw participants off balance when they visited the toilet. In some cases, this led to spillage outside the toilet bowl.

The aim of experiment 3 is to determine a comfortable posture in which a user of a urinal can direct the stream of urine most accurately while train movements are simulated.

6.13.1 Forces from train movements

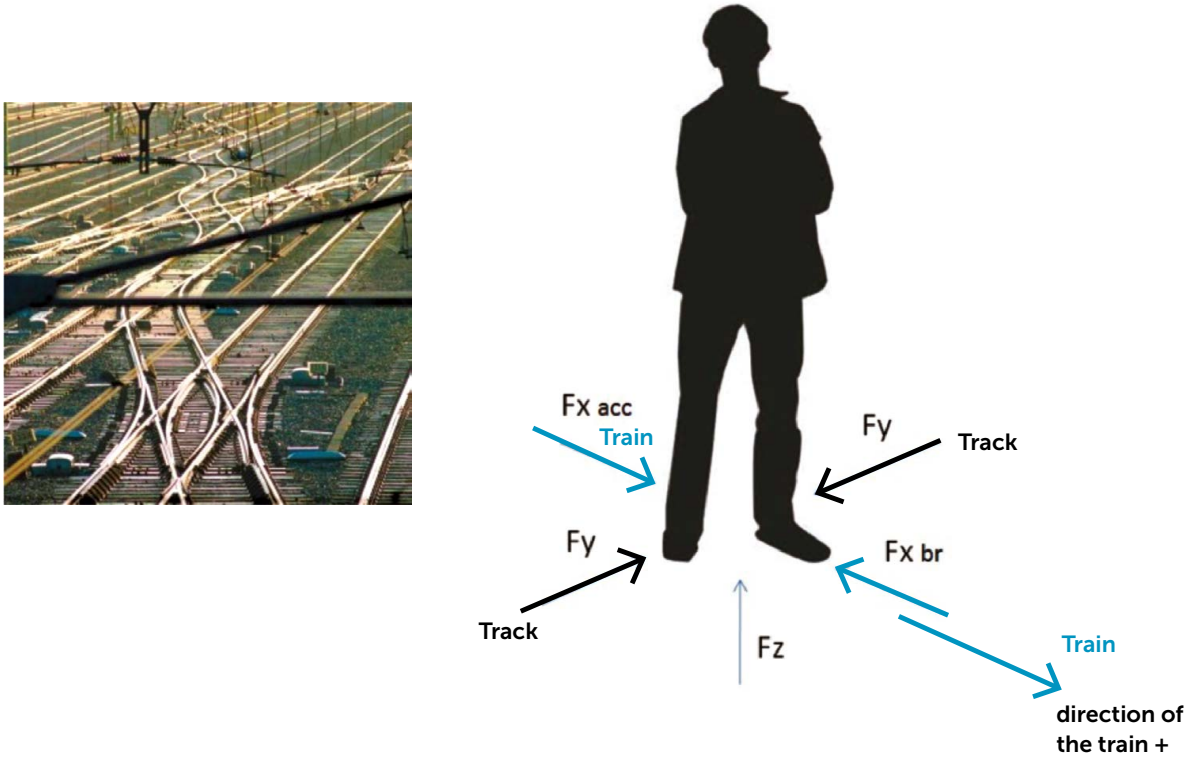


Figure 6.24 Track switches that cause lateral forces on a train traveller (Fy).
Blue arrow indicates the direction of the train causing the (Fx) forces on the train passenger during acceleration of the train (Fx acc) and deceleration Fx br(akes) (van den Meiracker 2011b, 23).

The shaking of trains, typical for train travel, can disturb the balance of men when using a train urinal in standing position. As a consequence, they can less accurately aim their stream of urine. These acute movements that create sudden forces on the human body are caused by track switches and the positions of the rails that do not precisely fit the wheels of the train. Moreover, acceleration (Fx acc) and deceleration (Fx br) of the train contribute to the instability in moving direction (Fx), but these (X) forces are less acute than the (Y) forces coming from the track (Fy) (figure 6.24) (Narayanamoorthy et al. 2008; van den Meiracker 2011).

6.14 Method a moving environment experiment 3

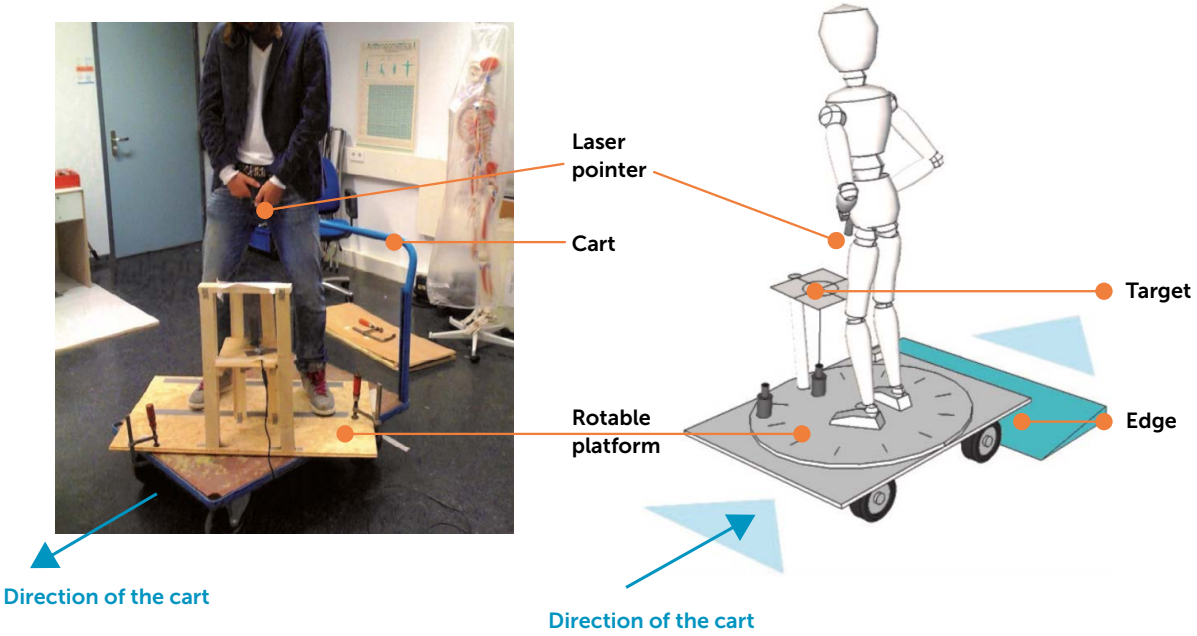


Figure 6.25 Test setup experiment 3 (position 3, see figure 6.27) with laser pointer as simulation of the penis, the blue arrows indicate the direction of the cart (van den Meiracker 2011a, L)

In the toilet laboratory, we created a test facility to conduct experiment 3 by simulating the movements of the train. In this section, we summarise how experiment 3 was performed.

Initially, we aimed to perform the test on a train, however train movements are unpredictable. In practice, a laboratory setting was preferable as we were able to standardise and simplify the movements so that the participants would encounter the same forces from one direction of impact.

We conducted a pilot with two participants prior to the actual test to check whether they understood the procedure and whether the questionnaire about the experience of comfort and stability was clear enough; we also tested the installation of the camera.

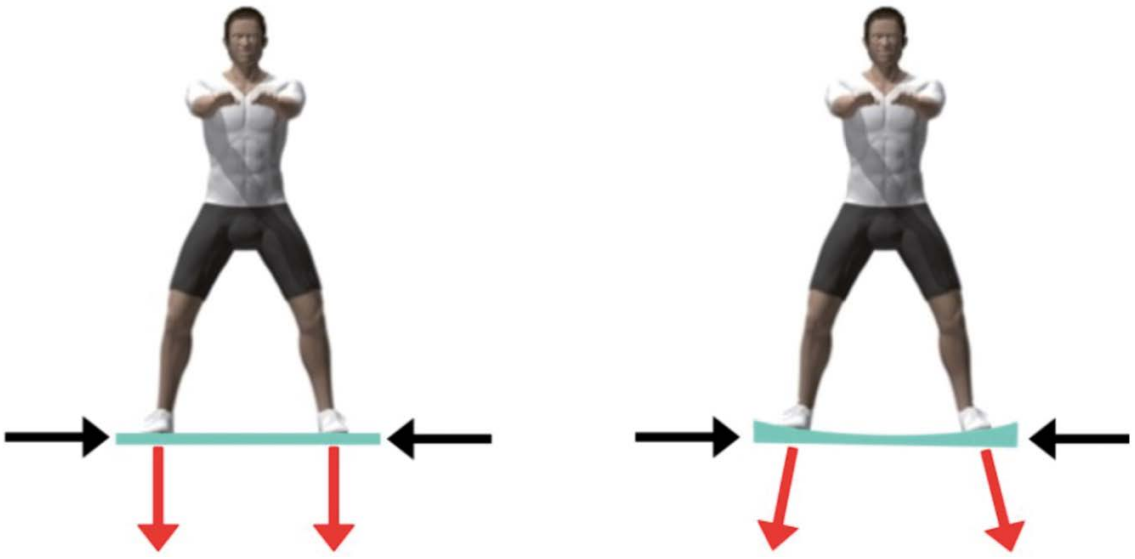


Figure 6.26a flat floor *Figure 6.26b curved floor*

Figure 6.26 Lateral forces (in black) on flat floor and curved floor and reaction of the traveller indicated with red arrows (van den Meiracker 2011b, 50)

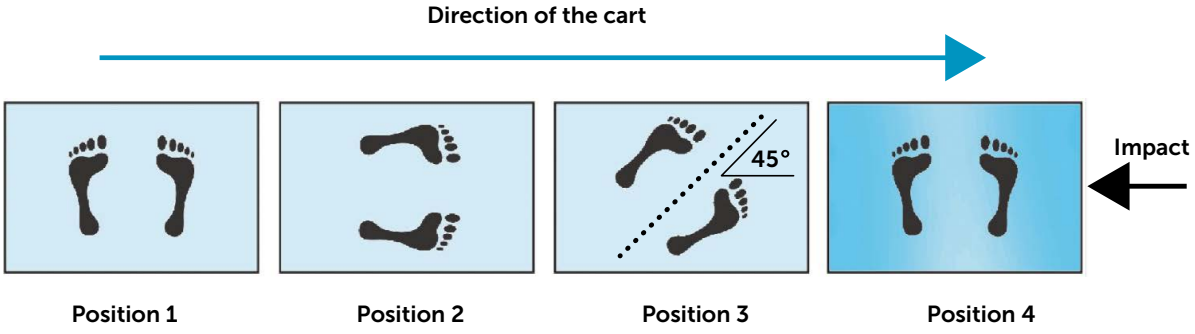


Figure 6.27 Four positions of the participants' feet, the blue arrow indicate the direction of the cart/train (van den Meiracker 2011a, appendix L)

We tested three positions of the human body on a flat floor (positions 1-3) and one on a slightly curved floor (see figures 6.26b and 6.27, position 4). We determined whether these positions give the human body or the feet a better grip while standing if a sudden shock occurs, without disturbing the direction of the urine stream/penis.

Position 1 gave a lateral impact; the moving direction of the cart was from left to right. Position 2 gave a frontal impact; the feet were in the direction of the cart's movement. Position 3 gave an impact in which the feet were at an angle of 45°. Position 4 was on a curved floor and gave a lateral impact similar to position 1; the moving direction of the cart was from left to right, see figures 6.25 and 6.27 for the positions; the blue arrow indicates the direction of the train or cart.

In the test, participants stood on a cart on which a rotating platform was attached that could assume the different positions, as depicted in figure 6.27. The target was

positioned at a height of 600 mm, related to the usual height of the underside of a urinal (van den Meiracker 2011). Eight participants were asked to use a laser pointer (to represent a penis) and continuously focus on a red dot on the target placed on A4 paper to overlap the centre of the target as closely as possible. The cart was rolled manually to a 15 mm high edge for each position which caused it to come to a sudden standstill, simulating the impact of the train's movements, see figures 6.25, and 6.27.

The eight participants tested four positions on the cart. Each participant started from a different position, which then continued in the same order to try to compensate for and avoid a learning effect from the previous position(s). For more detailed information about the method, the collection of the data and results, see appendix L "Accuracy test" by van den Meiracker (2011).

6.15 Discussion a moving environment experiment 3

In experiment 3, we tested four body or foot positions, three on a flat floor, and one on a curved floor, see figures 6.26 and 6.27. We tested whether 8 participants could continue to aim a laser pointer as a simulation of the penis while remaining stable in a simulated moving environment (figure 6.25). The results were analysed graphically to measure the impact, and questionnaires were held with participants to verify their comfort and stability during the impact. These are described in van den Meiracker 2011a, appendix L).

We were unable to use half of the graphs because the laser pointer as simulation for the penis exceeded the maximum value for the aspect ratios documented by the software. This resulted in only four graphs for analysis. The tests were based on human body positions at an angle of 0, 45 and 90 degrees (see figure 6.27). The final choice of 60 degrees was not tested.

The preference for a curved floor may be reinforced because it was the only option that distinguished itself from a flat floor. Some participants explicitly confirmed that they understood the curved concept better than the flat options. Although in principle, wheelchair users cannot use the urinal standing up, a curved floor prevents them from accessing the urinal area, making it an incompatible design in the context of inclusive design (University of Cambridge 2017). In addition, a curved floor implies an intervention in the design of the floor, whereas a flat floor does not, which makes a flat floor a simpler design and therefore easier to clean and maintain.

6.16 Implication for design to direct the urine stream in a moving environment

We concluded that a body posture under 60 degrees is more resistant to the forces resulting from the movements of the train than 45 degrees, because the impact in the test

came from one direction instead of the actual impact from two directions. In addition, the eight participants assessed the experience of stability and comfort relatively well for an angle of 45 degrees, however, in the case of a single force from one direction, it is assumed that they would also assess this for 60 degrees.

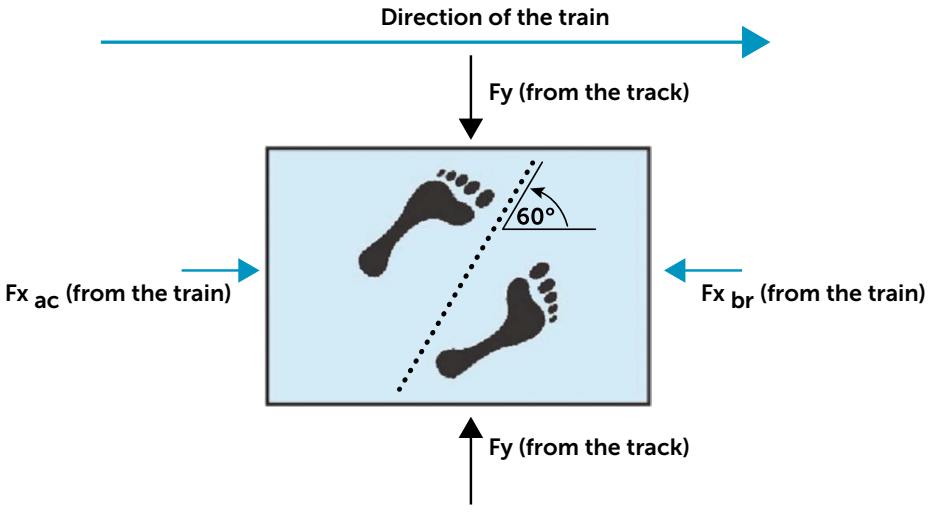


Figure 6.28 position human body at 60⁰ to withstand the lateral (Fy) (coming from the track) and directional forces (Fx) of the train while aiming the urine stream (see also figure 6.24, section 6.13.1)

We conclude that a posture of 60 degrees enables the human body to withstand the forces caused by the movements of the train because the lateral forces on the body coming from the track switches (Fy) have more impact than the (Fx) force (in the direction of the train), see figures 6.24, section 6.13.1, and 6.28.

6.17 Conclusion a moving environment experiment 3

1. The participants preferred a curved floor in order to improve stability while standing. However, a flat floor without deformation is preferred to provide accessibility for wheelchair users, and is preferable for cleaning and maintenance.
2. Analysis of the four graphs showed that male body posture affects the accuracy of aiming in response to a shock.
3. A lateral force can be best withstood when the position of the feet or body is perpendicular to that force (position 1). Conversely, if the feet/body are positioned in the same direction as the occurring forces (position 2), the shock cannot be resisted.

Implication for design

4. We recommend the NS to place a urinal at an angle of 60 degrees in the direction of the train. The male user can then remain stable, enabling him to direct the stream of urine in a controlled way under moving conditions.

6.18 Conclusion chapter 6 reducing urine spillage

In chapter 6, we performed three experiments, to inform the design of urinals and to answer RQ B3 of the thesis: 'How can urine spillage be reduced when using a urinal.'

In experiment 2, we focused on the distance of the urine stream, and in particular, on the last part where dispersion of the urine flow occurs. However, the spillage in the environment due to the dispersion was less than expected; no soiling appeared on the floor as a result of the dispersion. This in contrast to experiment 1, where it was shown that backsplash via the inside of the urinal caused soiling on the floor. Urine spillage when using a urinal is mainly caused by the backsplash, as demonstrated in chapter 5 and experiment 1 of this chapter. Therefore, to reduce backsplash when using a urinal, the physical distance between the human body and a urinal needs to be reduced, and in particular, the horizontal distance, as demonstrated in experiment 1. In other words, men should be encouraged to move one step closer to the urinal when urinating.

As an implication for design, men can be encouraged to stand closer to the urinal if the urinal is clean, by support options, and through a simple target in the urinal like a fly. Furthermore, the urinal surface curvature and depth of the basin should be able to contain the stream of urine along with its backsplash.

To remain stable while the train is in motion, a urinal should be placed at an angle of 60 degrees to the longitudinal axis of the train, as demonstrated in experiment 3.

Figure 6.29 Indication in a public toilet at a university in China to keep the urinals cleaner by a step closer. Photo: Pieter Jan Stappers

6.19 Acknowledgement chapter 6 reducing urine spillage

We would like to express our acknowledgement for the combination of enthusiasm, creativity, and rigour to the following research students who carried out the experiments as part of an elective of their Master's programme: Amit Gudadhe, Hanneke Hoogewerf, Wouter Horstink, Jorn Ouburg, and Laurien Wolfswinkel concerning the backsplash experiment 1, and Brenda van Geel, Helena Keizer and Bas van Leeuwen with regard to experiment 2, as well as for their in-depth approach in the dispersion study.

Part B: experiments

Recap

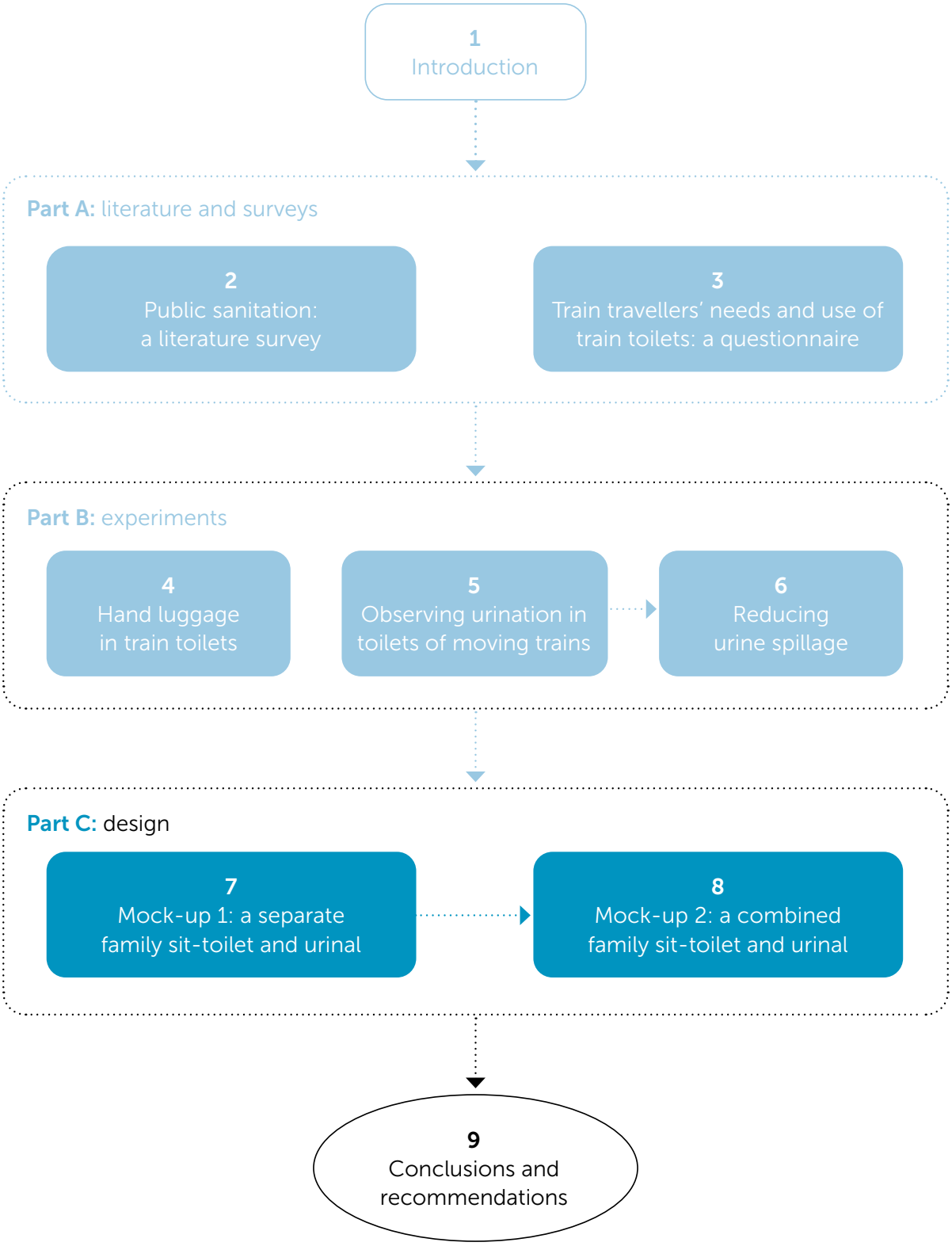
In part B we conducted experiments by setting up video recording facilities to conduct observational research in moving trains while participants used train toilets. In this way, we were able to explore the impact of both human factors and train movements on train toilet use. In another study, we designed a series of theoretical experiments to determine factors affecting spillage like the flow of urine, thereby excluding human and train-related factors.
In part B, we addressed the research question: **How does its usage affect train toilet hygiene?**

In chapter 4 we show that adequate storage facilities for hand luggage in train toilets would improve train toilet accessibility, reducing the barrier to visiting train toilets. Train travellers treated their hand luggage in train toilets as an equivalent of their bodies as they kept a large physical distance (P), between their hand luggage and the dirty locations, i.e., they tried to store their luggage far away from the toilet bowl and the floor. We observed that they most commonly used their bodies for storing luggage.

Subsequently, in chapter 5, we observed the physical distance (P) between human body and the toilet bowl when using the toilet, i.e., the distance that the urine stream needs to bridge. In chapter 6, we analysed this further.

A urinal reduces the physical distance (P) because the toilet is brought closer to the user's body, leading to less spillage, thereby enhancing hygiene. Thus, we recommend that a urinal is added to the train toilet to improve hygiene. In addition, to further reduce the physical distance (P), men can be encouraged to move one step closer to the urinal when urinating.

The findings and knowledge resulting from part B provided input for the design phase reported in part C of this thesis – an evaluation of the train toilet mock-ups.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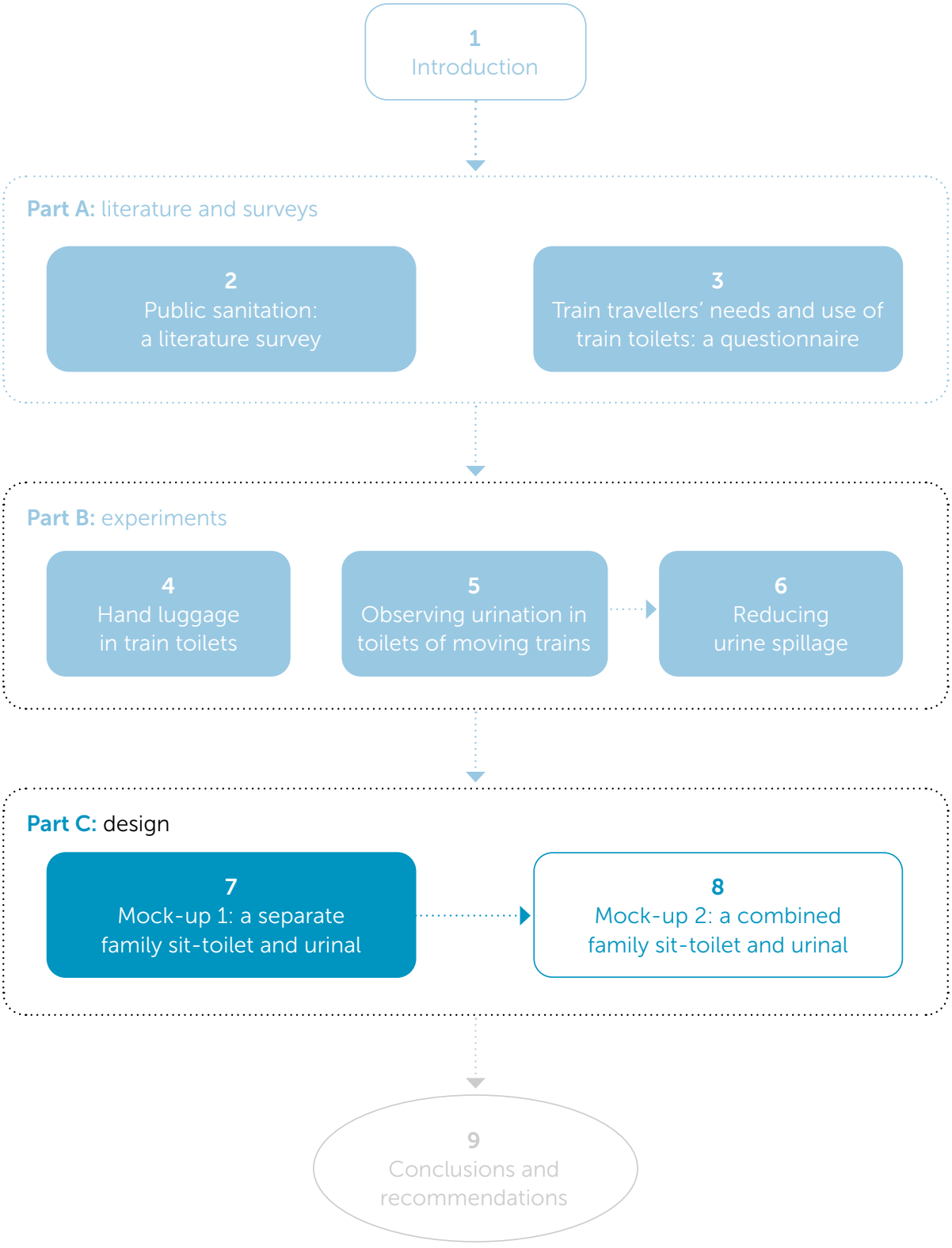
Part C: design

Introduction

In part C, the third and final section of our research project, we describe the design of the hygienic train toilet and the test of two mock-up train toilets.

In part B, we conducted observational research in moving trains to answer the question, 'How does its usage affect train toilet hygiene?' By observing the physical distance (P) between the body and the toilet bowl (chapter 5), we found that a urinal reduced the P, enhancing hygiene. This led to the recommendation that a urinal be added to the train toilet.

Part C answers the research question: **What are the implications for design of a hygienic train toilet?**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Chapter 7
Mock-up 1: a separate family sit-toilet and urinal

7.1 Introduction

In mock-up 1, the focus is on different toilet usage and makes a distinction in toilet posture. Therefore, it is a split design that has a separate sitting and standing zone in the form of a family sit-toilet and urinal. In this chapter we discuss the design and assessments of a full scale toilet-mock-up 1 with 26 participants. In particular, we observed and questioned the ergonomic needs of the different users by asking them whether the design and its elements were appropriate and usable. In addition, users assessed the different elements of mock-up 1 to answer the research question: **RQ C1: What are the implications for design through mock-up testing 1?**

In section 7.2, we introduce the mock-up 1 design. Section 7.3 describes the method of observational research with cameras and 26 different participants. Section 7.4 presents the results of the assessment of both the family sit-toilet and urinal. Section 7.5 discusses the results, and in section 7.6 we present our conclusions from the mock-up assessment and the resulting implications for design to improve the hygiene of a train toilet.

7.2 Design of mock-up 1

The design of mock-up 1 presents a train toilet as a unit, but consists of two separate mock-ups of a family sit-toilet and urinal. The design aim was to reduce the physical distance between the human body and the toilet (P) when the toilet is used. The family sit-toilet design encourages usage in a seated position, whereas it discourages standing urination which is facilitated by the design of a separate urinal. Mock-up 1 was designed to be usable and accessible for everyone able to travel by train.

7.2.1 Family sit-toilet

Figure 7.1a exterior and 7.1b interior of mock-up 1: family sit-toilet module

The family sit-toilet is suitable for everyone who uses toilets in sitting or hovering positions, i.e., women, men, children, and people who use mobility aids, such as wheelchairs, rollators, and strollers (Greed 2003; Anthony and Dufresne 2007; Molenbroek and De Bruin 2011a; University of Cambridge 2017; DTO 2018; BTA 2019; WTO 2019). It is a spacious, wheelchair-accessible train toilet. In general, all users benefit from the extra space. The respondents to the chapter 3 questionnaire regularly complained about the small size of Dutch train toilets. Mock-up 1 encourages users to sit down as this posture prevents urine spillage and therefore improves hygiene, as concluded in chapter 5.

The toilet design included the following facilities: child platforms, a special toilet seat, a facility to pre-clean the toilet seat, and horizontal and vertical support bars to support people when seated and more specifically, women when hovering. The support bars are also designed to hang up hand luggage, including coats and handbags, based on the findings presented in chapter 4. Mirrors are placed to make users aware of their toilet usage, for example a mirror was placed above the sit-toilet based on the assumption that men would be discouraged from standing urination by their reflection, and thereby encouraging them to sit down (figure 7.1b). Furthermore, a (sanitary) waste bin was positioned underneath the washbasin, which was placed at the height of 800 mm (figures 7.4b and 7.4c) as indicated by Greed (2003). Hence, young children can independently use both the washbasin and the toilet by using platforms, without their guardians having to lift them.

Lastly, the family sit-toilet was equipped with a baby changing table, so that the toilet encourages family use in privacy (figures 7.4,c and d) thereby improving the usability of the train sit-toilet for the different types of users.

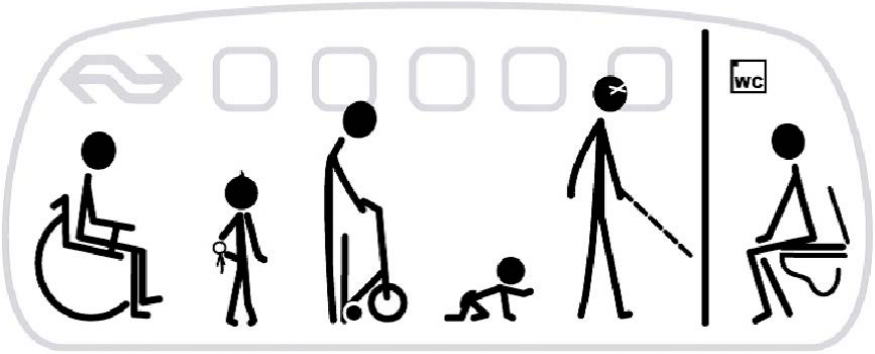


Figure 7.2 Including specific user groups in the design: Inclusive design of the train toilet
Graphic design: Tommy Louts

Special toilet seat

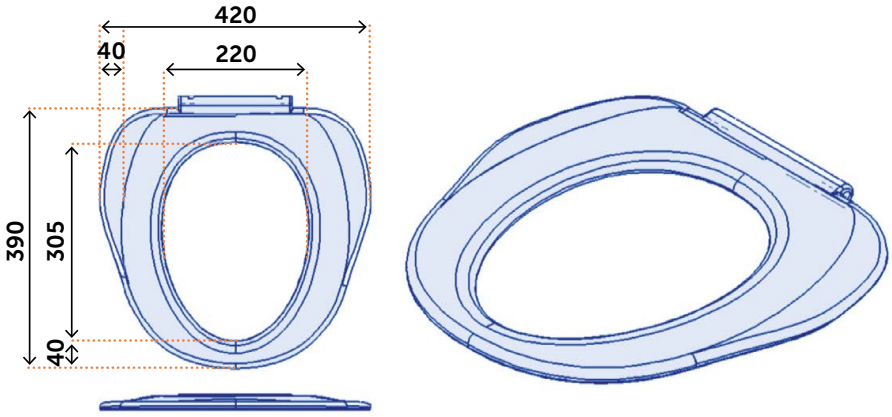


Figure 7.3 Extra broad toilet seat with larger opening (mm) compared to current toilet seat
Rendering and design: Jan van Dijk

The sit-toilet has a special extra-broad toilet seat with a larger opening, figure 7.3. The broad rim supports both wheelchair users with transfer, and helps young children to climb onto the sit-toilet. This seat with an extra grip replaces a support bar mounted on the wall next to the toilet, making the wall smoother and easier to clean. In addition, the broader seat provides more support, and the larger opening of the seat creates extra space that prevents the penis from touching the front of the seat while sitting, so that men can *sit* comfortably (McClelland and Ward 1982; van Dijk 2010). Moreover, based on observations in chapter 5 where male participants (n=28) all raised the toilet seat to urinate while standing, the toilet seat is fixed to the toilet bowl to prevent the toilet seat from being raised. The design of the family sit-toilet thereby aims to stimulate seated toilet usage.

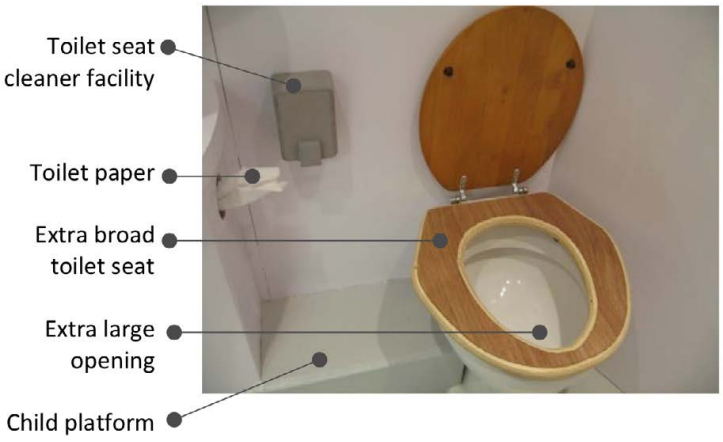


Figure 7.4a Sit-toilet

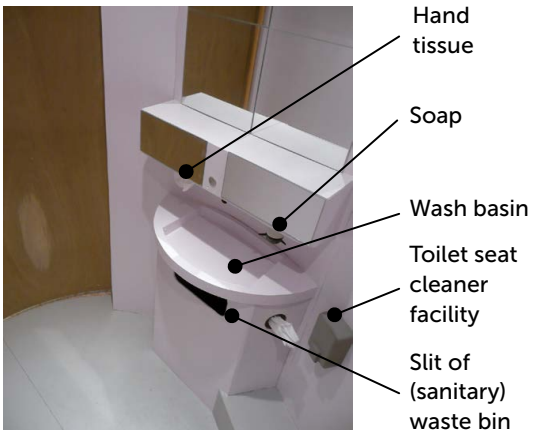


Figure 7.4b Wash basin

Figure 7.4c Interior family sit-toilet

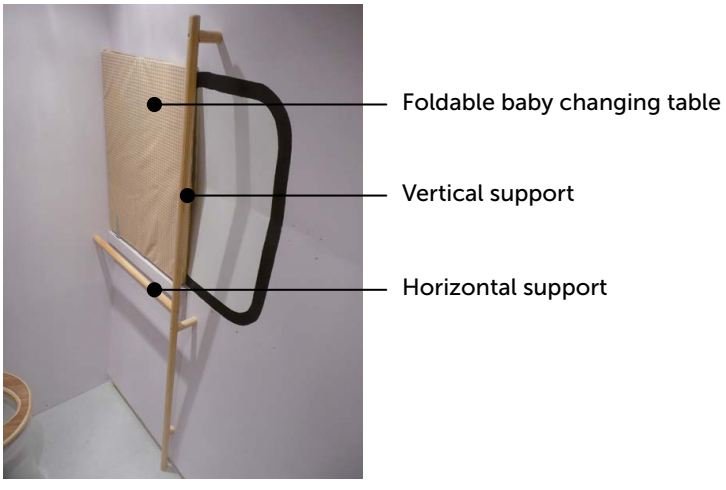


Figure 7.4d Foldable baby changing table and horizontal and vertical support

Figure 7.4 Elements of the family sit-toilet

7.2.2 Urinal

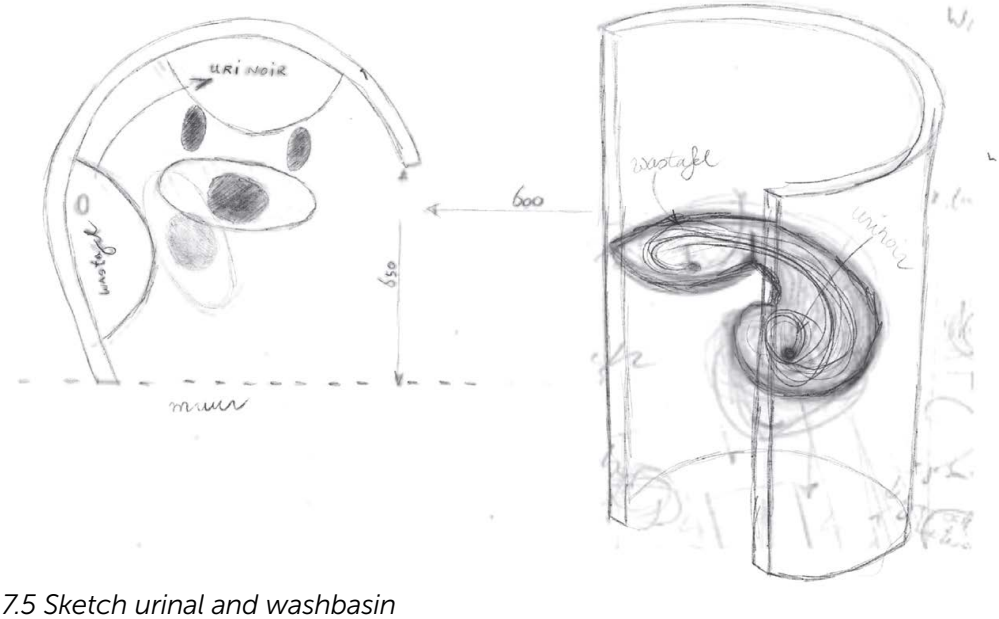


Figure 7.5 Sketch urinal and washbasin

Figure 7.6a. exterior and 7.6b Interior of mock-up 1: urinal module

Mock-up 1 facilitates standing urination by including a separate urinal. Accordingly, it distinguishes urination from defecation; faeces are not excreted into the environment. Since faeces are perceived as dirtier than urine, (Curtis and Biran 1998; van der Geest 2007; Pickering 2010), the environment is considered cleaner by separating urine from faeces, thus reducing the mental distance (M) between dirt.

The starting point of this design was to encourage users to wash their hands after using a urinal to demonstrate socially desirable behaviour. The semi-transparent element and partially open space (figure 7.6) can result in the effect of being watched (Bateson, Nettle, and Roberts 2006). Observations in chapter 5 showed that participants did not wash their hands even though they knew they were being observed.

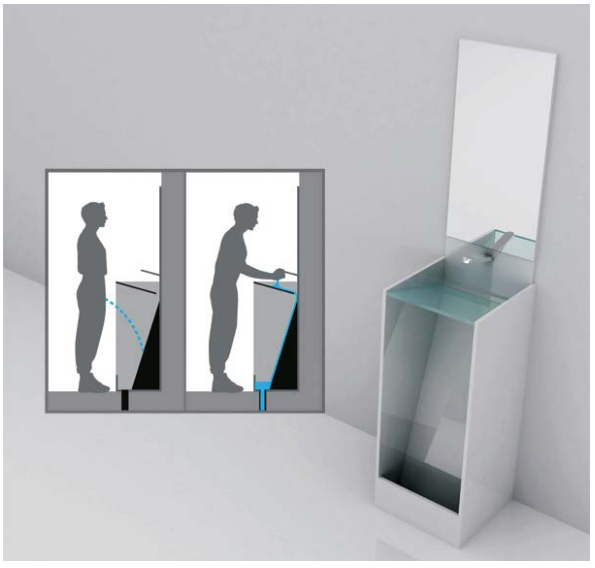


Figure 7.7 Concept by Yeongwoo Kim (2010)

The design of the train urinal and washbasin combination expresses both an interdependency and a conflicting function of both artefacts. A man or boy physically experiences the mutual distinction by taking a step to go to the washbasin after using the urinal. Our design contrasts with Joris Cijffer's and Yeongwoo Kim's concepts, see

figure 7.7, who placed the washbasin above the urinal (van Lier 1996; Volkskrant 1997; Seth 2010), whereby the urinal and washbasin were too close together. In the mock-up 1 design, the author (Loth) adds this 'physical' intervention so that users perceive the different functions of urinal and washbasin. Urinating in a urinal is a practice to clean the internal body, but urine is perceived as 'dirty' (Douglas 1966; Curtis and Biran 1998; Lea 2001); this in contrast to a washbasin used to clean the external body (hands) that people consider as clean. In brief, *a physical distance* was designed to represent the contrasting functions of a 'dirty' urinal versus a 'clean' washbasin, while both artefacts are interconnected.

Furthermore, the design is a touch-free zone; a male user does not need to touch a door handle, button, or tap. Hand wash and urinal are combined in one product to stimulate hygienic behaviour. When the user steps back from the urinal, a sensor activates the water's discharge from the tap. Subsequently, the sound of water flowing from the washbasin into the urinal reminds the user to wash his hands. The resulting 'grey' water concurrently flushes the urinal, thereby saving water (Loth 2011, 2013).

The range of facilities near the urinal and washbasin combination is simple: a 'waterfall' faucet, a soap dispenser, and an electric hand dryer. Due to a hand dryer's presence, it is assumed that a waste bin is not necessary. The absence of paper towels creates a cleaner impression as they cannot be deposited on the floor. The space is partially open (figure 7.6a); there is no door, while the visitors' privacy is guaranteed.

Figure 7.8 The design of the author is based on 'the Krul' designed by Johan van der Mey.

The exterior design of mock-up 1 is a modern version of the current Amsterdam street urinal 'the Krul' designed by the architect Johan van der Mey (1878-1949), figure 7.8

(Jongbloed and Sloot 2006; Kleijne 2008; Dekkers 2014). Lastly, the urinal's circular exterior roughly corresponds to that of the family sit-toilet, see figures 7.1 and 7.6. In this way, despite a different design approach translated into separate modules, the design elements still belong together because they both fulfil a train toilet's function.

Van den Meiracker (2011) used the same idea of a semi-open space and created a 'masculine' design. Moreover, his graduation project showed that the urinal should be placed at an angle of 60 degrees horizontally relative to the train's longitudinal axis. This supports stability during urination while the train shakes (figure 7.9), as described in chapter 6, sections 6.13-6.18. Furthermore, the washbasin was fixed outside the partition wall instead of inside as he assumed that 'social control' would encourage users to wash their hands after using the urinal. An additional benefit is that it can be used by all train passengers as they can wash their hands at any time, without being in the toilet. Randles (2018) also created a separate washbasin area outside an aircraft toilet, both to reduce visit time inside the toilet and, if possible, to reduce queues outside, and save space inside. He also reasoned that the social control element would encourage people to wash their hands.

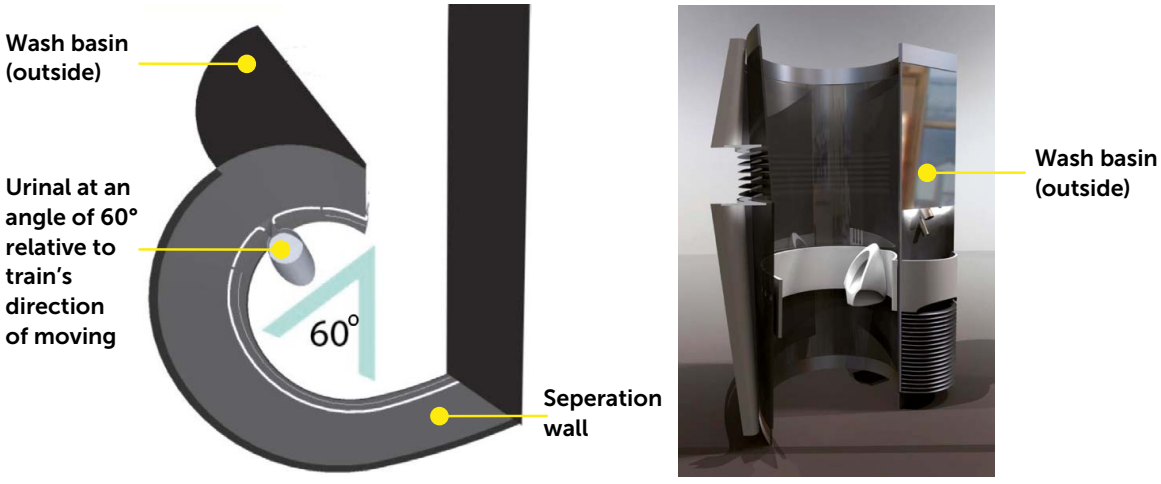


Figure 7.9 Urinal van den Meiracker (2011): a washbasin outside and a urinal inside at an angle of 60° for optimal posture stability

Discussion: Placing the washbasin outside the train toilet environment

The possibility of placing the washbasin outside the toilet area allows passengers who travel by train or plane to wash their hands without entering the toilet, as suggested by van den Meiracker (2011) and Randles (2018). In public toilet environments, a similar situation is found; the washbasins are also located outside the toilet cubicle/urinal area, but in this case, they are still within the public toilet environment.

People are generally aware that they need to wash their hands after using (public) toilets to enhance personal hygiene (Larson 1988; Aiello and Larson 2002). However, it remains a weak link in the toilet ritual (Judah et al. 2010), especially if the wash facility is 'hidden'

after closing the door. Our observations in chapter 5 reinforce this, as some participants skipped hand washing.

However, we expected that toilet users would be more likely to skip handwashing if the washbasin was placed outside the train toilet environment, despite possible social pressure from fellow passengers. Firstly, the effect of social control is limited, since train passengers are not concerned about whether fellow travellers wash their hands. Secondly, travellers who have just used the toilet finish their toilet ritual by grabbing their hand luggage and walking away. In this way, they close the train toilet door and leave the toilet's atmosphere and ensuing toilet rituals. Thus, they would not let themselves be interrupted by washing their hands outside, because they have already completed their toilet ritual. Once they enter the train's balcony, they are among fellow train travellers.

This contrasts with a public toilet environment where washbasins are separated from the toilets and the toilet ritual is prolonged after people leave the urinal/toilet cubicle. Subsequently, they leave this area through the door.

To conclude, it is necessary to place the washbasin within the train toilet environment to integrate it into the toilet ritual and encourage handwashing after use. An ideal situation would be if both options were available - a washbasin inside the train toilet area for toilet users and one outside for other passengers to wash their hands.

7.3 Method mock-up 1 testing

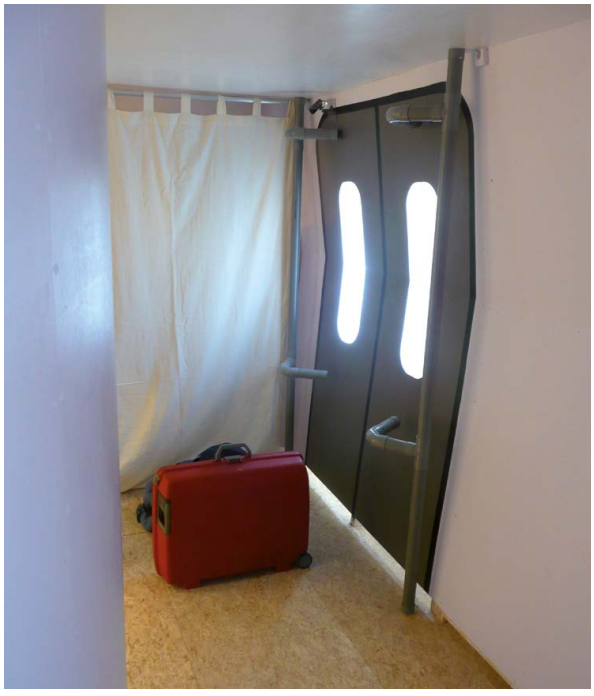


Figure 7.10 Impression train toilet lab

We created a 'toilet lab' to test the mock-up with participants, see appendix A.7.1. Students built mock-up 1 which included two separate full-size train toilet modules. This mock-up 1 was assessed by 26 participants who 'used' the toilet to answer research question: **RQ C1: What are the implications for design of mock-up testing 1?**

Participants and procedure

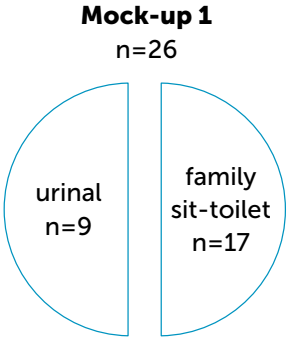


Figure 7.11 Mock-up 1 procedure

Participants

Toilet \ Participant	Wheelchair user	Rollator user	Young child girl	Young child boy	Male	Female	Total number
Family sit-toilet	4	2	2	-	3	6	**17**
Urinal	-	-	-	3	6	-	**9**
Total number of participants in mock-up 1	**4**	**2**	**2**	**3**	**9**	**6**	**26**

Table 7.1 Participants mock-up 1

Mock-up 1 testing consisted of two modules and involved 26 participants. They varied in age (3-68 years), gender, and physical capacity, including older adults, rollator users (two), wheelchair users (four), and young children, see table 7.1. They were recorded by four cameras and interviewed during their 'dry' usage of a train toilet module, i.e. they kept their clothes on. Because of the personal nature of a toilet visit, male participants were interviewed by a man, and female users by a woman (Molenbroek and De Bruin 2011b, 43). This with the aim of preventing a participant from feeling uncomfortable when discussing intimate matters such as wiping. The observations were recorded and then reviewed and analysed. Saskia Hoeksema drew the outlines of the participants in part C.

The location of the mock-up test

The mock-up testing was conducted in two steps in two different rooms located close together in the same corridor.

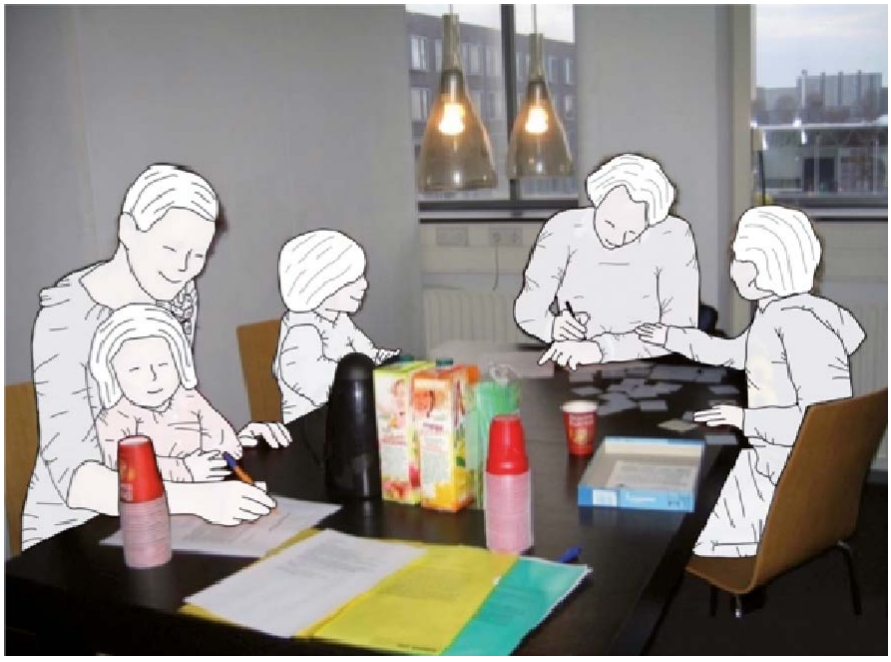


Figure 7.12 Hospitality lab

Participants were received and informed about the research in the 'hospitality lab'. The lab had a relaxed and homely ambiance and included a television, a couch, and warm lighting to make the participants feel at ease (figure 7.12). A researcher ran through the research protocol, explaining the procedure that participants remained fully clothed during the 'usage' of the toilet while being audio-video recorded, and that their free will was leading. The researcher emphasised that the participant could not do anything 'wrong', that they could stop whenever they wanted, and that they could disallow the use of observations. Lastly, they were asked for permission.

Accordingly, the consent form was signed in which they agreed to audio-video recordings being made while the researchers guaranteed their privacy, see appendix A.7.2 for the informed consent form. In addition, they also signed a non-disclosure agreement to exclude issues relating to the urinal's patent application (appendix A.7.2.3). We encountered no issues with signing of the consent form in contrast to other research (Rauhala 2011).

Finally, they were asked if they would use a urinal or a sit-toilet to urinate in a train toilet (both modules were set up in the toilet laboratory with a curtain in between). For example, if a participant selected the sit-toilet for urination, a researcher then covered the other mock-up module in this case the urinal, with a curtain, see figure 7.13.

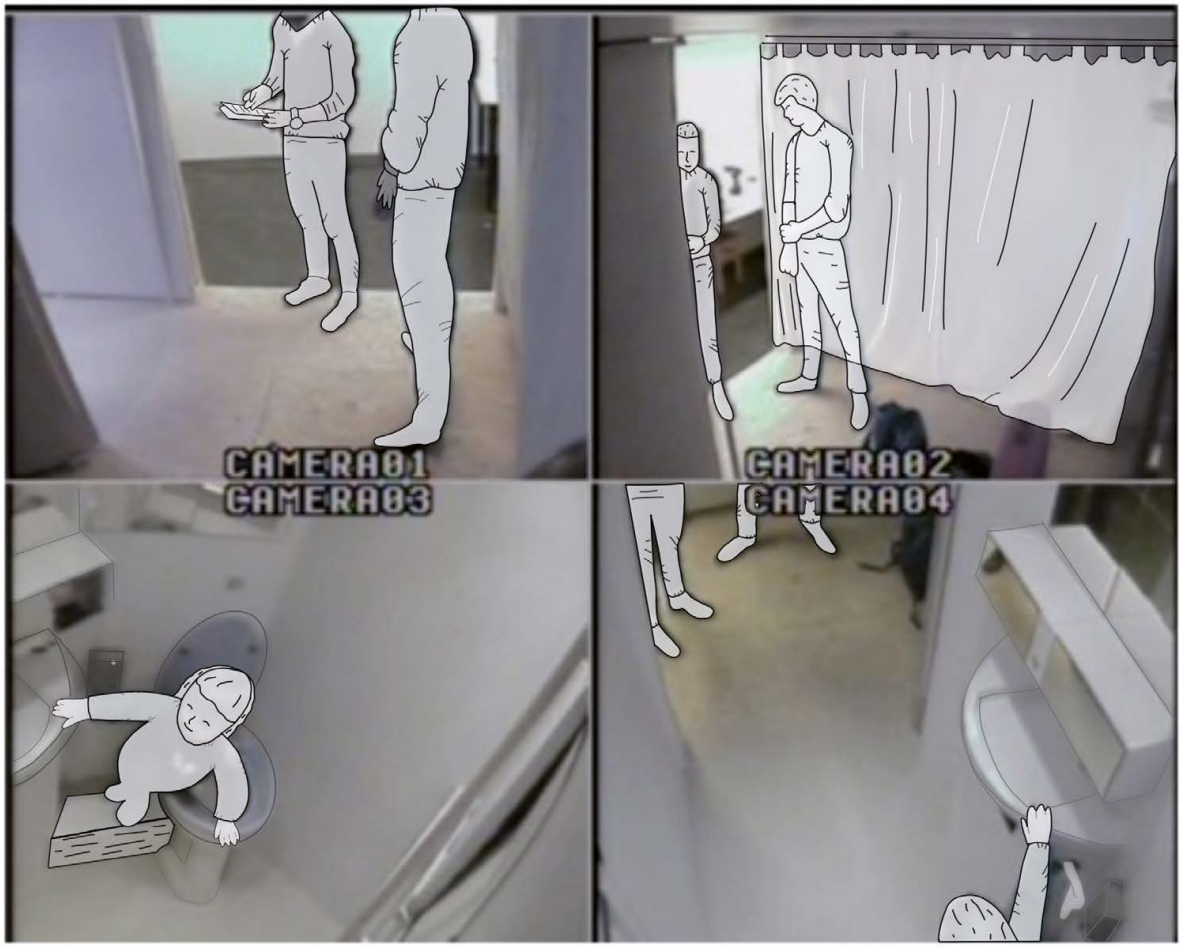


Figure 7.13 Mock-up 1 testing in family sit-toilet module with a young child and her father. The train urinal was covered with a curtain and therefore not visible for the participant(s). The child used the platform to climb on the toilet.

Subsequently, a researcher guided the participant(s) to the room where the mock-up test took place. Prior to the test, a researcher closed the curtain that hung between the two separate modules, so that only the chosen mock-up module, either the urinal or the family toilet, was visible and usable for the participant, see figure 7.13. A researcher asked the participant to use this train toilet module in the usual way, fully clothed.

During the 'dry' use of the train toilet module, the researcher interviewed the participant about toilet behaviour and usage. The questionnaire (see appendix A.7.3) addressed the different elements in the toilet, such as whether there was sufficient space. At the end of the survey, the participant received a 10 Euro gift voucher as a token of gratitude and compensation.

To summarise, the mock-up test was carried out in two steps. First, in the hospitality lab, the procedure was introduced and explained. Subsequently, the actual mock-up test was performed in the chosen module of either the urinal or the family sit-toilet.

7.4 Results

The results of the observations were split in using either the family sit-toilet or the urinal.

7.4.1 Observations family sit-toilet

Support

Figure 7.14 A female participant uses the vertical bar in front of the toilet while hovering above the seat

Observations showed that participants and especially wheelchair users and young children looked for support on the left side of the family sit-toilet as they sat down and stood up from the seat. As suggested by Buzink and Dekker (Buzink et al. 2004; Dekker et al. 2007; Buzink et al. 2011; Dekker, Buzink, and Molenbroek 2011), women used the vertical bar placed in front of the sit-toilet when they hovered above the seat, see figure 7.14. European Union 2007 specifies the outside diameter of the support options between 30 to 40 mm. A maximum of the outside cylindrical grip of 32 mm, particularly for older aduslts population, is advised by (Dam-Huisman et al. 2015).

Figure 7.15 Observational notes

Toilet seat cleaner, sanitary waste, and washbasin

In the observations, participants did not understand the 'seat cleaning' facility, see figure 7.15. When asked about this facility, one participant indicated that she had wondered what it was. Thus, the object raised questions among the participants and had to be explained. The three young children mainly used it as a support aid. When asking specific questions about the facility, participants were positive and said they would like to make use of it.

Several women (2 of 6) admitted that they sometimes throw hygiene products such as tampons into the toilet. This could block the (delicate) train toilet flushing system.

The washbasin was positioned at a low height of 800 mm above the floor. We observed that children and wheelchair users could properly use the washbasin. However, some large participants had to bend-over to use it. Our observations were supported by questionnaire answers.

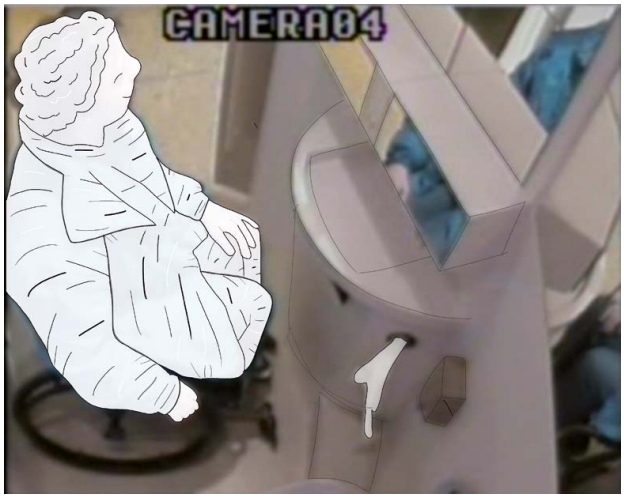


Figure 7.16 User of a small wheelchair could make a complete turn in the mock-up

Specific needs-users

We observed that one of the wheelchair users could make a full turn with his, admittedly, small wheelchair, see figure 7.16, while the others had difficulty turning. Two (wheelchair) users experienced the space as being confined. All the young children used the platform to climb onto the toilet, see figures 7.13 and 7.15.

Our observations showed that with regards to the baby changing table, a father closed the toilet lid so that his daughter could stand on the toilet (lid) near her 'sister or brother' (in reality it was a puppet), while the father changed its nappy. A woman was worried that the baby's head could fall in the gap next to the baby-changing table, see figure 7.4c, section 7.2.1. Table 7.2 shows the results of the family sit-toilet questionnaire.

7.4.2 Family sit-toilet questionnaire findings

The new shape of the toilet seat scored a 6.9 on a scale from 1-10 (1=very bad, 10=very good). However, we were unable to compare this with that of a current toilet seat. The toilet seat was fixed to the pot, nevertheless, some participants tried to lift it. Opinions about a wooden toilet seat varied from 'dirty', 'sharp', 'unhygienic' to 'cosy', 'warm' and 'firm'. The questionnaire results (table 7.2) show that the mock-up of the family sit-toilet provided sufficient space with an average rating of 7.3 on a scale from 1-10 (1=small, 10=large). However, wheelchair users rated the space with 5.7.

FAMILY SIT TOILET F: Female M: Male W: Wheelchair R: Rollator	Rating and remarks toilet seat: 1: very bad- 10: very good	Toilet seat inviting to sitdown? 1. yes 2. no 3. ?	Rating and remarks space: 1: too limited- 10: too large	Height and remarks washbasin: 1. too low 2. good 3. too high 4. no opinion	Remarks Female hygiene
1F	10. Good sitting, enough legroom	2. No, always hover	10. Too large	1. Too low, height acceptable	Tampons, throwing in toilet
2F	-, No opinion, I always hover	2. No	9. Large for a train toilet, not necessary	2. Good, cannot see the tap	Not applicable
3F	7. Good support	3. I always sit down, same as current toilet seats	8. Very large	1. Too low, cannot see my hands	Tampons and sanitary pads
4F	7.5. Good sitting	1.Yes, habit to sit down	9. Satisfied, comfortable	1. Too low. Low height, no problem	Tampons, not in train, afraid for infection. Thin sanitary pads
5F	8. Not bad, normal toilet seat		7. Perfect, just right	2. Good, cannot see my hands.	Tampon, sanitary pads. If there is not a small plastic bag available, I throw it in the toilet
6F	6. Not special or remarkable	2. No	7. -	1. Too low, a little bit too low	Tampons
7M	8. Spacious in front. Wood feels warm	1. Yes, because it looks solid and firm	8.	2. Good. -	Not applicable
8M	7. Opening of toilet seat large enough	1.Yes, if it is clean Spray: 1. Yes, if there are no persistent stains on it.	8. -	1. Too low. -	Not applicable

12FW	3. Preference for plastic seat. Wood not hygienic	2. No, It looks poor Spray: earlier	2. -	2. Good. -	Not applicable
13FW	3. Don't like the wooden material, Sharp, no support, no bars	2. No	1. Space is too small, nearly nothing fits in it	Too low, cannot see the tap	Sanitary pads. Difficult to take of the strip and find the waste bin
14FW	7. Normal, as at home	1.Yes, I always sit down, safer	7. -	2. Good -	Not applicable
15MW	7. Common toilet seat	1. Yes, different material, it gives something extra, better than plastic	5. Just good, can even make a whole turn	2. Good, Good height	Not applicable
16MW	8. Preference for plastic	1. Yes, a man needs to open the toilet seat Spray: Important	8-9. Too large, young people can go together	2.Good, reachable while in wheel-chair.	Not applicable
17MR	8-9. Fine	1. Yes, in the train always standing posture	10. Pleasant size. Enough space for rollator. Standing up goes well	1. Too low, Appropriate for the children	Not applicable
18FR	6. Moderate	1. Yes, I always sit	6.5.	2. Good	Not applicable

Table 7.2 Questionnaires of female, male, wheelchair and rollator users in the mock-up of the family sit-toilet

7.4.3 Train urinal observations and questionnaire findings

Two young boys preferred to use the urinal, which was also encouraged by their mothers, although the small boys could not properly reach the urinal due to its height. We had expected them to prefer the sit-toilet for urinating because of their experience at home and their length. Table 7.3 summarises the results of the train urinal questionnaire.

TRAIN URINAL M: Male B: Boy	Height urinal: 1. too low 2. good 3. too high 4. no opinion	Height wash-basin: 1. too low 2. good 3. too high 4. no opinion	Hand-washing suitable 1. Yes 2. No	Hand-washing under-standable? 1. Yes 2. No	Encouraging Hand-washing? 1. Yes 2. No	Enough privacy? 1. Yes 2. No 3. No opinion	Providing enough safety? 1. Yes 2. No 3. No opinion	Rating passage 1: too limited 10: too large
19M	2. Good	2. Good	1.Yes, basin large enough	1. Yes	1. Yes	1. Yes	1. Yes	8
20M	1. Too low, Little bit,(body-length 1.86)	2. Good	1.Yes	1. Yes	1.Yes, Rewarding by flushing	1. Yes, Perhaps sometimes problematic	1. Yes	10 Too large
21M	2. Good	2. Good	2.No, Washbasin too close to urinal	1. Yes	1.Yes, Seems cleaner 2.No, don't like the combination (clean and dirty)	1.Yes, space offers enough privacy 2. No, location urinal offers not enough privacy	1.Yes, not afraid	5 Little bit too limited
22M	2. Good	2.Good, Tap needs to be lower	1.Yes, Tap too high	1. Yes	1. Yes, When turning, you pass the washbasin	1.Yes, Sure	1. Yes, Unless someone intentionally enters	9
23B (10 years)	3. Too high. On tiptoes reachable	2.Good	2. No, sleeve becomes wet	-	-	2. No, I can hear the footsteps	Yes and no, afraid that someone will enter	5
24B (12 years)	2. Good	2.Good	1.Yes, Tap too much out	1. Yes, Good for the environ-ment	1. Yes, Due to the flushing	2. No, People come too close by	1. Yes 2. No, If it's full with other passengers	8
25B (14 years)	2. Good	2.Good	1. Yes, Enough space.	1. Yes	2. No, No difference	1. Yes	1. Yes	6
26M	2. Good	2. Good, Higher than normal, but good	1. Yes	1. Yes	Always wash my hands, perhaps yes	1. Yes, semi-trans-parency works well	1. Yes, more sense of supervision	6-7. Just good

Table 7.3 Questionnaires of 3 boys and 5 men in the mock-up testing of the train urinal

7.5 Discussion

The solution to improving train toilet hygiene is to add a urinal. A urinal reduces the mental distance between dirt (M) because the related urine backsplash is perceived as less dirt; there is no association with faeces/defecation. In addition, a urinal reduces the physical distance to the bowl (P) as men use the toilet in a standing position. This affects people's perception of the toilet seat of a sit-toilet; it remains cleaner. Furthermore, a family sit-toilet is introduced for people who would prefer to sit, including men who prefer to use the toilet while seated. In a family sit-toilet designed for seated usage, more women could be persuaded to sit on the toilet seat, breaking the vicious circle of maintaining an increasing physical distance from the toilet (Kira 1976). Finally, seated usage prevents urine spillage and keeps the seat dry (Loth and Molenbroek 2011).

The family sit-toilet is 'inclusively' designed and incorporates a number of adjustments: it includes children's platforms, a baby changing table, enough space for wheelchair users to manoeuvre, and extra bars to be able to remain stable in a moving train. Finally, we added an extra broad toilet seat for support when sitting and in the transfer to the toilet (van Dijk 2010; Molenbroek and De Bruin 2011b; University of Cambridge 2017: www.inclusivedesigntoolkit.com).

Train passengers assessed this split mock-up positively; however, we noted a number of shortcomings; these are discussed in section 7.5.1.

7.5.1 Study limitations

Participants

A variety of participants, corresponding to the diversity of train passengers, was involved in these mock-up experiments; however, there were too few participants for specific user groups. For example, only two rollator users and two young girls used the family sit-toilet, and we cannot therefore generalise their results to a whole group. However, for user research, this minimum number of rollator users and young girls indicated a direction of use (Kanis and Arisz 2000).

Furthermore, the young girls could not answer the questionnaire, so their results are not included in table 7.2. Their observations were used, and for further research, we recommend involving more representative numbers for the user groups.

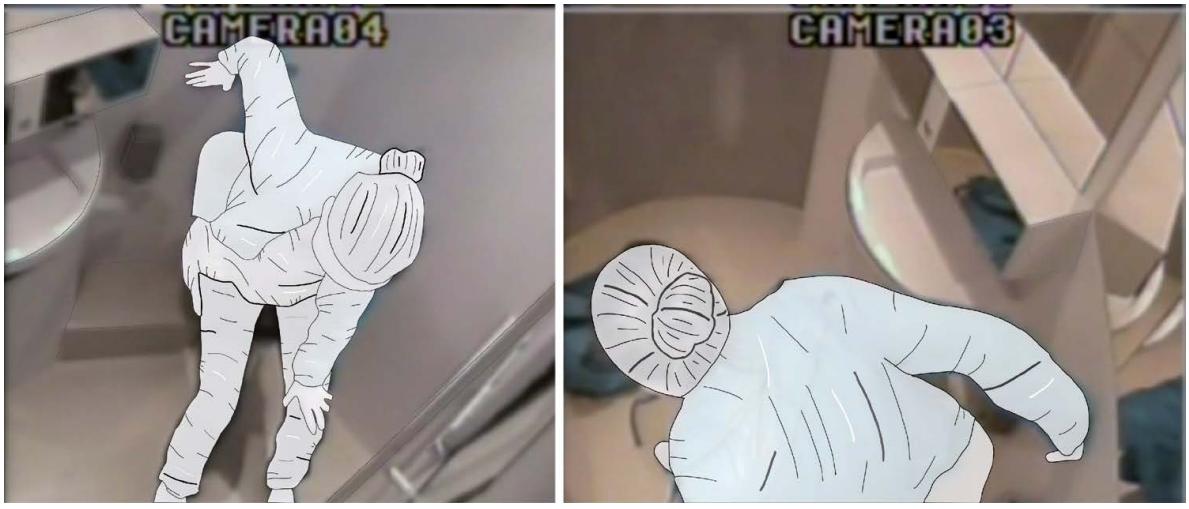


Figure 7.17 Female participant who used the wall behind her to support while adopting a hovering posture

Cleanliness

The participants were asked to assess the mock up on its ergonomics and the design itself, not on its cleanliness. However, the mock-up's location may have positively influenced participant evaluations; it was located in a laboratory environment at TU Delft. Moreover, participants were asked to retain clothing and mimic toilet usage actions, therefore, the mock-up was not dirty. In terms of usage, a female participant hovered over the toilet seat while using the wall at the back for support (figure 7.17). This may indicate that the participants showed their actual usage: despite the clean, unused condition, they could also sit on the unused, clean toilet seat. In brief, it is difficult to determine to what extent the static, clean and unused condition of the mock-ups affected the observations and assessments.

Rating scales

Furthermore, to minimise a positive influence of rating scores (*the Hawthorne Effect*), we chose not to assess the full mock-up because participants may have given a more positive score to please the researcher(s). Accordingly, the assessment was measured indirectly by scoring key elements of the mock-up, including the toilet seat, the family sit-toilet space, and the urinal passage. Nonetheless, some elements were rated poorly, so a positive influence was not demonstrated (Franke and Kaul 1978; Kumar 2005).

The rating scales (1-10) were understandable and did not cause ambiguity, however some participants interpreted the scales differently. For example, one participant gave a five for space, (15MW, table 7.2), while saying it was just perfect, not too small and not too large. We defined a five as an insufficient score, while the participant seemed to mean the opposite. Thus, this specific case had a negative effect on the average rating of the space, whereas we can assume that it was meant to be positive. On the other hand, one participant gave the toilet seat a 10, (1F, table 7.2). When asked to explain

this high score, she said that she had enough legroom, that it was good, and the sitting went well.

Another interesting example was the low scores given to interior space by two of the five wheelchair users (12 FW & 13FW, table 7.2). The observations showed that they were able to manoeuvre their wheelchairs sufficiently, but they were unable to make a turn. The interior space of the family sit-toilet mock-up is larger than current train toilets; some respondents rated the internal space as large.

7.5.2 Discussion design of mock-up 1; the family sit-toilet and urinal

In this section, we discuss the individual design features of the family sit-toilet followed by examining the design of the complete mock-up 1.

Special toilet seat

Three male participants commented that the larger opening of the toilet seat (compared to current standard NS toilets) offered more seating comfort (table 7.2). On the other hand, one female participant specifically mentioned that it was too large and that her buttocks fell through the opening. The extra broad edge at the back and side of the toilet seat provided extra support for the transfer of wheelchair users and young children and is therefore recommended. However, the larger opening needs to be further researched with more female participants.

Moreover, we cannot conclude that this new type of toilet seat will encourage the user to sit on it, although one participant explicitly indicated that he would because of the wide rim. The mock up was made of wood and poorly finished, which may have prevented people from sitting down. A more realistic toilet seat needs to be tested to be able to draw strong conclusions.

Option to clean toilet seat

We expect people to be more willing to sit on the toilet seat if they can clean the toilet seat in advance. However, this was not clear from the observations and we had to specifically ask for it in the questionnaires; only then were particpants positive about it, but why would they be negative? Because of the unclear reaction about the possibility to clean the toilet seat, further research on this is advisable.

Support options and sanitary waste bin

From the observations and the questionnaires, we conclude that an additional support bar on the left side of the toilet is necessary: the majority of participants expected an extra support bar at this spot. Another support feature, the extra broad rim of the toilet seat at the back, may form an alternative to an extra support bar on the wall.

In addition to a horizontal bar, we recommend installing a vertical bar in front of the user (figure 7.14, section, 7.4.1). This would provide support for women by reducing the physical distance to the bowl when adopting a hovering posture. In general, horizontal and vertical bars enhance stability; specifically for older adults who have a higher risk of falling in a moving train (Buzink et al. 2006, Molenbroek et al., 2011).

An extra sanitary waste bin near the toilet bowl is recommended to prevent blockage of the (delicate) train toilet flush system, as some participants (two of six) admitted disposing hygiene products into 'the nearest bin', i.e., the toilet (Greed 2003; Williams 2009)

Train urinal

The male participants were positive about the design and that they could use a urinal. It was clear how to use the urinal, and they thought it would catch the urine properly. Furthermore, the semi-open separation wall with semi-transparent elements offered sufficient privacy, and the washbasin combination encouraged hand washing, (table 7.3), and figures 7.5, 7.6b.

By providing a hand dryer, the issue of tissue waste on the ground is minimised. Further research is needed to determine whether the alternative of an electric hand dryer instead of paper to dry hands is appreciated as a more hygienic experience.

Interestingly, some of the small boys also wanted to use the urinal, while we had assumed they would rather use a sit-toilet as they would at home. Therefore, a children's platform would be necessary for them to reach the urinal properly.

Overall discussion mock-up 1

In retrospect, the design focus of mock-up 1 was too narrow; it was mainly aimed at reducing the physical distance (P) between body and toilet. Mental and social distances were addressed, but mainly for male participants as the separate urinal reduces their mental distance from dirt (M). A urinal excludes the element of excrement (faeces), thereby the mental distance (M) to dirt is reduced.

The mock-up environment separates defecation from urination, reducing the psychological distance from dirt as faeces are perceived as being dirtier than urine. A separate urinal also prevents mingling between female and male users, reducing the large social distance with regard to toilet usage between the sexes (Barcan 2005). At the same time, it is partially open and improves contact with other train travellers. In other words, it makes the toilet less anonymous and reduces the social distance (S) between train travellers.

In the mock-up of the family sit-toilet, we created a slight reduction in anonymity or

social distance (S) by making an interaction with the users themselves through mirrors that could create a degree of awareness about their usage. For example, we included a mirror above the sit toilet to discourage male users from urinating in a sit-toilet in a standing position. We hypothesized that men do not want to be confronted by their reflection in the mirror while they urinate in standing position.

Figure 7.18 (Louts 2011):
A circular occupation light covers the floor to reduce sense of anonymity in the train toilet

In his 2011 thesis, Louts, a TUD, IDE Master's graduation student, tackled the anonymity issue in train toilets. He discovered the issue of the large social distance in the train toilet environment and designed several solutions to reduce this. Under the door, he equipped the floor with "a circular occupation light" that prolongs the "spatial transition" of the user through the door. In this way, the train toilet is more visibly connected to its surroundings and is therefore less isolated. This circle lights up as soon as the user opens the train toilet door so that the sense of anonymity can be reduced, see figure 7.18 (Louts 2011).

Furthermore, the inclusion of child elements shows that the family sit-toilet is used by children, thereby reducing the mental and social distances to the family sit-toilet (M,S <). Due to their innocence, children's dirt tolerance is lower than that of adults (van der Geest 2007). Furthermore, we provided additional facilities for storing hand luggage integrated with the support options.

In summary, mock-up 1 focused too much on reducing the physical distance (P<) between the human body and toilet by designing separate male and family domains

in the form of a standing and sitting environment. This increased the social distance (S) between the sexes, in contrast to the pursuit of gender neutrality in public toilets (Molotch and Noren 2010). However, Greed et al. (2018) are critical of the issue of gender neutral toilets (GNTs), as they do not benefit in terms of specific female privacy toilet needs (application of make-up, acts related to menstruation). Moreover, GNTs do not help women with the ongoing under-provision of public toilets (Greed, Bichard, and Ramster 2018; Greed 2019).

7.6 Conclusions

Based on our analysis of the observations and questionnaires, the usability of a split train toilet of both a family sit-toilet and urinal is adequate for the various users. The 26 participants indirectly assessed mock-up 1 with an average rating of 7.1 on a scale of 0-10 (1= very bad, 10= very good). The space in the family sit toilet scored a 7.3 while the toilet seat scored an average of 6.9. The urinal's passage scored a 7.2. Based on these findings, we made improvements to the design, and tested these using a new design: mock-up 2. The results of these tests are presented in chapter 8.

We provide a summary of the main findings that answer the chapter 7 research question:
RQ C1: what are the implications for design through mock-up testing 1?

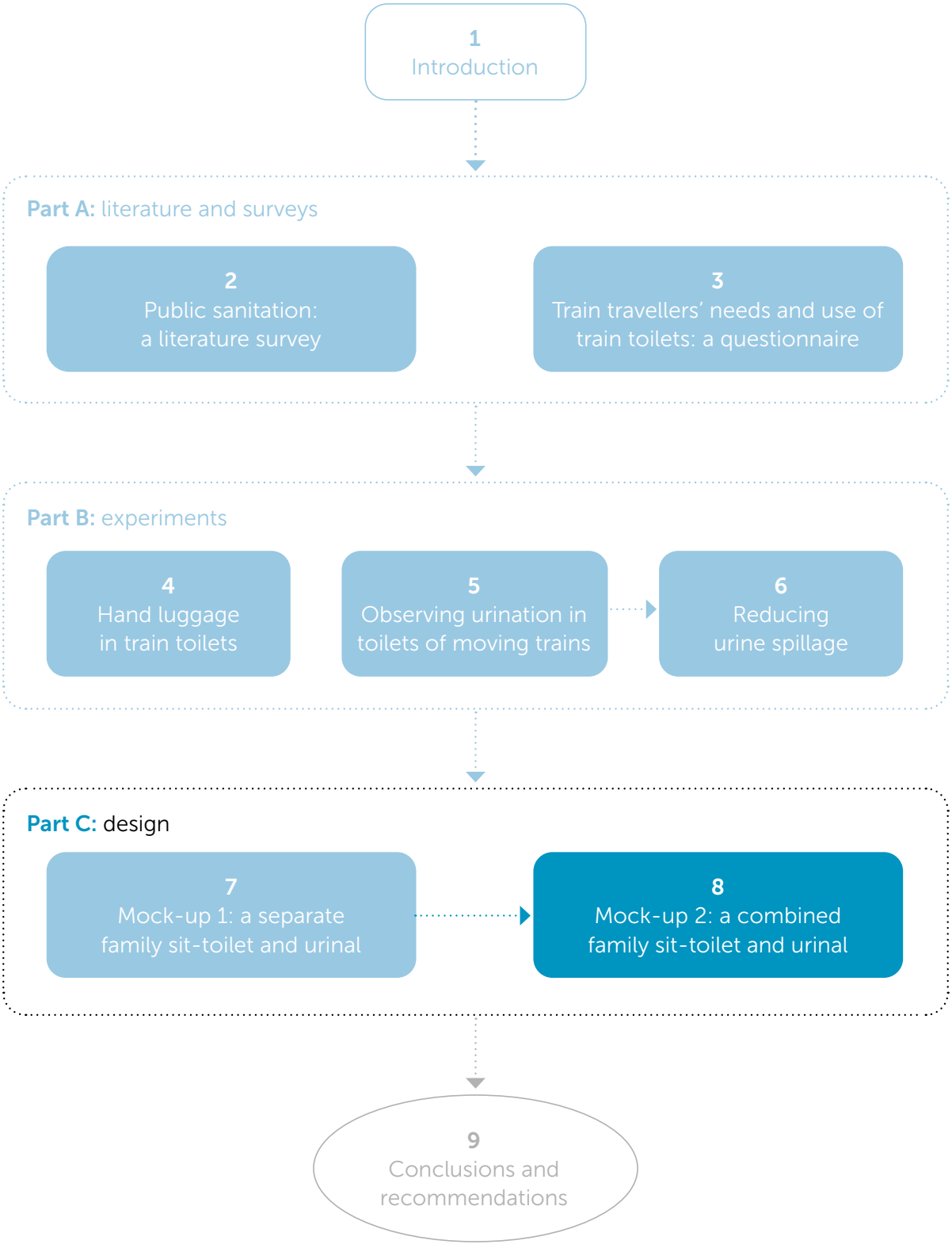
Family sit-toilet:
1. For additional support options due to the train's movements, install support bars
   1a. on the left side of the user/toilet
   1b. and with both a horizontal and a vertical bar in front of the user/toilet.
2. Include an extra broad rim on the back and side of the toilet seat.
3. Re-examine the larger toilet seat opening with more female participants.
4. Provide an additional sanitary waste bin to prevent blockage of the (delicate) train toilet flushing system.
5. Install the washbasin at a height of 800 mm.

Train urinal
6. Provide children's platforms for younger children to reach the toilet.
7. Provide security and privacy by using semi-transparent elements.
8. Position the urinal at an angle of 60 degrees to the train's moving direction to provide stability while urinating in standing position.

General
9. Characteristics of the family sit-toilet need to be combined with those of a urinal to reduce the three underlying distances, i.e., physical (P), mental (M), and social (S) distances between the toilet, dirt, and people/train travellers, respectively. The sit-toilet should include child platforms, a diaper changing table, extra support

options, and accessibility for wheelchair and walker users. The future train toilet should include a urinal and transparent elements.

Overall, an improved train toilet design should facilitate accessibility for all train travellers, promoting gender neutral integration in one space.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Chapter 8
Mock-up 2: a combined family sit-toilet and urinal

8.1 Introduction

In chapter 7 we described urinal mock-up 1. This can be characterised as a male domain that increases the social distance (S) between men and their fellow train passengers; it can only be used by men. Another premise of mock-up 1 was that men would wait their turn should the separate urinal be occupied, however in practice they may choose the family sit-toilet to urinate in a standing position, even though its design encourages seated usage. This contradicts the nature of our project: to create an inclusive train toilet environment.

A urinal improves hygiene by reducing the physical distance (P) between the human body and the toilet as it is used when standing. In this way, it reduces the distance bridged by the urine stream, resulting in less urine spillage, thereby improving hygiene. Furthermore, it reduces the mental distance (M), related to dirt, as a urinal is only suitable for urination and not for defecation; faeces are perceived as being dirtier than urine (Curtis and Biran 1998; van der Geest 2007; Pickering 2010)

We applied the findings from mock-up 1 to design mock-up 2, where we combined the urinal and the sit-down toilet. The design's focus is on reducing the three underlying distances, namely physical, mental, and social. In this way mock-up 2 should further improve train toilet hygiene, mainly by reducing urine spillage. We designed 2 versions of mock-up 2: mock-up 2a and 2b, where the results of the mock-up 2a tests led to modifications incorporated in mock-up 2b.

In this chapter, we describe our observations of the ergonomics of mock-up 2, i.e., participants' use and understanding of the main features of the combined train toilet. Participants also assessed these elements in a questionnaire. In this way we answered the research question **RQ C2: What are the implications for design through mock-up testing 2?**

In section 8.2, we describe the process of designing a combined train toilet which includes a family sit-toilet and a urinal. Section 8.3 describes the methods used for observation and assessment. In sections 8.4 and 8.7 we discuss the results of the two-step mock-up testing with 33 and 114 participants respectively. In section 8.5 we address the discussion and conclusions drawn from mock-up 2a as input for mock-up 2b, which

is then described in section 8.6. Section 8.8 discusses our findings on mock-up 2a & 2b and finally, section 8.9 closes with implications for the design of a hygienic train toilet.

8.2 Design of mock-up 2

Figure 8.1 Mock-up 2: Photo: Maarten Wijntjes

The integration of both types of toilets (sit-toilet with family facilities and urinal) was paramount to this design. The main components of the new train toilet proposal (sit-toilet, urinal and washbasin) with their elements such as family facilities, the mirror, and decoration were arranged in such a way that they contribute to the user's hygienic perception (see figure 8.1). In the following sections we describe the design steps: the layout of the main train toilet components in 8.2.1, the interior decoration in 8.2.3, and the semi-transparent wall in sub-section 8.2.4.

8.2.1 Train toilet layout

Mock-up 2 was designed as part of the modernisation programme of the NS VIRM type of train. It integrates the urinal with semi-transparent elements on one side with the sit-toilet and related family facilities on the other side, all in one space. The design was based on the findings from mock-up 1; 'Hygienic Train Toilet' (HTT), and a design by NS (ns.nl 1 n.d.) see figure 8.2.

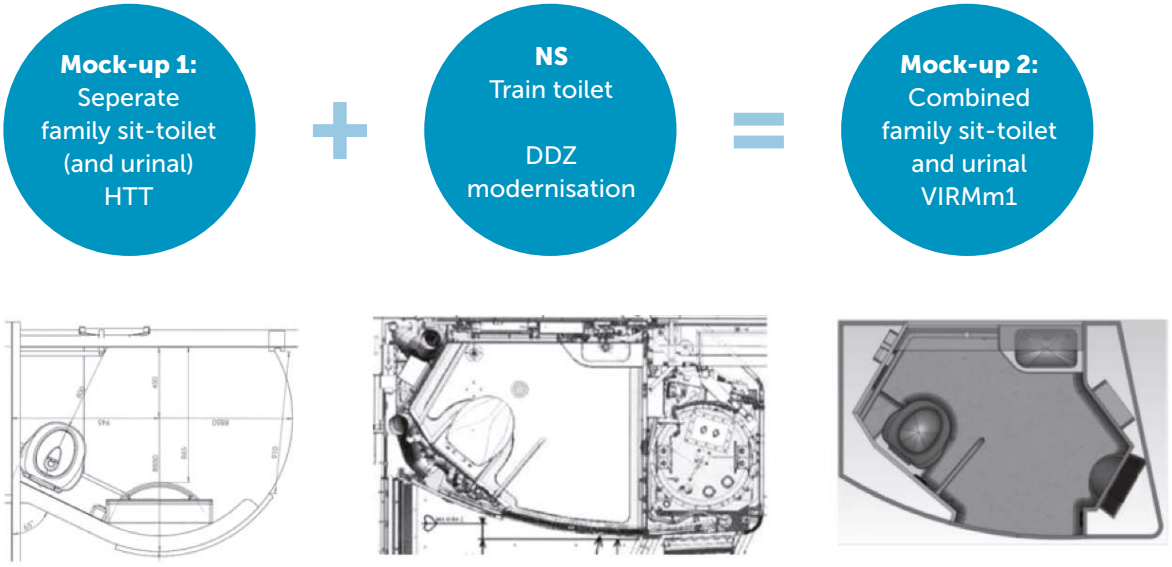


Figure 8.2 Mock-up 2 development

The design of the train toilet layout follows users in their order of their hygienic perception during toilet usage. After opening the round sliding door, they first catch a glimpse of the elements, i.e., the mirror, the washbasin, and the wall of nature, all of which give a positive hygienic perception as they are not associated with dirt. Secondly, they notice the toilet elements (sit down toilet, urinal) that are associated with dirt; however, their experience depends on the cleanliness of these elements.

Figure 8.3 Lay-out train toilet, urinal is hidden in a recess
Rendering: Tommy Louts and Fleur Derks

The urinal is concealed in a recess and placed at an angle of 60 degrees horizontally to the moving direction of the train to improve stability in a standing posture (see chapter 6, sections 6-13-6.17). In brief, the layout contributes to giving passengers entering the train toilet a clean first impression.

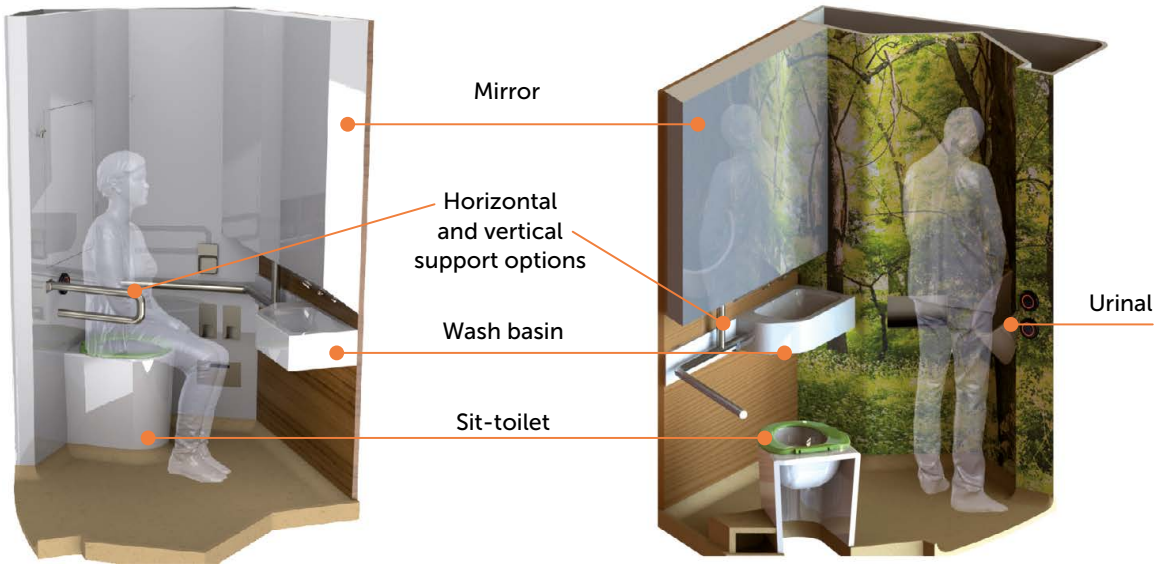
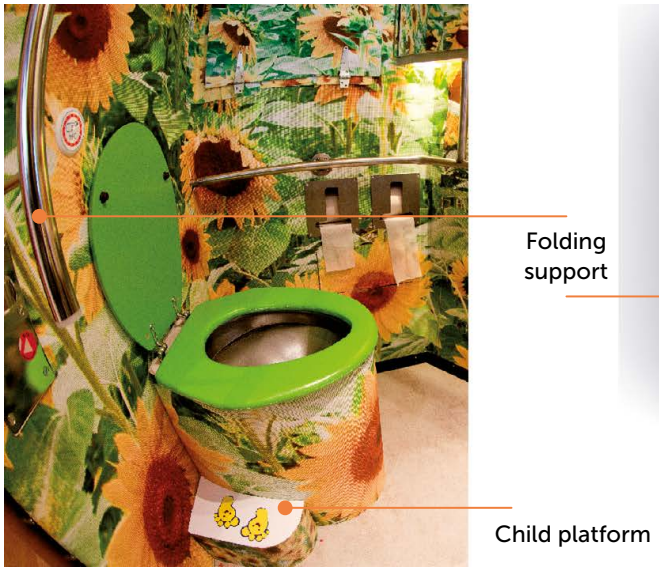


Figure 8.4 Mock-up 2a integrates two types of toilets for 8.4a hovering or sitting postures and 8.4b standing urination. Rendering: Tommy Louts and Fleur Derks



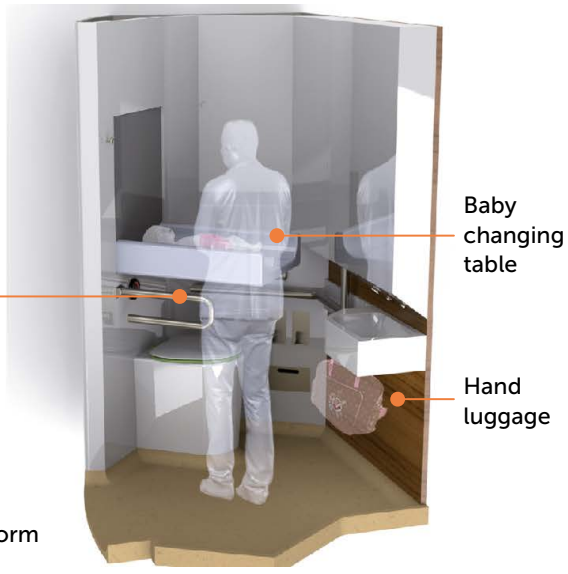


Figure 8.4c Child platform sit-toilet
Photo: Job Jansweijer

Figure 8.4d Baby changing table
Rendering: Tommy Louts and Fleur Derks

Figure 8.4 Sit-toilet and related family facilities

Mock-up 2 is 'inclusively' designed (Greed 2003; Anthony and Dufresne 2007; Molenbroek and De Bruin 2011; University of Cambridge 2017; DTO 2018; BTA 2019; WTO 2019) and focuses on 'access for all': anyone who is able to travel by train. In addition, further to the attention paid to the needs of men, women and transgenders without mobility problems, the design caters to family needs, i.e., from babies, toddlers, and (young) children as well as those of wheelchair and walker users and older adults. As a consequence, mock-up 2 includes a baby-changing table (figure 8.4d), children's platforms (figure 8.4c) and a foldable platform for young boys under the urinal (figure 8.3), wheelchair accessibility (figure 8.7) and extra support options (figures 8.4, 8.5, 8.7).

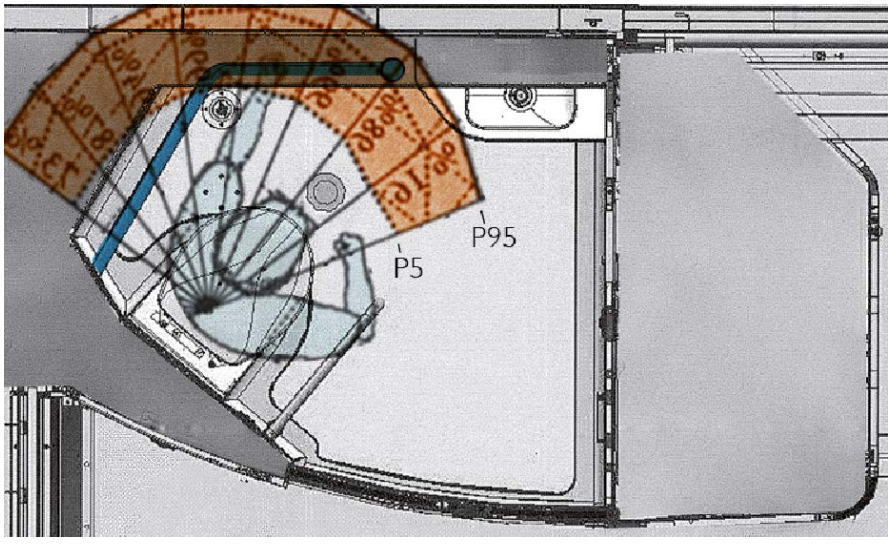


Figure 8.5 Vertical and horizontal) support options (figures 8.1 and 8.4)

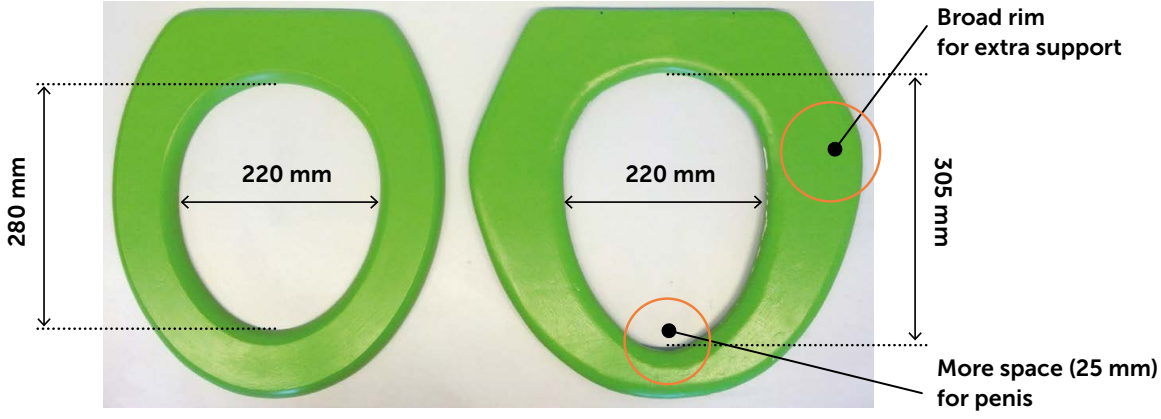


Figure 8.6a Common toilet seat *Figure 8.6b Special toilet seat (design: Jan van Dijk)*

Figure 8.6 Toilet seat (see also figure 7.3)

Figure 8.7 Wheelchair accessibility. Rendering: Tommy Louts and Fleur Derks

8.2.2 Lay out and Physical, Mental and Social distances

The layout and facilities contribute to reducing the physical distance (P) in the train toilet and mental distance (M) to dirt. On entering the toilet, travellers first perceive a clean train toilet because the elements are not related to human waste, which reduces the mental distance (M). They then see the toilet elements between which the mental distance (M) is large, i.e., the corresponding dirt can include human waste that is out of place (faeces and urine). These elements, i.e., sit-toilet and urinal, are thus perceived as being 'dirty'.

In a descriptive sense, on entering the toilet, users see themselves in the large mirror (1), with a washbasin and handwashing facilities to clean their hands (2). At the same time, they enjoy a fresh and relaxed atmosphere conveyed by the natural elements and enhanced by the mirror's reflection (1 and 2). Next, (3) if they turn to the left, they see the sit-toilet, or if they turn to the right, they see the urinal concealed in a recess.

Physical distance (P) is reduced by improving accessibility for people with mobility issues and children. The children's platforms allow young children to bridge a smaller physical distance between their bodies and toilets and improve the usability of train toilets because they can use them independently of their guardians. The urinal and sit-toilet optimise the different toilet positions of adults, reducing the physical distance between their bodies (P) and the different types of toilets. Moreover, all users can bring their bodies closer to the toilet using the support options.

Furthermore, the family facilities such as the children's platforms and baby changing table reduce people's social distance (S<) between people and children, and to a lesser extent their mental distance from dirt (M). These facilities tell the user (through design) that children and babies can visit a train toilet which may, in general, be associated with 'dirt', but we can tolerate this easily because we consider children (and their dirt) as being 'innocent' (van der Geest 2007).

For the Physical, Mental and Social distances P, M and S, respectively, we use the abbreviated notation for reducing or increasing the distance by noting P< or P>, M< or M>, and S< or S>.

8.2.3 Decoration wall

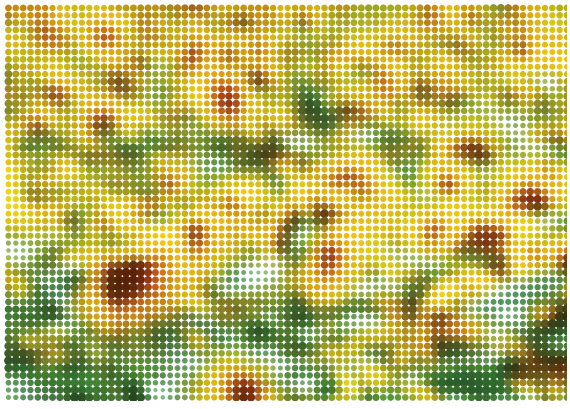


Figure 8.8a. Sunflowers (and a forest, see figure 8.4b and 8.40)
Photo: NadezdaVenaminova Naagen-Shestakova

Figure 8.8b Scribble-wall
Raster: Fleur Derks and Rein Pas

Figure 8.8 Nature wall to reveal a relaxed environment and "scribble-wall" to discourage scratching and graffiti

In mock-up 2, we paid special attention to the interior wall design, mainly to reduce the mental (M) and physical (P) distances; (M and P <). In chapters 2, 3, and 5, we concluded that train passengers experience stress from train toilets because they expect a dirty environment and therefore postpone their use until their need is urgent. This illustrates the mental distance (M) they expect to encounter that initially erects a physical barrier (P>) between the toilet environment. Therefore, we decorated the interior of mock-up 2 with landscape images based on the "healing environment theory" to reduce the user's mental distance from dirt (van den Berg and van Winsum-Westra 2006).

By using natural wall murals of sunflowers and trees, users feel that they are in a natural surrounding which reduces their stress when they enter and are inside the train toilet. environment. The sit-toilet area wall is decorated with sunflowers, which we assumed would make the user feel they are 'hiding' in the middle of a sunflower field while using the sit-toilet in hovering or sitting toilet postures, see 8.4c and 8.8. The wall murals place the user in a different natural environment and they therefore ignore any dirt that can be found. The tree behind the urinal helps men adopt a natural standing position while urinating, as if urinating 'against a tree', see figure 8.4b.

In this way, the sunflower field and the forest connect the travellers with nature. In a more abstract sense, it seems as if they are feeding the sunflower field and the trees with their faeces and urine during their visit. They are connected to their surroundings (Pickering 2010). Because of this feeling of connectedness they sense less physical distance (P) to the spot with their body (P<), and to a lesser extent, they also perceive less social distance due to the reduced anonymity (S<) (Mayer and Frantz 2004), whereas, their privacy is guaranteed.

Figure 8.9 Graffiti in a (dirty) train toilet environment deteriorates the perception of hygiene Photo NS

The natural wall also tackles the issue of graffiti and scratching in train toilets. Graffiti is common in existing train toilets (figure 8.9). The combination of a dirty environment and graffiti and scratching reflects disorder and increases the perception of dirtiness; "dirt is essentially disorder" (Douglas 1966, 2; Keizer, Lindenberg, and Steg 2008). In this way, graffiti reduces people's perception of hygiene.

The wall murals incorporate a grid of pixels that serves as an anti-graffiti wall (figure 8.8b). In this way writing 'a tag' becomes less conspicuous, making it less appealing. This concept is based on Menno Oosterhuis's award-winning concept of "Scribble Camouflage" that we call the 'scribble wall': after our observations in moving trains (chapter 5). The idea arose in the "Battle of concepts" that specifically asked for concepts to be generated to prevent scratching and graffiti on train toilet walls (Battle of Concepts 2010; https://services.starthubs.co/creative-challenge-case-ns/).

In brief, the natural walls are designed to relieve passengers' stress about dirt (M<), thereby the use of the train toilet (P<) and concurrently, to discourage users from applying graffiti and scratches on the wall. Accordingly, physical, mental and social distances are reduced by creating a relaxed and connected environment with nature (P,M and S <).

8.2.4 See-through door

Figure 8.10 See-through door mock-up 2a
Photo: Maarten Wijntjes

The design of the mock-up 2 entrance door tackles the issue of anonymity (large social distance S) in train toilets. Hygienic social behaviour such as leaving the toilet clean for the next user can be enhanced by reducing anonymity. Earlier experiments with semi-transparent facets were evaluated positively, as described in chapter 7 on the separate urinal in mock-up 1. Men perceived sufficient privacy and safety while the toilet environment was relatively open, see Figures 7.6a, 7.8, and table 7.3, section 7.4.3.

In mock-up 2, a semi-transparent door was fitted based on the hypothesis that people would show the desired social hygienic behaviour by the "unconscious effect on the participants' perception' that they are being watched, and hence reputational concerns may be extremely powerful in motivating human cooperative behaviour". Earlier work by Bateson, Nettle, and Roberts (2006, 412, 413) inspired this; they describe the eyes as a "subtle cue to evoke the psychology of being observed". They "believe that images of eyes motivate cooperative behaviour because they induce a perception in participants of being watched".

Our research showed (chapter 3, after toilet usage by Louts who conducted 29 hidden toilet observations, and chapter 5) that people were willing to leave the toilet cleaner for the next user.

This situation is depicted in figure 8.11. On the streets in The Hague in the Netherlands, large eyes with a sign 'keep it clean' are 'watching' whether people are keeping the surroundings clean from different kinds of waste that they should deposit at the intended places for bottles, paper, plastic and garbage.

Figure 8.11 'big brother eyes' and indication to keep the environment clean

In mock-up 2 we replaced these 'big brother eyes' by a semi-transparent door through which people become visible as a kind of shadow; the degree of transparency is limited so that privacy is sufficiently respected, see figure 8.10.

We also included a so-called 'Adam's leaf', as urinating men want extra privacy. It is based on the murals of the forest and represents a fallen leaf that is stuck to the door, shielding the view of the male genitals.

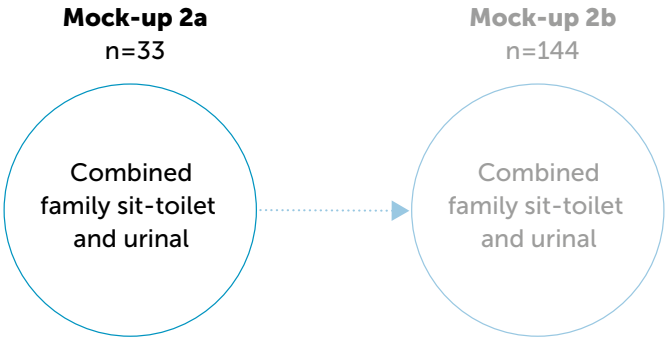
Figure 8.12 Leaf shape used as 'Adam's leaf' to offer additional privacy when men use the urinal

The semi-transparent door with an Adam's leaf creates more connection with the surroundings and reduces the social distance (S) between train travellers compared to a solid door (S<), see figure 8.10. The resulting reduction in social distance (S<) is designed as an incentive to reduce scratching and graffiti and to encourage users to leave the toilet clean for the next user. In this way, the semi-transparent door leads to cooperative (hygienic) social behaviour; train travellers will leave the toilet 'tidier' for the next user through the perception of reduced social distance (S<).

To summarise, we expected that thanks to the semi-transparent door, travellers would take more care of the train toilet's tidiness and cleanliness. The addition of a large mirror makes users more aware of how they use the train toilet through reflection and seeing

it through their own eyes. By reducing the social distance between train travellers, we expect train toilet users to behave in a more socially desirable way because they are more aware of other train travellers (S<). It places the usage of the toilet in a social context, even though the desired use is a private matter. In this way, we are appealing to people's cooperative behaviour, and we assume that with the expected effect users will leave the toilet cleaner for the next user (Bateson, Nettle, and Roberts 2006).

8.3 Method



We set out to answer the research question **RQ C2a 'What are the implications for design through mock-up testing 2a'.**

We constructed two versions of mock-up 2 based on the findings of mock-up 1 (chapter 7). First, mock-up 2a was tested in the toilet laboratory by 33 participants, who answered five sub-research questions (in)directly (see 8.3.1). In section 8.3.2 we describe the participants and in 8.3.3, the materials and procedure.

8.3.1 Research questions

The participants answered five sub-research questions regarding the main characteristics of mock-up 2a, i.e., the urinal, family facilities, and the semi-transparent door. We did not directly assess their view of the natural wall coverings to avoid participant question overload and because the first question: 'What is your first impression of the interior' indirectly asked participants to assess this aspect of the toilet (see appendix A.8.4 for the complete questionnaire).

Urinal
A central aspect of the mock-up 2a test was whether people who do not use a urinal would recognise its value. They may consider it as being an undesirable feature of the train toilet. This led to the first sub-research question:
RQ C2a-1: Do women accept a urinal in the mock-up of a new train toilet?

We expected male users (adults & boys) to appreciate the inclusion of a urinal given the positive assessment of the separate urinal of mock-up 1 and the fact that they are

familiar with urinals in public toilet areas (Möllring 2003; Williams 2009). Nevertheless, we verified whether they appreciated a urinal in the train toilet containing a sit-toilet. This led to the second sub-research question:
RQ C2a-2: How do male participants assess the urinal?

Family facilities
Although most train passengers do not travel with (young) children or use mobility products such as walkers, wheelchairs, and strollers (chapters 3 and 4), it was important to discover whether they would appreciate the inclusive design of these family facilities (children's platforms, baby changing table, extra broad toilet seat) added to the sit-toilet to improve accessibility for families travelling by train. The third sub-research question is:
RQ C2a-3: How are the family facilities experienced?

Semi-transparent door
The principle of the semi-transparent door is to reduce anonymity in the train toilet, in other words, to reduce the social distance between train travellers (S<) as a method to improve hygiene. On the other hand, toilet usage is a private matter, therefore, the fourth sub-research question addressed whether participants would accept this door:
RQ C2a-4: Do participants accept the transparency of the door?

Mock-up 2a as a whole
Mock-up 2a was assessed indirectly to prevent the *Hawthorn effect* of 'pleasing' the researcher by answering questions positively (Franke and Kaul 1978; Kumar 2005). Two sub-questions were asked regarding the toilet's (1) cleanliness and (2) pleasantness to answer the next research question:
RQ C2a-5: What is the assessment of a combined train toilet?

8.3.2 Participants

Participant / Mock-up	Wheel-chair user	Rollator user	Young child girl	Young child boy	Male	Female	Visual-restricted	Total number
Mock-up 2a Combined module	4	4	2	8	6	9	-	**33**
Mock-up 2a Combined module	-	-	5	-	26	78	5	**114**
Total number of participants in mock-up 2	**4**	**4**	**7**	**8**	**32**	**87**	**5**	**147**

Table 8.1 Participants' overview mock-up 2

To test mock-up 2a, 33 participants assessed the ergonomic and hygienic aspects of the toilet by answering the 5 sub-research questions. We invited a diverse group of train travellers in terms of age, gender, mobility, and frequency of train travel. The respondents were aged between 4-66 and included 16 females and 17 males. Seven participants were (young) children, and eight adults used mobility aids like walkers, wheelchairs, and a mobility scooter, (table 8.1). A note regarding a mobility scooter: one female participant was a mobility scooter user. A train and thus also a train toilet have limited access for mobility scooter users, which means that NS is not legally obliged to make trains accessible for them. However, in the future, trains will also become accessible to mobility scooter users (NS internal memo).

We recruited the participants in a number of ways: as a predominantly convenience sample. In an announcement in the elevator of the TU Delft IDE faculty, the lab manager invited (older) adult participants who used mobility aids. The mobility scooter user was invited via organisation Voorall (www.voorall.nl). The group of (young) children was approached personally from our network of colleagues, friends, and family members.

The participants were informed verbally about the purpose and nature of the ergonomic mock-up testing: their 'dry' (clothes on) toilet practices would be observed and recorded audio-visually. Therefore, they were asked to provide informed consent, while the researchers guaranteed their privacy (appendix A.8.3). The young children's guardians gave informed consent on their behalf.

8.3.3 Materials and procedure

Cameras

Four cameras were installed in the mock-up to record four different viewpoints of the participants in the test setup, see figures 8.1 and 8.10, section 8.2. The cameras were positioned high up outside the direct field so that they were less conspicuous and intrusive when recording.

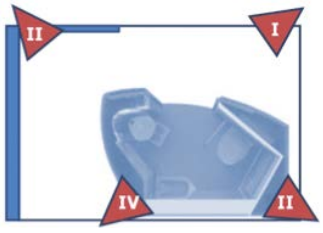
Type	Camera position	Cameras in mock-up 2	Screenshot (Example)
 Standard CCD4Q Elro (PAL)	I. Entry outside (urinal) II. Entry outside (sit-toilet) III. Inside urinal and washbasin area VI. Inside sit-toilet area	 Camera positions I, II, III and IV	 Camera I: Participant at urinal

Figure 8.13 Observation equipment

Procedure

The procedure was similar to that described in chapter 7 for mock-up 1 tests. For the mock-up 2 tests, we added a question session, including participant background information, to the research protocol (appendix A.8.4.1). Furthermore, all participants performed the mock-up test in one train toilet instead of being divided between two separate modules.

Participants were welcomed in a first room where they gave their background information (age and gender), and information on their train travel (travel frequency, train toilets), see appendix A.8.4.1 for the questions. Subsequently, we followed the same procedure described for mock-up 1, with a combination of questionnaires and observations (section 7.3). In brief, in the hospitality lab (figure 7.12, chapter 7), a researcher explained the procedure and the participants were asked to sign an informed consent form while the researchers guaranteed their privacy (appendix A.8.3). Finally, a researcher guided the participant to the third room, the mock-up testing room, where another researcher asked the participant to enter mock-up 2a (figures 8.1, 8.3, 8.7, 8.10) and 'use' it as he or she would normally do, but in this case fully clothed.

The tests took about 45 minutes and were conducted in January 2012. Participants were rewarded with a fee of 15 euros. Furthermore, taxi transport was arranged and paid for participants who used a wheelchair, walker, or mobility scooter.

Questionnaires

Participants were divided into groups depending on gender, mobility and age. We developed a different questionnaire for each of the groups: men (n=6) and women (n=8) without mobility restrictions, men and women with mobility aids (n=9), and lastly a questionnaire for children (n=10); see table 8.1, section 8.3.2 for an overview of the participants, and appendix A.8.3 for the different questionnaires.

Figure 8.14 Structure of the questions

The interviewer asked participants to assess an element in the mock-up on a scale of 1-10 (1=very negative, 10=very positive), e.g. the washbasin, the size of the room, and then to explain their rating, as shown in figure 8.14.

The questionnaires were built up gradually, with the first question being the same: all participants were asked to assess 'what is your first impression of the interior' using a scale of 1-10 (1=very negative, 10=very positive), see appendix A.8.4. Subsequently, to

gain fresh insights regarding mock-up 2a, participants explained their impressions. We expected they would mention the presence of a urinal and give impression of the natural wallpaper.

Following this initial question, the interviewer instructed: 'pretend you need to urinate, you can keep your clothes on'. Participants could decide whether to choose a hovering or seated position (sit-toilet), or a standing posture (urinal); the interviewer did not specifically ask them to use a sit-toilet or a urinal. The interviewer then used the corresponding questionnaire (see appendix A.8.4 for the different questionnaires).

Consequently, participants who opted for the urinal (standing position) on their own initiative were asked questions about the urinal. This group was asked direct questions about the urinal because this is something they are used to, and the train-toilet urinal was not expected to be a problem for them. For those who chose hovering or sitting, the questions were about the sit-toilet. However, for this group, no questions were suggested about the urinal to prevent directing attention to it. In this way we avoided forcing participants to express an opinion about the urinal as this would have contradicted the study's aim of being conducted as neutrally as possible.

In brief, the neutral question on 'the interior' was used as a starting question to provoke spontaneous reactions about the urinal and/or natural wallpaper. We then asked respondents up to 20 user-group specific questions about their toilet practices. The questionnaire ended with the final question 'do you have any comments'. The session was closed with a reward of 15 Euros for gratitude and compensation.

The questionnaires can be found in the appendix; the questions were as neutral as possible to avoid any possible influence on the interviewer's answers. In the assessment, we used a 10-point rating scale. We defined a score of one to five as negative, six as neutral, and seven to ten as positive. For more details, see appendix A.8.4.

8.4 Results

8.4.1 Background information of participants

Thirty-three participants with a mix of gender, age, and travel frequency were observed and interviewed In terms of travel frequency, the majority (16) occasionally took the train, eight travelled frequently; nine participants did not provide any information.

Of the 20 children and people using mobility aids such as wheelchairs and rollators, all rarely took the train: three never travelled by train, two travelled one-three times a month, and ten travelled less than once a month; five missing values were noted in this group.

Two people spontaneously complained about the accessibility of the current train toilet, while this was not asked for. The different participants assessed the current train toilet with an average score of 5.8 (17 of 33), see appendix A.8.4.1.

We describe the results per question in the following sections: 8.4.2 (urinals), 8.4.3 (family facilities) and 8.4.4 (semi-transparent door).

8.4.2 Results mock-up 2a urinal

Results for RQ C2a-1: Do women accept a urinal in the mock-up of a new train toilet?

Respondents indirectly answered this first research sub-question by answering: 'what is your first impression of the interior' and the final question: 'do you have any comments'. In this way, participants were able to respond spontaneously to the urinal. These two questions were designed to enhance the study's neutrality. A urinal in a train toilet was hypothesised to provoke an adverse reaction, especially from those who do not use it for urination, such as women and wheelchair users.

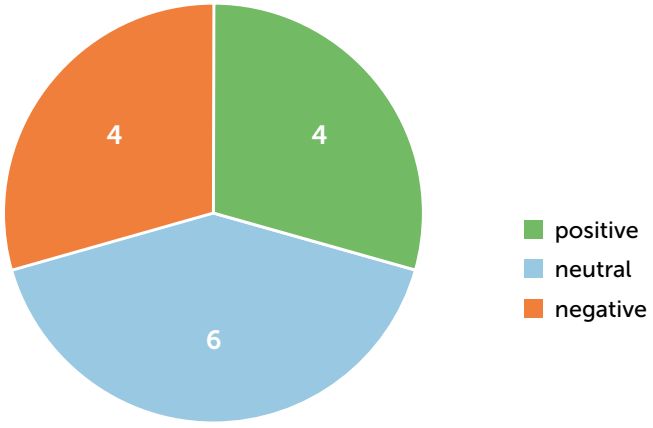


Figure 8.15 Approach urinal of female participants (n=14)

The majority of women were neutral or positive about the presence of a urinal in the train toilet mock-up 2a, see figure 8.15. Nevertheless, their reactions differed. Eight recognised the urinal and reacted either positively (n=4) or negatively (n=4). Six (of 14) women did not react, so we considered this a neutral approach to the urinal. The urinal was not an issue for the two young girls aged four and seven; they did not say anything about it. However, we only took the comments of the 14 adult women into account, with the reasoning that young girls have less experience with urinals.
Examples of reactions of two female participants:
1F: 'Pleased to have a urinal available, would also like to have a urinal at home'.
3F: 'Urinal is dirty, not nice to look at'.

Results RQ C2a-2: How do male participants assess the urinal?

Only men and (young) boys without mobility limitations (n=14) chose to urinate in a standing posture, and as a consequence, they were asked questions specifically about the urinal. They rated the urinal positively with a mean score of 6.9 on a scale of 1-10 (1=very bad, 10=very good), see figure 8.16.

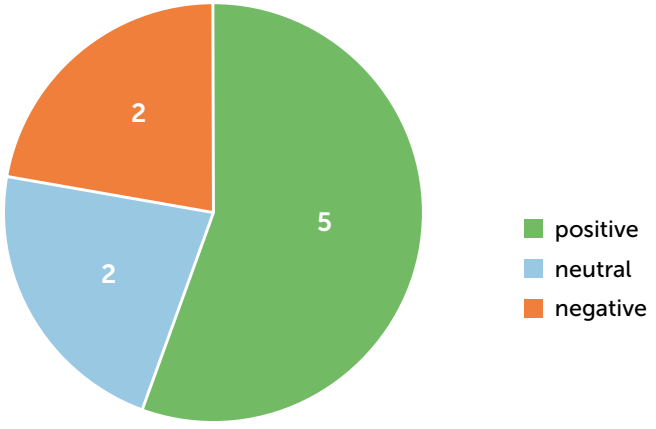


Figure 8.16 Approach urinal by male and boy participants (n=9)

They valued the hidden location of the urinal in the recess and stated that the urinal's presence was clear and easy to reach. They understood how to use the urinal. Three men had doubts about the limited depth of the urinal that could cause backsplash (see chapter 6). A male participant wanted a support bar at the urinal, and another supported himself on the sidewall, see figure 8.17

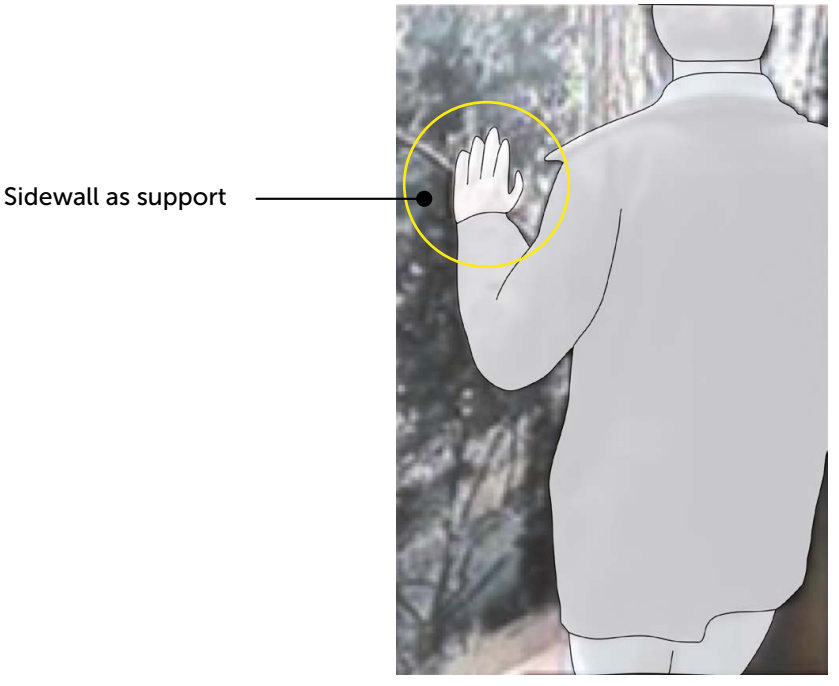


Figure 8.17 A male participant used the wall as support option when 'using' the urinal

One participant (16m) chose to 'use' the sit-toilet and therefore he was questioned about the sit-toilet, and not asked to assess the urinal. In answer to the first question, he

mentioned the urinal as a positive aspect in addition to 'nice mirror, hand washing, nice toilet, the door is splendid'. He had no negative comments and noted that he preferred a support option for the urinal although he did not use the urinal during the mock-up test. The three male wheelchair participants did not comment on the urinal.

8.4.3 Results mock-up 2a family facilities

Results for RQ C2a-3: How are the family facilities perceived (child platforms, baby changing table, and extra broad toilet seat)

Child platform under the urinal
Young children or parents/guardians did not always notice the children's step under the urinal; once they recognised it, they preferred to use it. Some young boys unfolded the platform themselves (figure 8.18); the happy feet helped. The observations showed that they operated the platform by hand or by foot.

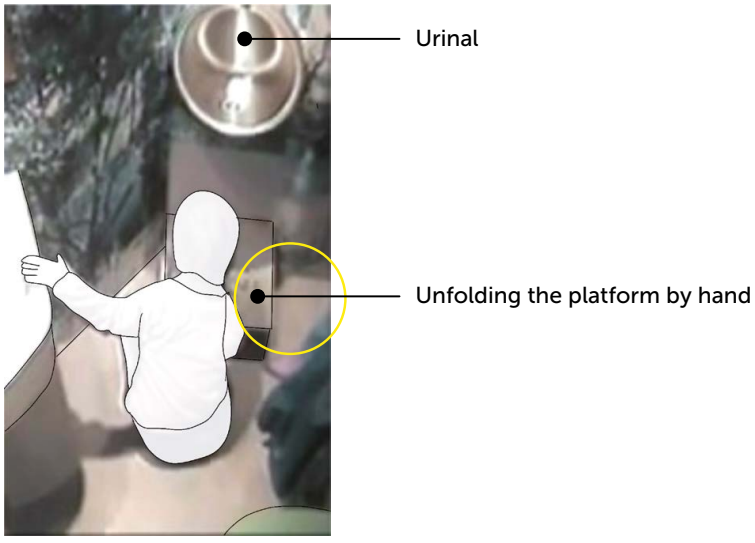


Figure 8.18 A young boy unfolded the children's platform by hand

Child platform adjacent to the sit-toilet and in the corner of the train toilet
The folded support hindered a girl from climbing on the toilet and she used the toilet sideways (figure 8.19). Another girl used the sit-toilet without the step. The surface of the step adjacent to the sit-toilet was limited because of wheelchair accessibility (see figure 8.4c, section 8.2.1). A second step was placed in the corner of the sit-toilet, but this platform was not noticed.

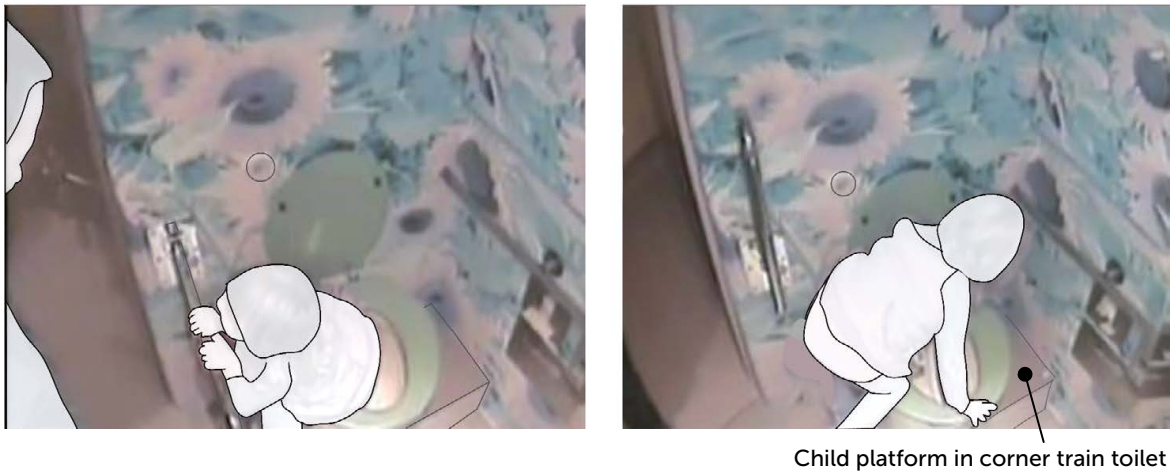


Figure 8.19 Child platform adjacent to the sit-toilet

Baby changing table

Four participants tested and assessed the baby changing table, giving it an average rating of 7.5 (n= 4: 3 women, 1 man), see figure 8.20. Three participants had never changed a nappy. The location of the baby changing table was modified before mock-up testing 2a due to restrictions in space for manoeuvring caused by the mirror wall (figure 8.4d, section 8.2.1). This alternative offered more space for the person who changed the nappy (figure 8.20). The current connection to the walls caused uncertainty for the participants, one participant found it risky because one side of the baby changing table was not enclosed by a wall (figure 8.20b).

Figure 8.20a Woman unfolds the baby changing table *Figure 8.20b*

Figure 8.20 Baby changing table in mock-up 2a

Toilet seat

As a reminder, the toilet seat was designed to provide more sit-stability: it had a larger sit-area (see figures 5.1, 7.3 and 8.6) and the extra width was designed to provide extra support for young children and wheel chair users. The toilet seat was also designed to provide more sit-comfort for extra-size people, and seated men had more space in

front for the penis (figure 8.6). The toilet seat was fixed to the toilet bowl to prevent it from being raised, which would lead to standing toilet usage. Overall, the toilet seat was meant to stimulate seated usage.

From both the observations and the questionnaire, it was inconclusive whether the toilet seat stimulated seated toilet usage. Two participants with a wheelchair said that they use a catheter and therefore close the toilet lid to prepare the catheter while sitting on the toilet as 'a chair'. However, this was not observed.

Figure 8.21 Child uses the toilet seat as extra support while sitting

8.4.4 Results mock-up 2a semi-transparent door

Results RQ C2a-4: Do participants accept the transparency of the door?
Most participants (11 of 24) were negative about the degree of transparency of the door; they rated the transparency with a score under six. However, eight participants were positive, rating the door transparency with more than a six. Five were neutral; scoring a six on a scale of 1-10 (1=far too transparent, 10 =very good), see figure 8.22 and table Appendix A.8.5.

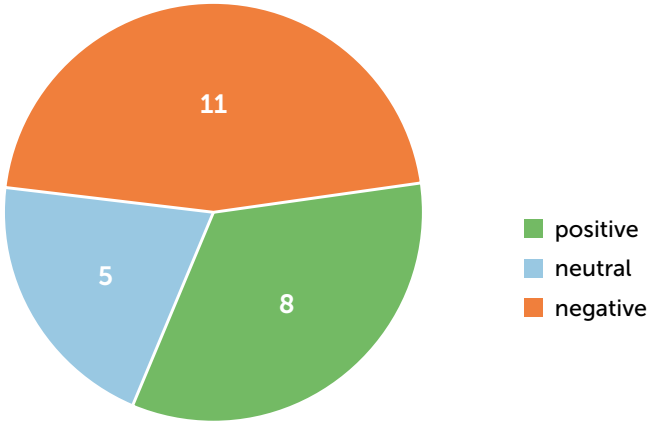


Figure 8.22 Approach semi-transparent door (n=24)

Results RQ C2a-5: What is the assessment of the combined train toilet mock-up 2a?

Finally, mock-up 2a was assessed on two ingredients, namely cleanliness and pleasantness; the key aspects the train toilet module needs to meet. The average rating for the cleanliness of the combined train toilet mock-up was: 7.1; n=22 (11 missing values), and the average rating for the pleasantness of the combined train toilet mock-up was: 7.7; n=24 (9 missing values). As a result, we consider the overall average rating of mock-up 2a with a score of 7.4 as good; n=23 (10 missing values). Moreover, NS internally referred to mock-up 2a as being a 'clean and pleasant train toilet'.

Other findings

The horizontal and vertical support options functioned as expected and were perceived as pleasant by users. The folding support was not used by wheelchair users. They used their own wheelchair as a support when transferring to the toilet.

The space under the washbasin was considered unpleasant by the three wheelchair users because there was not enough space under the washbasin for their legs (figure 8.23). Moreover, the manoeuvring zone around the sit-toilet was not sufficient for the majority of the participants. During various sit-toilet actions, four participants pushed their heads against the large mirror that protruded relatively far into the sit-toilet area (figure 8.24).

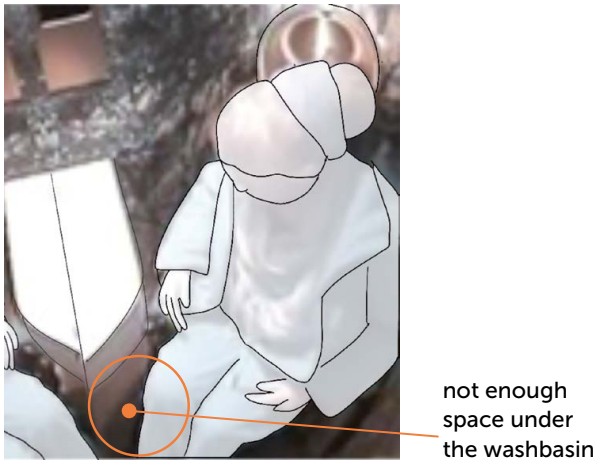


Figure 8.23a

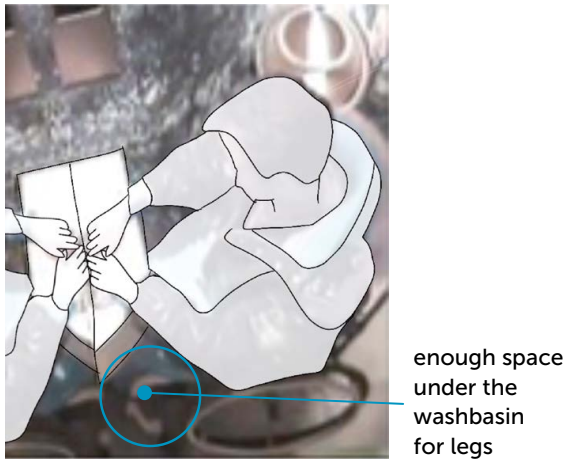


Figure 8.23b

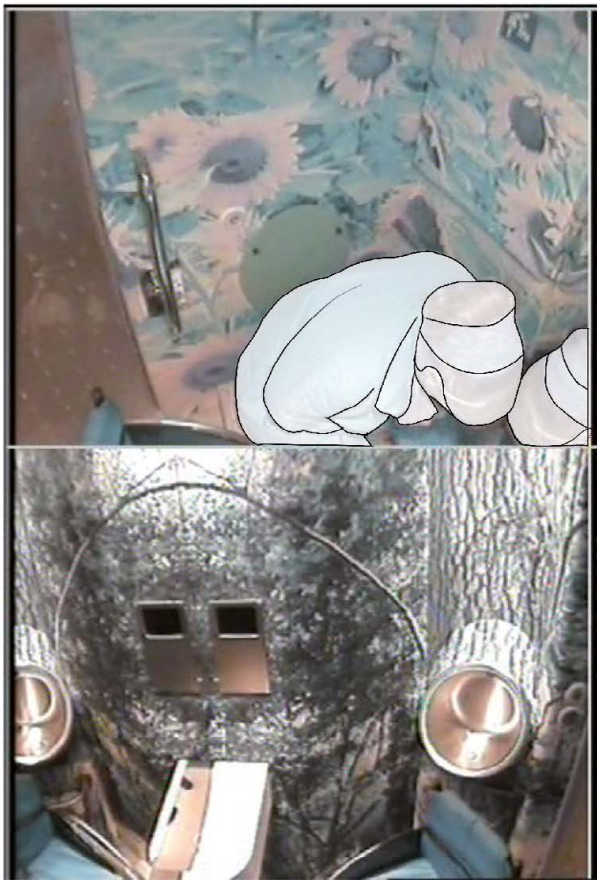


Figure 8.23 Wheel chair user and space under the washbasin for their legs

Figure 8.24 Manoeuvring zone around sit-toilet was insufficient: four participants bumped their head against the mirror.

8.5 Mock-up 2a test: discussion and conclusion

8.5.1 Discussion

The first research question about the acceptance of a urinal in the proposed design of a new train toilet among female participants was inconclusive regarding how women valued the urinal: an equal number of women (4 of 14) were negative or positive (4 of 14) about the urinal, while the majority (6 of 14) were neutral, (figure 8.15). A relevant factor is that mock-up 2a contained a clean urinal.

A number of participants bumped their heads against the mirror. It turned out that space was initially measured incorrectly; this was adjusted in mock-up 2b by making the mirror 4 cm thinner.

The overall assessment of the mock-up 2a was based on cleanliness and pleasantness factors. Other aspects, i.e. their first impression, the space and hygiene were excluded. The answer to the first question about users' first impression was designed to get a spontaneous overview of positive and negative aspects, and A 8.3.1. Separate assessment of the space of mock-up 2a (7.6:n=19) was also not included because, based on the participants' explanations, it was already part of the pleasantness factor. Further, the hygiene assessment was not included because this rating (7.06; n=26) was approximately the same as the rating of cleanliness (7.1; n=22): participants considered the concepts of hygiene and cleanliness to be similar. Therefore, the overall score of mock-up 2a consisted of an average of the two ingredients: cleanliness and pleasantness: 7.4 (see results RQ C2a-5).

Regarding participant diversity, we noted that younger girls and toddlers should be recruited for the following test, as more young girls need to be tested on the children's platform of the sit-toilet. In addition, we needed to include visually restricted participants, train travellers who in terms of mobility are mainly dependent on train travel because they cannot use an alternative like the car. Their reaction to the urinal as well as to the wall-decorations would be valuable as there is less contrast in the surroundings than the current NS train toilet's grey wall.

A further recommendation was the addition of a horizontal support bar independent in terms of positioning of whether a man, including rollator users, is left or right-handed. The bar provides support so the user can maintain a clear view while urinating and aiming. The positioning of this horizontal bar in mock-up 2a is based on the observations in chapter 5, see figure 8.17.

The comments about the wall were generally positive. Respondents found it conveyed a pleasant atmosphere; one termed this as 'fresh', however two commented that it was 'too busy'.

8.5.2 Conclusions

The observations and questionnaires led to a generally positive assessment of mock-up 2a: it scored an average of 7.4 regarding factors of cleanliness and pleasantness. We considered these factors to indirectly indicate the participants' desired hygienic and usability/ergonomic values. However, the majority of the participants experienced the door's transparency as unpleasant. In addition, although the tests showed that the urinal was accepted, the NS found the results inconclusive.

These conclusions provided input for the design of mock-up 2b and its assessment. We noted the need for the following adjustments to improve the ergonomic needs of the participants for the design of mock-up 2b.

RQ C2: What are the implications for design through mock-up testing 2a?

Urinal

1. A horizontal support bar 140 mm above the urinal is necessary as a support option for men using the urinal.

Family facilities

2. The usability of the step to the sit down toilet was inadequate. The children's platform in the far corner of the mock-up was not noticed and needs to be tested with more young girls. The platforms (including under the urinal) need to be at a height of 200 mm.
3. The baby-changing table should prevent a baby from rolling off it. If there is a side that is not enclosed by the wall or guardian who changes the nappy, baby's feet or head should lie towards this open end.
4. The special toilet seat needs to be tested with more participants. It was used as extra support, but does not encourage people to sit-down.

Semi-transparent door

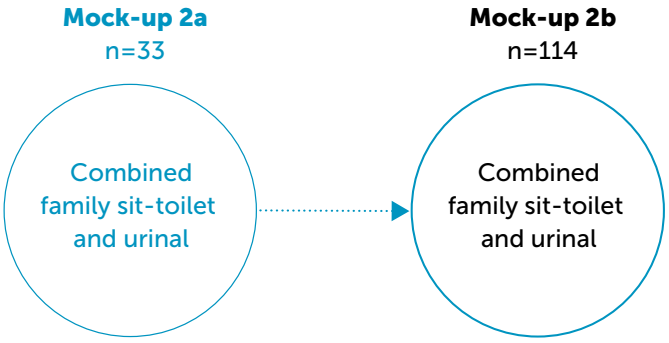
5. The door needs to be less transparent to respect the privacy of the participants.

Other elements

6. The washbasin needs to be placed 100 mm higher: at 900 mm.
7. The decorative wall is recommended.

Moreover, the participant group needs to be extended to test these design adaptations, including young girls and visually restricted participants. This will provide more ergonomic and hygienic input about the urinal and other elements of the mock-up.

8.6 Testing mock-up 2b



Minor adjustments were made to mock-up 2a, resulting in mock-up 2b, see figure 8.25. The inner dimensions were the same for both versions.

Figure 8.25 Mock-up 2b with minor adaptations

Firstly, the door was made less transparent by adding four semi-transparent leaf shapes. Secondly the washbasin's height was raised to 900 mm from 800 mm. Thirdly, a horizontal support bar was installed above the urinal at a height of 1,400 mm (figure 8.25a). Lastly, we removed one of the two platforms at the sit-toilet (figures 8.4c and 8.19). We made the remaining platform conspicuous by adding (happy) hands on the wall, and feet on the floor that were also used for the children's platform under the urinal (figure 8.25b).

Figure 8.25a Horizontal support bar

Figure 8.25b Children's platform at a height of 140 cm from the ground; sit-toilet with (happy) feet and hands above support bar

8.6.1 Method

In the mock-up 2b test, we increased the number of participants and included young girls and visually restricted participants. We also dirtied the urinal when assessing its acceptance. Furthermore, we conducted a double-blind test, where the researchers involved did not know the chief researcher (author) so that they had a more independent position in relation to the author's dependency on the results; the researchers were not informed about the purpose of the research.

To summarise: the research method used in mock-up 2b differed slightly from the mock-up 2a test. The number of participants group was increased, the study was conducted double-blind, and four scenarios were used.

Participants
A professional research agency, Newcom (www.newcom.nl), was hired via NS to recruit a large group of participants. They approached train passengers directly through the NS panel. We announced the assessment in Dutch as; 'Proefzitten', which can be translated as a 'sitting test' instead of a test of a train toilet mock-up. This was done to keep the participants as neutral as possible so they could not form an opinion about train toilets prior to the test.

Cameras
In mock-up test 2b, we experimented with a Kinect camera that immediately made the participants unrecognisable and anonymous, see figure 8.26. However, the Kinect camera did not work properly. The mock-up tests were eventually recorded with the same cameras used in the mock-up 1 and 2a test (section 8.3.3.)

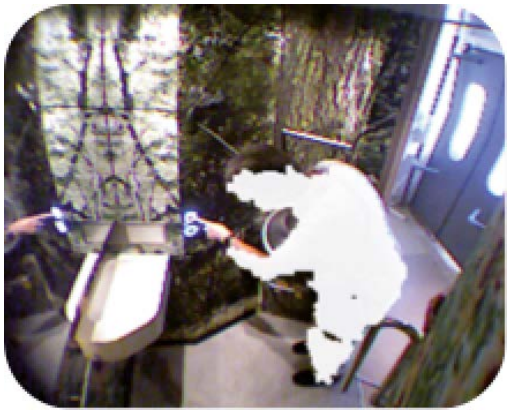


Figure 8.26 We experimented with Kinect camera that immediately makes participants unrecognisable

Double-blinded assessment and scenarios

The same procedure was followed as in the mock-up 2a assessment, i.e., observations, questionnaires and interviews at three locations (see 8.3.3). The mock-up 2b assessment was conducted double-blind; the author was minimally involved to ensure an independent position; she would have benefited from a positive response to the urinal as she had advised Dutch Railways to add a urinal in the train toilet as a hygienic improvement. In addition, the researcher performing mock-up 2b test was not informed about the content and purpose of the research. For example, she was instructed by another researcher to do the research protocol with informed consent, and to ask questions as neutrally as possible. She had no contact with the author.

Figure 8.27 four scenarios mock-up testing 2b

Four different scenarios were used: first, whether or not family facilities such as the children's platforms, baby changing table, and the specific toilet seat were provided; second, the presence of a clean or artificially soiled urinal, see figure 8.27.

Figure 8.28 Soiled urinal used in scenario's 3 and 4

The urinal was consistently made 'dirty' by inserting a hair and fake urine in the form of drops of diluted white wine vinegar (figure 8.28).

8.7 Results mock-up 2b testing urinal

What is the assessment of a (dirty) urinal in the mock-up of a train toilet?

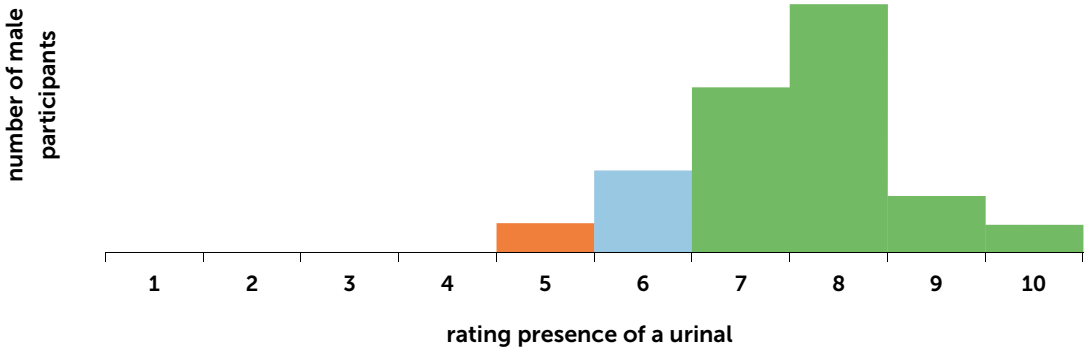


Figure 8.29 Rating of male participants (n=26) about presence of a urinal

In mock-up 2b, 26 men took part, and almost all (n=25) were neutral or positive about the presence of a urinal in the train toilet. One male participant rated the urinal with a 5 stating: 'the urinal is not deep enough and will cause backsplash' (figure 8.29).

Female participant ratings

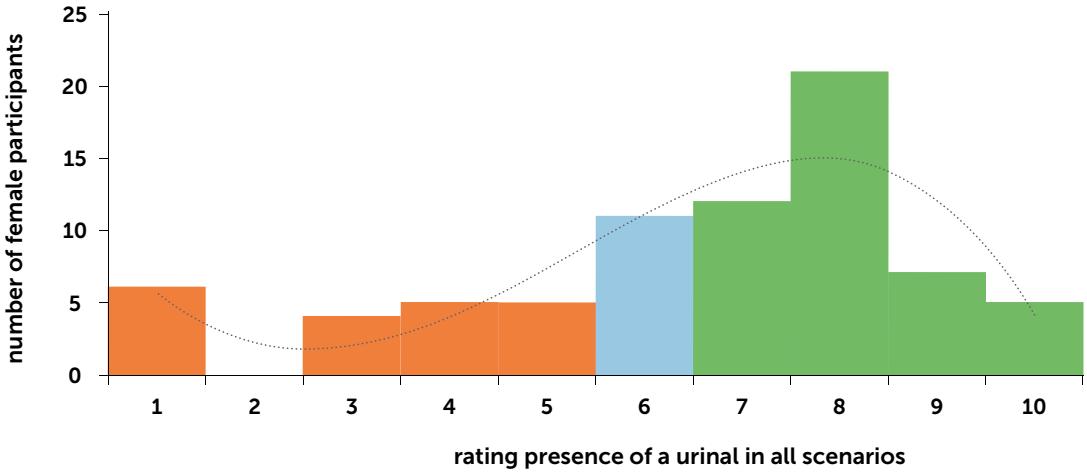


Figure 8.30 Rating of female participants (n= 76) about presence of a urinal

A total of 78 women participated in the mock-up 2b test, of which results of two female participants were excluded because their first impression did not match with the assessment they gave (attitude: negative; rating 8). The majority of female participants were neutral or positive about urinal's presence in the train toilet (figures 8.30 and 8.31) with reactions varying from 'very confrontational' to the idea that 'the toilet stays clean'. The 21 female participants who were negative about the urinal's presence stated that a urinal is a dirty addition to a train toilet's area. Nonetheless, 34 female participants spontaneously mentioned positive reasons (a reason was not explicitly requested) that if men used the urinal, they would no longer dirty the sitting area. Four (of 78) female participants did not notice the urinal until the researcher specifically asked about it at the end of the mock-up testing, see appendix A.8.7 for the questions.

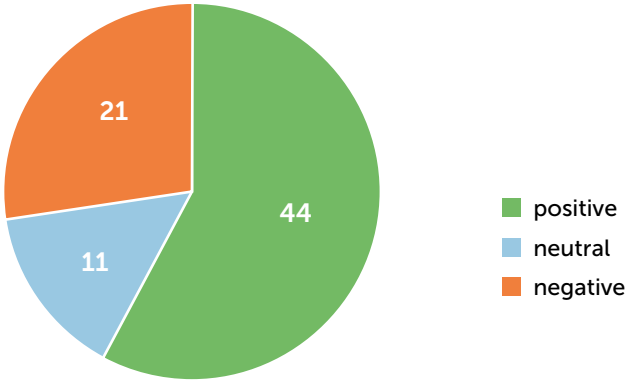


Figure 8.31 Attitude female participants (n= 76) about presence of a urinal

Missing values

We missed some participants' background information on train travel and personal information; the forms may not have been correctly distributed to all participants.

When asking the children questions, they sometimes did not understand or answer them. The questionnaire and questions were mainly written for adults, and sometimes it was necessary to give the children an explanation, however this did not always occur as the interviewers had been instructed not to change the way of asking questions to avoid any possible influence.

Attitudes per scenario

Between 18 - 20 women participated in each scenario. The majority of women were neutral or positive about the presence of a urinal in each scenario. In scenario 1; clean urinal with family facilities, the least number of women (3) were negative. In each of the three other scenarios, five participants were negative about the urinal (figure 8.31).

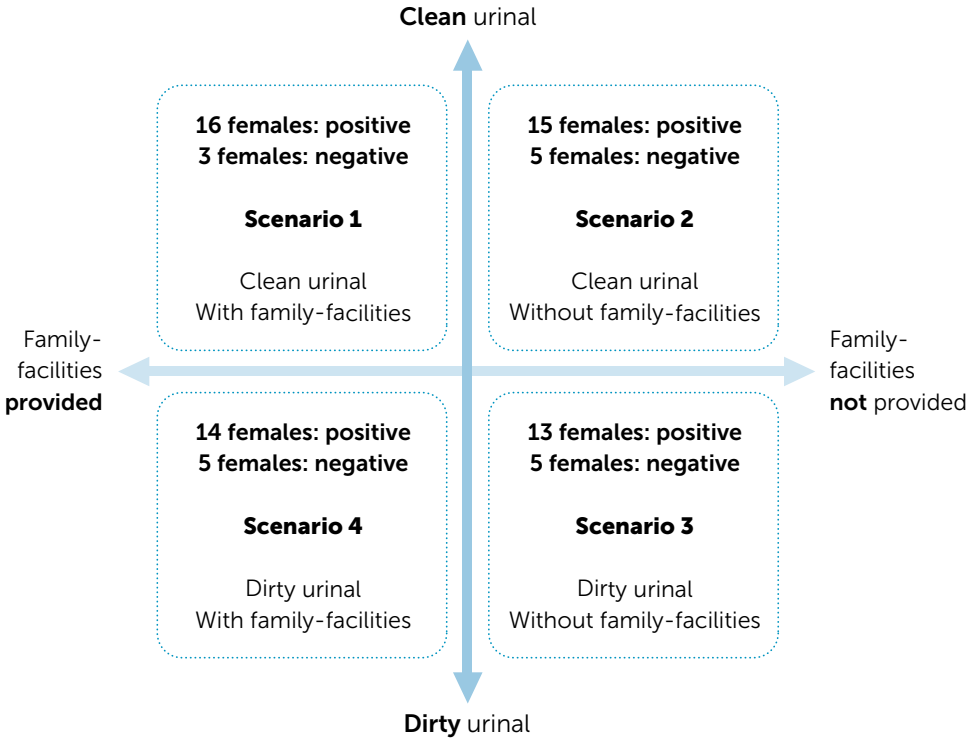


Figure 8.32 Positive and negative attitudes towards urinal of female participants per scenario

RQ: Do the family facilities have a positive or negative effect on the urinal assessment?

Rating of the presence of a urinal per scenario

A marginal difference was found between the assessment of a clean or dirty urinal for the scenarios where family-facilities were available or not. The dotted trend line (figure 8.33) slightly shifted in favour of the assessment in 'clean urinal' scenarios 1 and 2. This also occurred with a positive-neutral assessment (≥6) in favour of 'the family-facilities' scenarios, 1 and 4. The opposite happened when the family-facilities received a negative rating < 6, the trend line shifted at the expense of the family-facilities; scenarios 1 and 4; (figures 8.33 and 8.34).

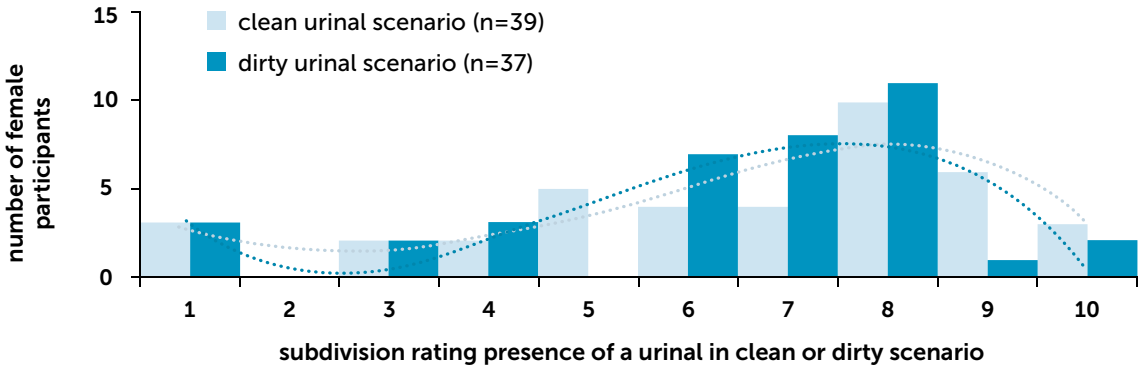


Figure 8.33 Rating presence of a urinal in a clean either dirty condition

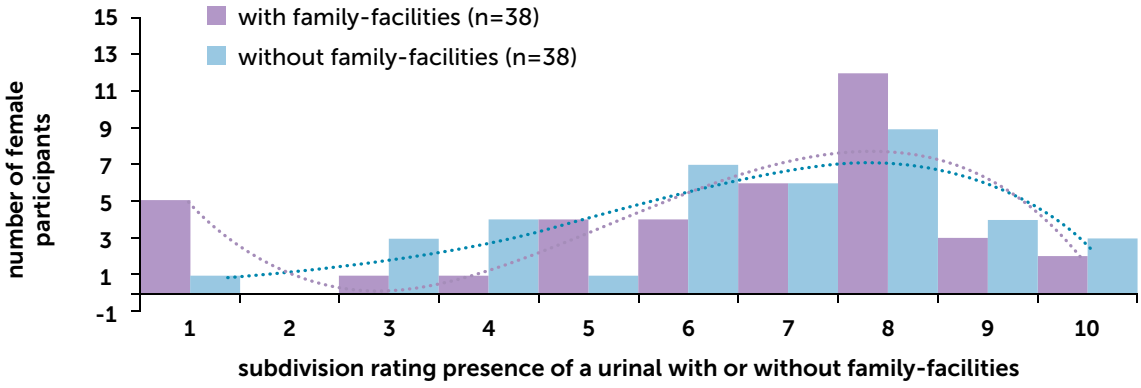


Figure 8.34 Rating presence of a urinal with or without family-facilities

Results young girls

The participant group was extended to test the design adaptations of mock-up 2b, and included five young girls. This resulted in more ergonomic and hygienic input on the children's platform near the toilet, the 10 cm higher position of the washbasin, the urinal, and other elements. The advantage of locating the children's step in the corner was that users would not be hindered by it, however this was also a disadvantage because the five young girls and their guardians did not directly recognise the indications of the step. After a while, thanks to the happy feet, three participants did notice it, however the hands on the mural wall were not noticed. After hints given by the researcher, two girls used the toilet sideways via the platform and one girl, on her mother's instruction, hovered above the seat using the platform. During the mock-up tests, the parents showed that they influence their children's use of the train toilet, and therefore of the toddler step. However, a toddler step is an unusual feature and parents need to get used to it.

The higher washbasin was too high for one girl who was also the smallest (1m).

Figure 8.35 The washbasin can be independently used by three of the five young girls

Results visually restricted participants

The participant group for mock-up 2b also included five participants with a visual restriction. Auditory feedback, especially that the door is locked, is important for this group. The function of each button needs to be clear as this group have difficulty distinguishing which function a button has. The most logical place for door controls is on the inside of the door, directly next to where the door opens.

Four of the five participants touched the urinal with their hands as soon as they entered the train toilet. The folding support provided for wheelchair users directly indicated where the sit-toilet is located. Adding a facility to clean the toilet seat in advance is important for visually restricted people because they find it difficult to determine the hygienic condition of the toilet seat. The flush knob was difficult for them to find.

Figure 8.36 Visual restricted participants touch the urinal when entering the train toilet

Results RQ C2a-4: Do participants accept the (reduced) transparency of the door of mock-up 2b?

In comparison with the semi-transparent door of mock-up 2a (figure 8.10), privacy was added (social distance increased S>) in the door sections of mock-up 2b (figure 8.25). As a result, the participants accepted the resulting reduction of anonymity; the majority of the participants (72%), n=104) experienced sufficient privacy and accepted the mock-up 2b door. Eleven participants were positive about the increase in spaciousness and security (<S). However, 28 % of the participants (n=104: 23 women and 6 men) were negative about the new see-through elements. Participants with a negative attitude doubted whether their privacy in the train toilet remained guaranteed. One female participant, noted that it would prevent her from using the train toilet.

Summary of results

Almost all male participants (25 of 26) were neutral or positive about the urinal's presence in the train toilet. The majority of the female participants were also either neutral or positive regarding the urinal's presence. Whether a urinal was clean or made dirty and providing family-facilities or not did not influence the females' evaluation. Despite the positive results of the test with a wash basin placed at 900 mm, we still recommend a height of 800 mm. Literature research and our own research in mock-up test 1 showed it to be the most appropriate height. In addition, it is important that young toddlers (2.5-4 years) can also use the washbasin. The semi-transparent door elements were accepted by the majority, however, a quarter reported having some difficulty with the transparency.

8.8 Discussion mock-up 2a & b

In this section, we discuss mock-up 2a and 2b and introduce study limitations.

To summarise, the following items were included in the design of the mock-ups to enhance train toilet hygiene: the integration of the urinal, family facilities, semi-transparent door elements, and the natural wall coverings. The integrated urinal played a central role in giving a hygienic impulse within the confined space of a train toilet. It reduced the mental distance (M) related to dirt and physical distance (P) between human body and toilet; this was enhanced by the natural wall. Social distance (S) between train travellers was mainly reduced by adding semi-transparent elements to the door; these were accepted by the majority, however it remains an issue that needs further research.

The tests conducted in mock-up 2b were double blind and held with a larger number of participants. The urinal was also made 'dirty' in some scenarios to gain more input about its acceptance by non-urinal users. The mock-up 2b results confirmed the mock-up 2a findings, mainly regarding the urinal's acceptance. The main result was that the urinal was accepted and train toilet users who do not use the urinal such as women and wheelchair users recognised its added hygienic value.

8.8.2 Limitations

Dirty urinal?

Mock-up 2b testing simulated a dirty urinal by inserting hair, smells, and fake urine (vinegar) (figure 8.28). We had expected that the urinal assessment would be more realistic and therefore lower if the urinal was made 'dirty', however this did not affect the toilet's assessment by female participants. Possible reasons for this lack of impact are discussed below.

First, the decorative and 'busy' wall print covered with natural elements (the "scribble wall") may have distracted participants' attention from a 'dirty' urinal. Furthermore, the decorative wall print discouraged scratching and graffiti by making it less visible in the background. We postulate that 'dirt' is much less visible on a colourful background.

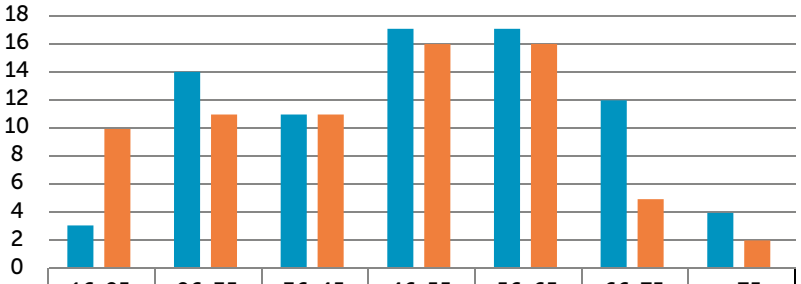
Secondly, the test situation was not a realistic 'dirty' environment. The participants were personally tested in a protected lab environment while pretending to use the train toilet; they kept their clothes on. Therefore, it was not possible for them to expect or encounter a dirty urinal similar to that in public environments where other users are involved. As a result, the participants may have neglected the dirt, and therefore did not take it into account in their assessment.

Thirdly, the level of soiling may have been too limited and even though it was consistently applied, it was difficult to perceive (also in figure 8.28). In addition, only the urinal was made dirty and not the other elements of the mock-up such as the washbowl, sit-toilet, mirror and floor. Therefore, the degree of dirtiness chosen by the researchers may not have had the desired effect on each participant.

In brief, participants may have perceived the dirty state of the urinal as unreal, perhaps enhanced by the smell of vinegar that is different from the smell of urine. For further research, it is recommended to apply the dirt in a more realistic setting with a higher, more visible level of dirt. Furthermore, the dirt should be not limited to the urinal. To conclude, the dirt needs to be applied in such a way that it appears realistic.

Female participant representativeness.

The majority of the female participants had a theoretical education and relatively few young people (aged 16-25) were recruited, (figure 8.37). The type of education (theoretical or practical) is assumed not to affect a toilet's assessment, as using a toilet is independent of education type in the Netherlands. However, this needs further research. The influence of age on the perception of hygiene also needs more research. Overall, the conclusions are expected to be valid with regard to age and education type.



	16-25	26-35	36-45	46-55	56-65	66-75	> 75
female participants	3	14	11	17	17	12	4
females Dutch population (CBS, 2011)	10	11	11	16	16	5	2

Figure 8.37 Age distribution of female participants (n=78)

Hawthorne Effect: to be extra positive to please the researcher

The double-blind mock-up assessment was introduced to minimise the Hawthorne Effect; a participant tends to please a researcher for the attention received and consequently be more positive about the mock-up. To avoid this, in mock-up test 2b, questions were asked as neutrally as possible, and the researcher was distanced from the research aims and the author. As some participants rated the urinal (very) poorly, the Hawthorne effect was not demonstrated (Franke and Kaul 1978; Kumar 2005). Moreover, the mock-up 2a tests were not conducted double-blind; they also did not show a Hawthorne effect.

Position flush-knob visually restricted participants

The flush-knob was difficult to find for the visually restricted participants, therefore the knob needs to be closer (10 mm) to the unfolded toilet lid, see figure 8.38.

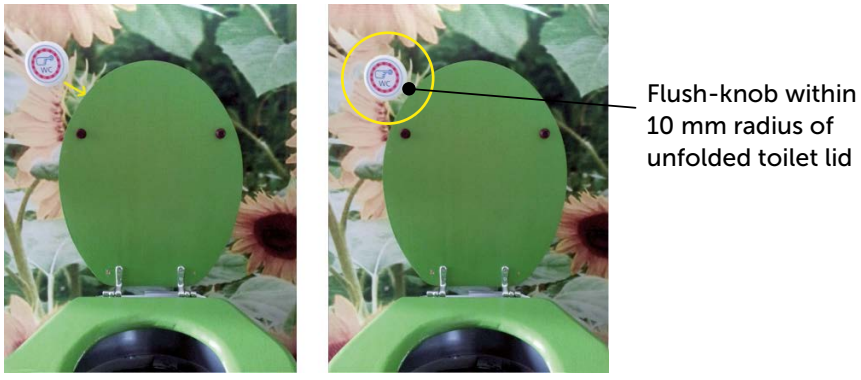


Figure 8.38 Flush-knob within 10 mm radius of unfolded toilet lid

Contrast indication children's platform sit-toilet

The hands on the mural wall were not noticed while the feet with a white background were. The combination of the hands and feet had the desired effect that some girls were led to the platform. Therefore, it is recommended to increase the contrast between these elements and the underlying 'scribble wall', see figure 8.39.

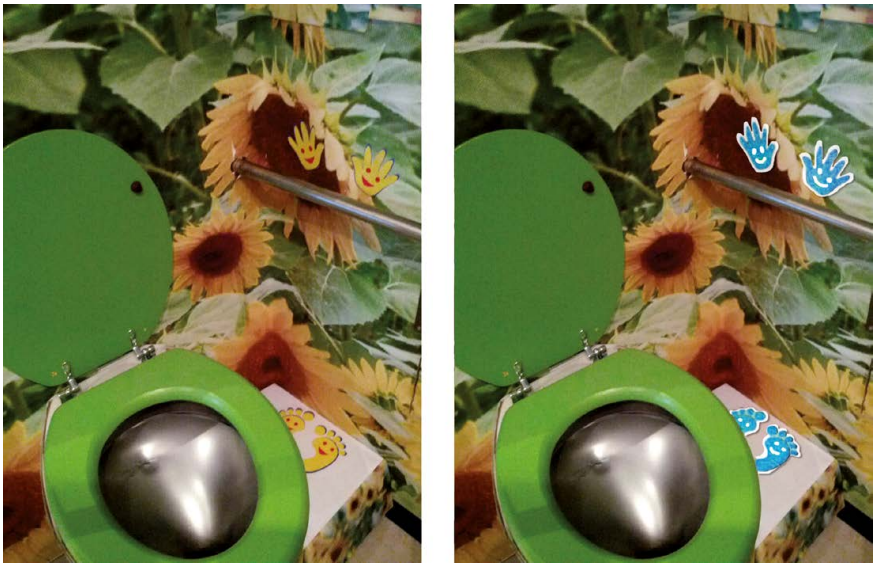


Figure 8.39 Adaptation of the children's platform indication sit-toilet

Wall decoration

The wall decorations were tested in a realistic situation in a moving train, see figure 8.40. The sunflower decoration was a victim of graffiti, in contrast to the forest wall. In addition, tags were applied on the light-coloured ceiling. Graffiti and scratching are perceived to reduce people's perception of hygiene and are complicated phenomena that need to be addressed and investigated further. Graffiti-artists are continually searching for a moment to deliberately place the tag, which is difficult to prevent in a private confined space with a maximum social distance between people (S).

Figure 8.40 Wall decorations tested in NS train toilets

8.9 Mock-up 2a & b conclusions

RQ C2: What are the implications for train toilet design through mock-up testing 2a & b?

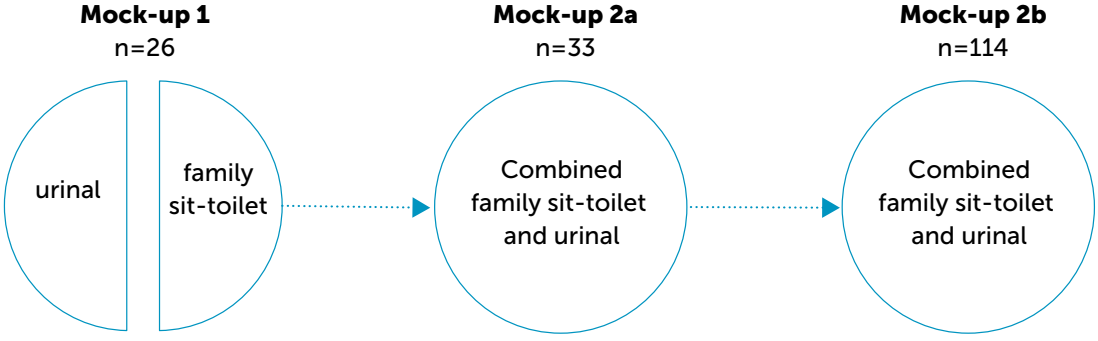
1. A toilet lid that closes the sit-toilet is necessary. For example, a sit-toilet with a folded lid is sometimes used as a chair to prepare a catheter.
2. The decorative wall is recommended, and for variety, five different prints could be used within the nature theme.
3. The door covered with semi-transparent elements was accepted, however this aspect needs to be examined further. Alternative methods to reduce social distance (S<) by creating a certain level of perception of train toilet visitors and other train travellers also need to be explored.
4. The baby-changing table should prevent a baby from rolling off it. If there is a side not enclosed by the wall or guardian changing the nappy, the baby's feet should lie towards this open end.
5. The extra broad toilet rim with an extra-large opening was rejected.
6. The height of the washbasin should be 800 mm.
7. A foldable child platform under the urinal and a child platform in the corner of the sit-toilet at a height of 200 mm are recommended.
8. A horizontal support bar should be added at a height of 1,400 mm from the ground above the urinal.
9. The family sit-toilet integrated with a urinal was positively assessed. The majority of female participants understood the hygienic value and will accept the presence of a urinal in a train toilet environment.
10. Statements by female users show that the presence of a urinal encourages female users to use the sit-toilet while seated, thus reducing physical distances to the different types of toilets.
11. The community of visually-restricted people such as Bartiméus and Visiris needs to be informed about the presence of a urinal in the train toilet.

Overall, we conclude that a urinal combined with a sit-toilet, with additional support options for hands, including horizontal and vertical support bars, and support platforms for children's feet, need to be integrated into train toilets to improve usability and related hygiene.

The addition of a urinal alongside a sit-toilet, added child and baby elements, support options, and a natural wall decoration with a large mirror, will reduce the underlying physical (P), mental (M), and social (S) distances between train toilet, dirt, and train. We recommend that this type of new train toilet be implemented by the NS.

Part C: design

Recap



Testing and design development of mock-ups 1 and 2 with 173 participants

In the design of part C, we answered the research question: **'What are the implications for design of a hygienic train toilet?**
In the mock-ups, we brought together our research and design elements, using observations, questionnaires, assessments, and comments from 173 participants.

A high degree of anonymity (large social distance (S)) and movement are predominant in a train toilet environment. Therefore, compared to public toilet design, the design of mock-ups 1 and 2 paid extra attention to the anonymous (large social distance S) and shaky environment of train toilets using transparent elements to reduce social distance (S) and by providing additional support options.

The mock-up 1 train toilet design concept of chapter 7 was based on train toilet usage. It resulted in a separate standing and sitting/hovering domain of use, translated into two modules of a urinal and a family sit-toilet, respectively. A urinal reduces the physical distance (P) between the human

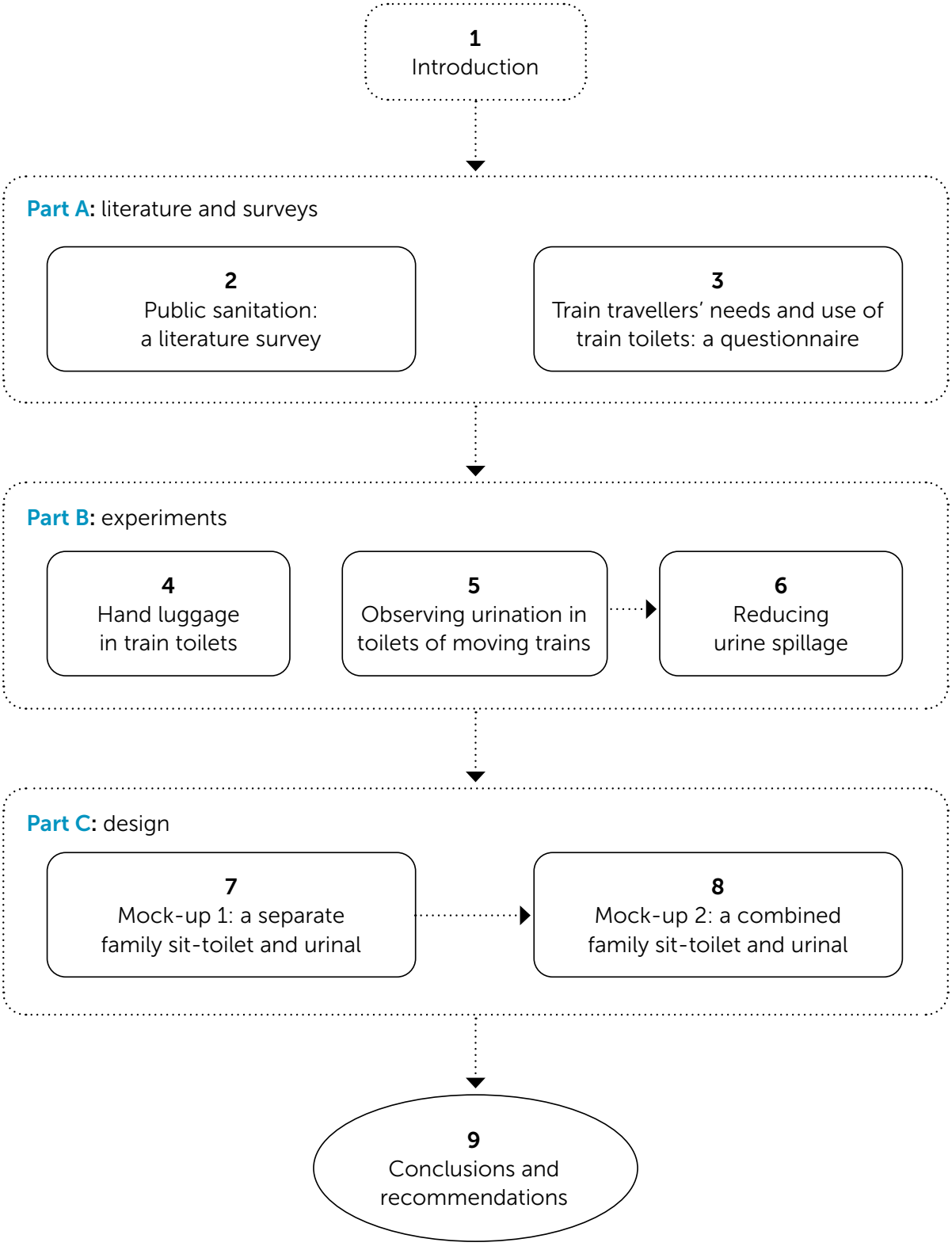
body and the toilet while using the toilet, because the toilet is brought closer to the user's body. It also reduces the mental distance between dirt (M). A urinal is used for urination; it excludes 'out of place' faeces from unknown users, which generates the greatest mental distance (M).

The family sit-toilet contained the family-elements such as the special toilet seat, additional support options, children's platforms and a baby changing table in a space that is locked by a round sliding door. This module was designed to encourage users to reduce physical distance (P) by moving their body towards the toilet in a sitting or hovering position.

Chapter 7 shows that participants rated mock-up 1 positively, but, the separate urinal, in particular, created a social distance (S) between men and other users such as women, wheelchair and rollator users, young girls, babies and transgenders, which compromised the design's inclusiveness.

Therefore, in Chapter 8, we tested two versions of mock-up 2 where we integrated the design aspects of mock-up 1 in one module. The urinal was combined with a sit-toilet, with additional support options for hands, including horizontal and vertical support bars, and support platforms for children.

We tested this mock-up with more participants including visually restricted people regarding ergonomics and the recognition of a urinal. The resulting design is currently being implemented in Dutch intercity trains.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Chapter 9 Conclusions and recommendations

9.1 How design influences train toilet hygiene

This PhD project was initiated in 2009 as a partnership between Delft University of Technology (TUD) and Dutch National Railways (NS) with the aim of changing the undesirable situation of dirty train toilets that affect peoples' willingness to travel by train. NS wanted to find ways of improving their intercity train service by prioritising hygiene in train toilets for longer journeys. This would remove a potential barrier to train travel for specific traveller groups like older adults, especially those with mobility problems, and families with younger children.

Primary toilet use is a little-studied field; only a few papers have been published (e.g., on urination, defecation and and practices related to menstruation). These concern stationary public toilets; no prior research has been conducted on the use of train toilets in a moving environment. We therefore set out to determine how a design team can improve the cleanliness of moving train toilets. The focus is on train toilets in Dutch trains and how train toilet usage affects hygiene. The central research question is therefore: **How does design influence train toilet hygiene?**

As *human-product-interaction* is the central issue, the TUD research team addressed the project at three levels: At faculty level, this project addressed one of the three key TUD research themes – Mobility. At the level of Human Centered Design, the team approached it from the perspective of usage, comfort and safety. At an Applied Ergonomics and Design level, we examined hygiene as an independent phenomenon and evaluated the interdependency with usage.

The phenomenon of hygiene is a human 'life issue' and can be interpreted as a 'broad' phenomenon. Therefore, we decided to approach this study and examine its counterpart, the phenomenon of dirt. People consider sanitation 'dirty', they are unwilling to deal with it i.e. they keep a large *distance* from it. NS facilitated a set of experiments so that we were able to research 'live' train toilet usage to show how train passengers engage with their personal hygiene in the context of train travel. Our model shows the interaction between the 3Ts: travellers (personal hygiene), toilet (product hygiene), and the train (environmental hygiene).

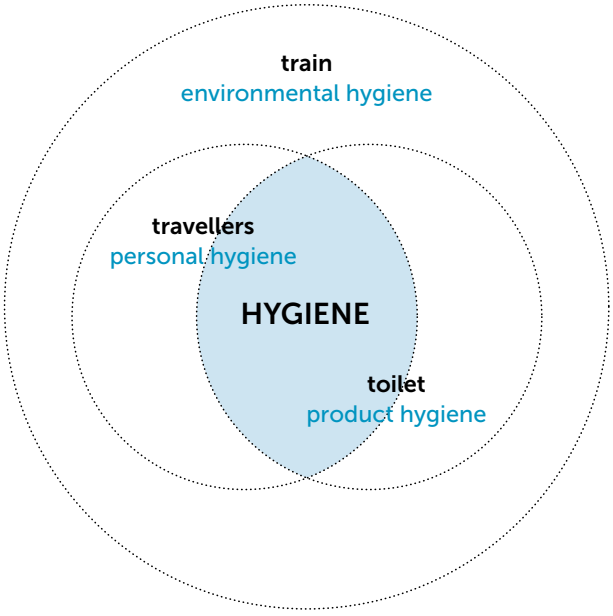


Figure 9.1 Research model

In section 1.5, the research questions addressed in this dissertation are described in detail, grouped in three parts. In chapter 9, the three main research questions are revisited. These are summarised below.

PART A: LITERATURE AND SURVEYS

Part A is a theoretical exploration of the phenomenon of hygiene based on literature research and a questionnaire completed by 1267 respondents, in which travellers revealed their personal hygiene needs and toileting usage in the context of train travel. In summary, people perceive public and train toilets as being dirty, but why is that? We answered the research question:

RQ A: Why are train toilets perceived as being dirty?

PART B: EXPERIMENTS

In Part B, we used this knowledge and studied the interaction between toilet usage and hygiene through experiments and explored the effect of train toilet usage on train toilet hygiene. We answered the research question:

RQ B: How does its usage affect train toilet hygiene?

PART C: DESIGN

In Part C, we translated the resulting knowledge into a physical design of two mock-ups, 1 and 2, and described the tests of these mock-up among 173 participants. We answered the research question:

RQ C: What are the implications for design of a hygienic train toilet?

Finally, we address the overarching research question is this chapter: Chapter 9:

CONCLUSIONS AND RECOMMENDATIONS

RQ How does design influence train toilet hygiene?

In sections 9-2-9-4, we describe RQs A, B and C and finish with answer to the overall question of how design influences train toilet hygiene in section 9.5, followed by a proposal for a hygiene model of sanitation, developed based on the knowledge gained in parts A, B and C. Subsequently, in section 9.6 we reflect on the project's strength and weaknesses, and in section 9.6.3 we add a reflection on Covid-19, the pandemic that arose when writing this last chapter. We close the thesis with recommendations for further research in Section 9.7.

9.2 Why are train toilets perceived as being dirty?

In part A, we set out to answer the **research question: 'Why are train toilets perceived as being dirty?'**

In chapter 2, we addressed the **sub-question A1: 'What has been researched in public/train toilets and hygiene domain?'** We reviewed the literature on sanitation and the history of personal hygiene as well as findings from regular NS surveys. We found that toilets and related systems have played a leading role in improving hygiene conditions; clean toilets are a symbol of development and civilisation. Furthermore, we described the surveys of the Dutch National Railways (NS), in particular, their customers' findings.

The conditions of train toilets worsen people's perceptions of hygiene because they are intensively used by a wide variety of people in a moving, confined, anonymous and gender-neutral environment. In between, they are infrequently cleaned; a facility for cleaning a train toilet for those who have just used it is unavailable in train toilets. Gradually, the train toilet becomes increasingly dirty.

Subsequently, in chapter 3, we placed the needs and usage of train toilet users in the context of train travel. Together with the NS, we designed an online questionnaire that was sent out to the NS travellers' panel to answer **sub-question A2: 'How does train travel affect train toilet users' needs and usage?'** The 1267 NS panellists who responded formed a solid basis that eventually led to the design of a new NS toilet that will improve the hygiene of train toilets and, as a consequence, their use.

Our findings helped us identify the three key elements of our proposed model. We noticed a **Physical** distance (P) between human body and public/train toilets (figure 9.2a), including issues like carrying hand luggage in train toilets.

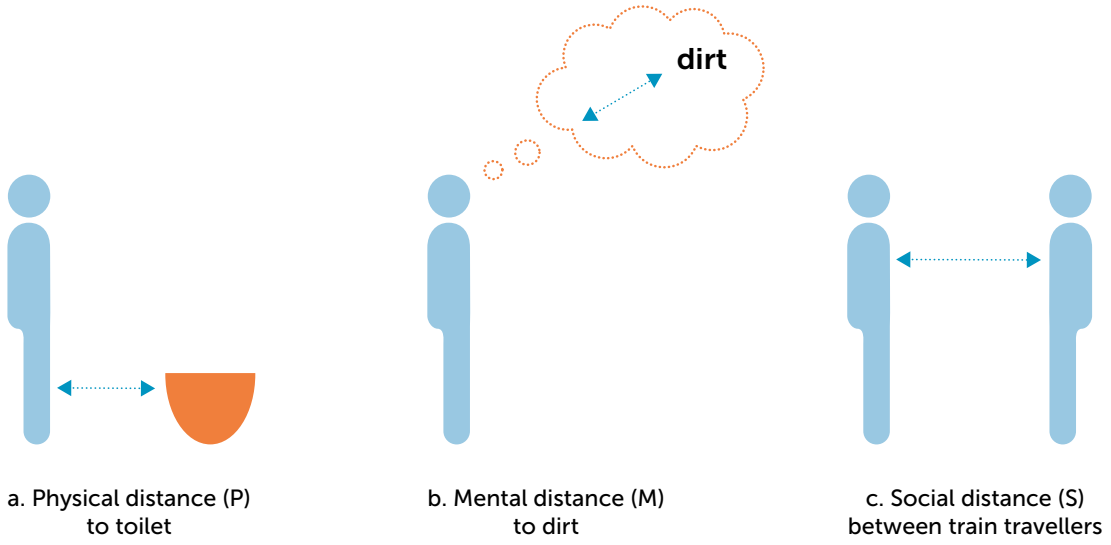


Figure 9.2 The identified distances that influence (train toilet) hygiene

People perceive a **Mental** distance (M) between the human body and what we have defined as human 'dirt': toilets with faeces, urine, blood, and toilet paper, out of place (figure 9.2b). We find this type of (human) dirt particularly disgusting, and have learned to avoid it to prevent disease.

We identified the **Social** distance (S) that occurs when the dirt belongs to unknown users, i.e., between whom there is a wide social distance. This is defined as the distance between people's bodies, (figure 9.2 c). Travelling by train in the Netherlands is already relatively anonymous. The remote location of the train toilet on the balcony reinforces the wide social distance (figure 2.14).

9.3 How does its usage affect train toilet hygiene?

In Part B, we describe a series of research experiments in which participants' train toilet use was observed in train toilets in moving trains. The experiments were made possible in collaboration with NS (Dutch railways), with cameras and recording equipment being placed in the toilets to observe exactly how a group of participants (with informed consent) used the toilet while urinating or defecating. The research sub-questions answered in chapters 4-6 were based on the results of the literature review and the questionnaire sent to participants, described in Part A. We found a number of factors related to the use of train toilets: access is affected for people carrying luggage, and people have hygiene issues related to their main use, urination.

The experiments in part B thus focus on the use of the train toilet with regard to hand luggage and urination, the themes of chapters 4 and 5 respectively. In chapter 6, we further investigate the issue of urine spillage observed in chapter 5. Taking the findings from chapters 4-6 together, Part B answers the **main research question: How does its usage affect train toilet hygiene?**

In chapter 4 we addressed the **sub-question B1: What do travellers do with their hand luggage when using the train toilet?** Our observations showed that travellers maintained the largest *physical* distance possible between their hand luggage and dirty locations; they tried to store their hand luggage far away from the (dirty) toilet bowl, and the majority did not place their luggage on the (dirty) floor. Travellers where possible stored luggage using their bodies rather than on the currently available storage hook for coats and hand luggage.

We conclude that when designing adequate storage place in train toilets, designers need to account for both comfort and hygienic aspects. The use of people's bodies for luggage storage while using the toilet is not ideal. In terms of comfort, the storage facility needs to be within easy reach of all travellers, i.e. a hook at appropriate height, visibility and safety. Lastly, designers need to investigate how to provide adequate storage places for other 'luggage' items such as diapers, colostomy equipment, catheters, wheelchairs, walkers and strollers, as well as suitcases.

In order to answer **RQ B2 'How do train movements affect urination performance?'** chapter 5 focuses on the answers to the four research questions: 'What postures do people adopt while urinating in train toilets?', 'Which urinary hygiene actions (UH) are used?' and 'Does urine spillage occur, and why?'

Most men stood while urinating (figure 9.3a), and women hovered or remained seated in equal numbers (figure 9.3b and 9.3c). This corresponds to males' first nature; they are reluctant to adopt seated usage. In contrast, sitting is women's second nature, gradually adapted from a first nature of squatting. As UH actions, most male participants use agitating and squeezing as UH action, and women use toilet paper, reflecting their first and second nature, respectively.

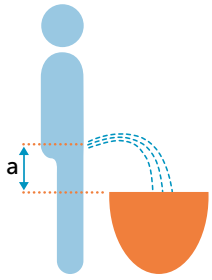


Figure 9.3a Standing posture

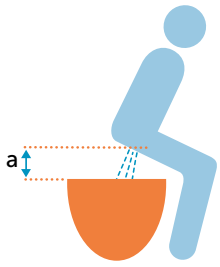


Figure 9.3b Hovering posture

Figure 9.3c Sitting posture

Figure 9.3 The larger the physical distance (P) between human body and the toilet, the dirtier toilets become

We observed that urine spillage was common and strongly related to the standing urination posture of male participants. In chapter 5, we describe how we used a thin sheet of paper to demonstrate the spillage of fine urine sprays. The urine stream needs

to bridge a long physical distance (P) until it reaches the sit toilet. Women, on the other hand, can reduce this distance and the resulting spillage by bending their knees, which is unnatural for a man as they naturally remain standing without bending their knees (figure 9.3).

Train movements caused participants to take support actions to achieve posture stability. Because of the movements, women are more likely to sit down on the toilet seat as mentioned in the questionnaire in chapter 3 and as observed in chapter 5. This in contrast to the men, who remained standing while urinating. Spillage directly linked to the train's movements happened in several observations. In chapter 6, we show that the larger the physical distance (P) between the toilet and the body, the more urine spillage outside the bowl, mainly resulting from backsplash.

We observed that the usability of train toilets containing only sit-toilets was inadequate. Furthermore, the movements of the train sometimes threw the participants off balance and often caused them to use support actions to maintain posture stability. Therefore, we recommend that, in order to improve hygiene by reducing spillage, the NS adapt their train toilets to include both a sit-toilet for hovering and sitting postures, and a urinal for the standing posture.

Therefore, a urinal should be added to the current toilet placed in a higher position, thus shortening the distance between the urine stream and the toilet. This gives the user greater control over the flow of urine and reduces the backsplash that leads to spillage; this was examined further in chapter 6. Moreover, having men use the urinal can encourage female users to use the sit-toilet while seated, a urination posture that also provides stability. Furthermore, support bars should be positioned in the vicinity of the sit-toilet and urinal and close to the washbowl to provide users with posture stability. For children, we advised NS to integrate child platforms into the confined space. Chapters 7 and 8 describe the train toilet designs and the research conducted with 173 participants.

In summary, a urinal combined with a sit-toilet, with additional support options for hands, including horizontal and vertical support bars, and support platforms for children's feet, need to be integrated into train toilets to reduce urine spillage and improve hygiene and usability.

9.4 What are the implications for design of a hygienic train toilet?

Part C describes the design of the hygienic train toilet and the test of two mock-up train toilets, complete with urinal and sit toilet. The mock-ups and the tests were designed to answer the final research question: **RQ C: What are the implications for design of a hygienic train toilet?**

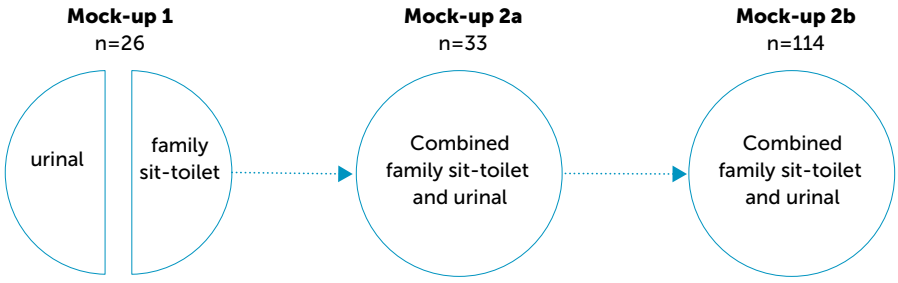


Figure 9.4 Testing and design development of mock-ups 1 and 2 with 173 participants

In chapter 7 we describe the design of the mock-up 1 train toilet. We created a separate standing and sitting/hovering domain of use, translated into two modules: a separate urinal and a family sit-toilet. The urinal reduces the physical distance (P) between the human body and the toilet, as the distance from the user's body is minimised. This also reduces the mental distance (M) associated with dirt, as urine and faeces are separated.

The separate sit-toilet contained family-elements such as the special toilet seat, additional support options, children's platforms, and a baby changing table in a space locked by a round sliding door. It was designed to encourage users to reduce the physical distance (P) by directing their bodies towards the toilet as much as possible.

The test of mock-up 1 showed that participants rated the new toilets positively, but, the separate urinal created a social distance (S) between men and other users, which compromised the design's inclusiveness.

In chapter 8, we describe the design of mock-ups 2a and 2b based on the findings from mock-up 1. The design of the mock-ups was based on our take on the saying, 'if the toilet environment cares about its users, they will take care of their train toilet environment', known as the "broken windows" theory. Our second saying is, 'the perception of train toilet hygiene of the train toilet is greater than the sum of its parts' – which include the toilet bowl, the toilet seat, the urinal, the washbasin, the children's platforms, the support options, the hand luggage hooks, the mirror and the natural wall.

In mock-up 2, extra attention was paid to reducing the social distance (S) by including transparent elements in the door. Furthermore, the toilet was fitted with additional support options and 'natural' wall coverings. In mock-up 2a, we integrated the design aspects of mock-up 1 in a single module: the toilet included both a urinal and a sit-toilet with additional support options including horizontal and vertical support bars, and support platforms for children.

Following the test of mock-up 2a with 33 participants, we changed a number of design elements and tested mock-up 2b double-blind with greater numbers of participants (114), including young girls and visually restricted people, to assess the ergonomics and the recognition of the urinal. The mock-up 2b results confirmed the mock-up 2a

findings, mainly regarding the urinal's acceptance. The main result was that the urinal was accepted and that train toilet users who do not use the urinal recognised its added hygienic value.

The tests of the mock-ups 2a & 2b successfully answered RQ C. We demonstrated that public toilet hygiene, including train toilets, can be improved by applying design elements to reduce the three underlying distances: the physical distance between the toilet (P), the mental distance between dirt (M), and the social distance between train travellers (S).

The final toilet design was based on the findings from mock-up 2. It is currently being implemented in Dutch intercity trains.

9.5 How does design influence train toilet hygiene?

We set out in this dissertation to determine how the design of train toilets can improve both usability and the related hygiene so that users can leave the toilet cleaner and tidier for the next user. The central research question is therefore *how does design influence train toilet hygiene?* We interpreted hygiene as a broad concept, therefore, we examined the counterpart of hygiene, the phenomenon of dirt, which Mary Douglas describes: "as a matter *out of place"*.

During the three phases of this thesis (A, B, and C), we observed three underlying and connected distances: (P, M, S) that influence hygiene perception (H). We describe the relation between design and these terms and propose a hygiene model of sanitation.

9.5.1 Relation between Design and observed distances

Design influences hygiene positively by reducing the underlying Physical distance (P) between the user's body and the toilet, the Mental distance (M) between user and dirt, and the Social distance (S) between user and people/train travellers, see figure 9.5.

To reduce the physical distance between the human body and the toilet (P<), the facility can either be moved to the human body, or the opposite, the human body can be guided to the product. Therefore, we designed a toilet which included a urinal alongside a sit toilet and support options. Accordingly, the design prevented dirt from ending up "out of place"; indicated as spillage in the train toilet environment.

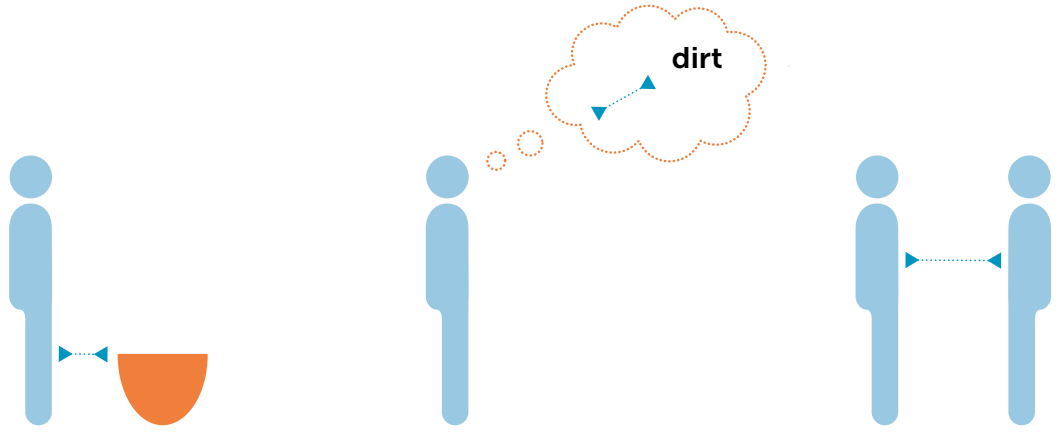
To reduce the mental distance between user and dirt (M<) their attention can be shifted from a dirty to a clean (first) impression when users enter the train toilet. They first are confronted with aspects unrelated to human dirt: i.e., themselves in the mirror, washbasin, and the nature wall with a coating to combat graffiti and scratching. Subsequently, they notice a urinal that specifically emphasises urination, visibly

excluding defecation, between which the mental distance (M) related to faeces is greater than that of urine. In general, people visit toilets more frequently to urinate than to defecate.

Furthermore, the elements for children (platforms and baby changing table) reduce the social distance between people/children (S<), and to a lesser extent the mental distance (M <) because our dirt tolerance towards children is higher.

The social distance between a user's body and other people can be reduced (S<) by introducing the following design elements: a wide sliding door, the addition of tables, folding chairs, or a hand wash facility in the anonymous balcony area, all of which can create a certain level of perception of mutual presence. Nonetheless, the desired privacy (i.e., a minimum social distance) when using the toilet is guaranteed because the door can be closed and locked. Accordingly, we hypothesise that the increased perception of train toilet visitors by other train travellers will encourage the user to remove a train toilet's dirt for the next user. However, this hypothesis needs further research.

Adding to the design implications, we propose to support the users' hygienic intentions caused by reduced social distance (S<), as it would be beneficial if the user's dirt remains were removed immediately after usage. Therefore, on the one hand, and currently -in relation to Corona - we propose that the train toilet be equipped with a facility that allows the user either to pre-clean the contact surfaces before using the toilet; or a hand wash facility that helps the user not to touch a surface with bare hands after washing their hands. We also recommend designing a device that allows the user to clean the train toilet after use. We assume that this will reduce physical distance and mental distance because, in physical terms, users may be less reluctant to touch surfaces with their bodies after cleaning them (P<). In mental terms, these design interventions give the user the ability to influence the removal of dirt on surfaces and thus reduce the mental distance between dirt (M<).



a. Reducing physical distance (P) to the facility

b. Reducing mental distance (M) related to dirt

c. Reducing social distance (S) between people

Figure 9.5 Reducing Physical, Mental and Social distances

9.5.2 A proposed Hygiene model of Sanitation

In this subsection, we propose a hygiene model of sanitation that consists of the three underlying and interconnected distances. We discuss the following opposite situations: one perceived as very dirty, indicated as H ≈0, and the other with excellent hygiene, expressed as H ≈ 1

We describe Hygiene (H) as a function of the Physical (P), Mental (M) and Social Distance (S) as follows. In this thesis, we propose an initial formula that can be quantified and verified by future researchers:

$$H = \frac{a}{P} + \frac{b}{M} + \frac{c}{S}$$

H = Perception of hygiene of the user (of the public toilet environment).
We define hygiene as the opposite of 'out of place' sanitary dirt.
The aim is that the sanitary/human dirt (faeces, blood, urine, hairs, paper, and water) ends up in the intended places, "not out of place", and therefore is no longer perceived as dirt.
Sanitation describes the facilities that manage human waste and where people can clean their bodies (i.e. toilet and sewage system, bidet, washbasin, bath and shower).
The value of H lies between 0: extremely poor hygiene and 1: excellent hygiene.

a,b,c = Weighting factors depending on context.

P = Physical distance between human body and toilet or other sanitation amenities such as a washbasin, shower, bath and bidet (inversely proportional with hygiene).

M = Mental distance related to sanitary dirt, i.e., the psychological or emotional distance people keep with their body from dirt, out of place (inversely proportional with hygiene).

S = Social distance between the user of the sanitary amenity (with or without toilets) and other people in the vicinity. A distinction is made between private and public environments. In a private situation, social distance is small because the toilet users are known. In contrast, in a public space that concerns public hygiene, the users are unknown (inversely proportional with hygiene). Moreover, there is a limit to the degree of social distance in a public space as people desire a minimum degree of anonymity.

Explanation relationship (P, M, S): H ≈ 0: Poor hygiene

Very poor hygiene (H≈0) is assumed in a situation of a public toilet cubicle with a sit-toilet without an installed water flush, for example as at a public toilet facility along the motorway: $P^{largest}$, $M^{largest}$, $S^{largest}$

P. The physical distance is largest (P>). Firstly, this type of toilet can raise a barrier to toilet entry in the first instance (P>) because of the expected large mental distance

(M), which shows the interdependence of both physical and mental distances (P and M).

M. The mental distance is largest because all human dirt types come together and cannot be removed by a water flush (M>). Water has a hygienic value, therefore reduces the distance between dirt (M<).

S. The social distance (S) is largest ($S^{largest}$) because the facility is installed in an anonymous environment (S>). Users of the facility and others in the environment have little or no perception of each other (S>).

Automated toilets that clean a (public) toilet after each usage reduce mental distance between dirt (M<) because they remove dirt immediately. As a result of their cleanliness, they reduce the Physical distance (P<). Consequently, the perception of hygiene increases as both the physical and mental distances are reduced (P, M <). However, automated toilets increase Social distance (S>) because the sense of anonymity intensifies. There is a lack of a human aspect as cleaners are not involved in automated toilets.

H ≈ 1: excellent hygiene

The conditions for excellent toilet hygiene can only be achieved in a 'family home' situation:

P = 0, M = 0, S = 0.

P. The physical distance is small (P^{small}). It is assumed that the toilet is used in sitting posture: (P = 0). If men or (young) boys use the toilet in a standing position, the physical distance increases: (P>).

M. The mental distance is reduced (M<) if faeces are not involved and the toilet is clean (by frequent cleaning), M ≈ 0. The mental distance is small ($M^{small)}$, but M > 0 if faeces are involved in a private toilet environment.

S. The social distance is the smallest (S = 0) when partner and or children are involved because they are part of the 'intimate-family' who use the toilet.

However, social distance increases (S>), and the perception of hygiene decreases when other people use the family home toilet, for example, visiting grandparents, other family members, (close) friends or neighbours. This depends on the *relationship* people have with these users.

Anonymity is the dimension in public toilets that we aim to influence by reducing social distance (S<); this improves hygiene according to our proposed hygiene model. However, the degree of social distance has a limit because the physical and social distances (P and S) are closely linked. Alternatively, a barrier to using the toilet may arise S<, P>. In other words, *we desire a certain minimum degree of anonymity* in relation to other toilet users, which, it is worth noting, also depends on culture. (Smin). In the case of train toilets, for example, or office toilets, too many (familiar) people in the vicinity of the toilet may prevent its use because of a desire for privacy to avoid a sense of embarrassment.

Further research is needed into the specific value set regarding the distances (P, M, & S) and the proportions that the separate distances take in relation to the perception of

hygiene (H). We determined that we could express the physical (P) and social distances (S) in metres, i.e., the distance between the human body and the used facility(P), and between other users or people (S). However, further research is needed on how to quantify the more 'abstract' concept of mental distance (M).

9.6 Reflection

9.6.1 Process

TUD approached NS Dutch Railways to collaborate on this thesis, and we were fortunate; with our research question, we were in the right place at the right time. The project grew during the dissertation and many research opportunities came along with it. A toilet lab was set up (appendix A.7.1), and many students were involved in this study with their own projects (appendix A.1.1). The NS gave us access to their research, agencies, and panel.

At the time, the modernisation of the intercity train had appeared on the horizon. The strength of the project was the close cooperation between TUD and NS, right from the start. The problem was clearly recognisable: dirty train toilets, an issue which everyone involved was prepared and willing to tackle. The transparency of the available information improved the quality of cooperation.

In terms of planning and focus, one party, the public press, kept the author sharp and on her feet, but this required a great deal of effort, and distracted her from the more academic side of the work: the dissemination.

With regard to searching the literature, the academic environment seems to have kept a safe distance from toilet-related research; little has been published. Moreover, it was difficult to obtain ethical approval afterwards and get chapter 5 published, because of the 'controversial' subject of urination. Together, this led to great delays in writing it: the final publication is now part of this dissertation, rather than a separate publication. The process for the work discussed in chapter 4 also took time, with extensive revisions to be accepted. Still, this was a more straightforward process as it was related to the subject of hand luggage, which the scientific community has slightly less problems with than the subject of urination.

Funding the research was a major concern; it would have been better to have longer term funding than the piece-meal funding received each year. On the other hand, I benefited from the experience gained by writing proposals for financial support.

Hygiene is a broad phenomenon. Getting a grip on it is no easy task, in this or in other areas. It is unsurprising that the millennium goals related to sanitation are nowhere near the targets set. Furthermore, toilet design has not really changed in the last century

due to all the restrictive standardisation guidelines: it seems that innovation in the toilet world is a complex task.

The valuable lesson learned for the author herself is that the essence of doctoral research and perhaps in general for any project, is to find and keep the focus. Moreover, by writing this thesis, I have learned to find silence by reflecting on the differences between all your own expectations and those of others.

9.6.2 Outcomes

Train toilet design
Recently, NS modernised the double-decker VIRM intercity trains including the new NS train toilet designed by the author in cooperation with NS (figure 9.6). Furthermore, the specifications for a hygienic train toilet resulting from this research will become the standard for NS intercity trains. This new train toilet ergonomically and hygienically supports different forms of usage.

We designed a train toilet that integrates a sit-toilet (1) with a urinal (2) and other items such as a baby changing table, extra support options for the hands of all users (3), and platforms for children's feet (4), into the confined space.

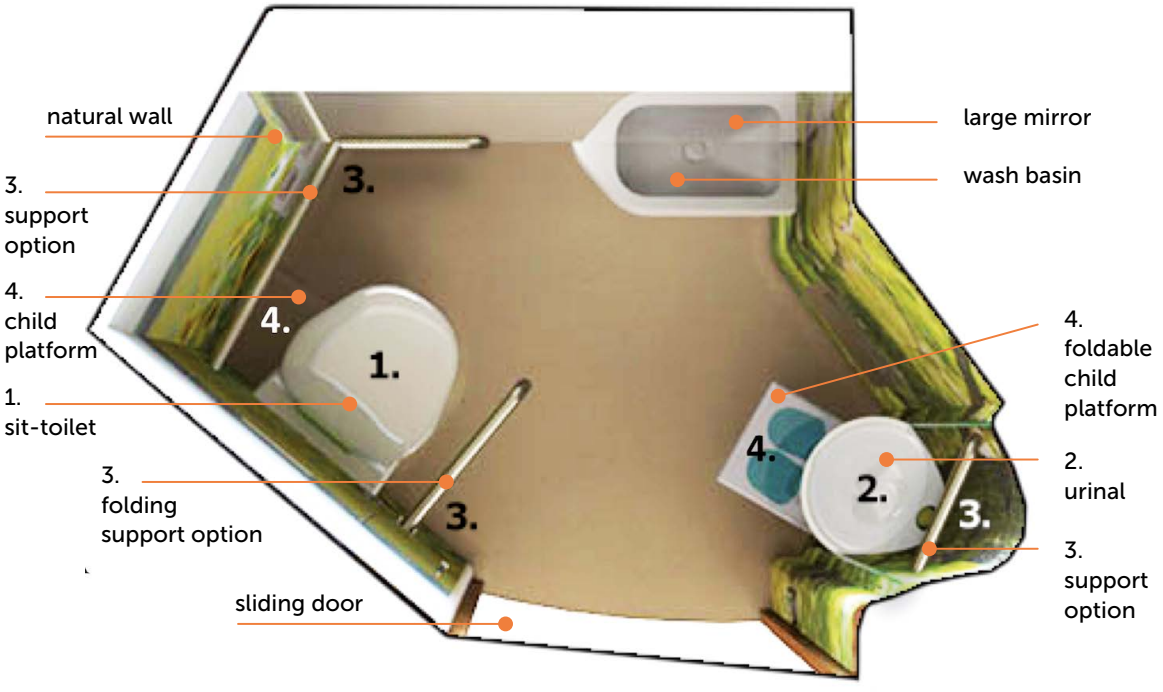


Figure 9.6a Train toilet design proposed by the author

Figure 9.6b NS train toilet currently being implemented in intercity trains

Figure 9.6 New train toilet design 1= sit-toilet, 2=urinal, 3= support options, 4= children's platforms

The following elements were not included in the NS train toilet mainly for cost reasons, but also due to usability issues: children's platforms (4, figure 9.6a), baby changing table, the special toilet seat 1, figure 9.6a), the horizontal support bar above the urinal (3, figure 9,6a), and finally, the door with semi-transparent elements (figure 8.25). We reflect by summarising a number of these items and refer to Appendix A.9.1 for an extensive explanation.

We rejected the special toilet seat (1, figure 9.6a) because the mock-up testing 1 and 2 did not show that it stimulated seated usage, which was the main reason for its introduction. The reason for replacing the tested (26 male participants) horizontal support option (3, figure 9.4a) with an untested vertical support bar (3, figure 9.6b) was likely to be because of its easier installation. Further research of this vertical support bar is necessary with regard to its usability and view on the direction of the urine stream.

The door with semi-transparent elements was not adopted mainly for costs reasons, but more research is also needed with regard to the wish of privacy when using a toilet, which is becoming increasingly important. The see-through elements were replaced by a large sliding door (figure 9.4a) that creates a moment of perception when opening and closing the door when entering and after using the train toilet, thereby reducing social distance (S<), while during toilet usage, the maximum social distance remains. Thanks to the reduction in social distance, people are more aware that not only they, but also other people use the toilet. It places the usage of a toilet in a social context, even though they consider it a private matter. We postulate that the user is more likely to leave the toilet cleaner for the next user because of an incentive to show hygienically cooperative behaviour. This aspect needs to be confirmed by research.

Furthermore, the NS design team added more storage space for hand luggage both at the entrance of the train compartment, placing an additional hook in the new train toilet design, see appendix A.9.1, and figure A.9.1.1.

In addition, the NS have created design interventions to make train travel less anonymous. By placing lounge sofas in trains their designers created social encounters reducing social distance (S <) (figure A.9.1.1a). They involved the train toilet more in the train's interior and atmosphere by using the same look and feel and design decorations on both the train and train toilet walls (figure 9.6b). They also added a folding seat on the balcony in the vicinity of the train toilet.

9.6.3 Covid-19

Hygiene matters. While writing this final chapter, we found ourselves in the middle of the Corona (Covid-19) pandemic, which has put public hygiene in the spotlight. Toilet paper appeared to be a primary necessity in the western world; people started hoarding it from fear of depleted supplies. In the Netherlands, the government's central policy to prevent Corona is: not to shake hands, wash hands intensively, and maintain a social distance (S) of 1.5 m. If that is impossible, a face mask is required, such as in trains and airplanes and although a face mask was not mandatory in other public spaces, it is strongly recommended. More recently, the strict recommendation to wear a face mask has now shifted to an obligation when entering public indoor areas such as school buildings and shops.

The weakest link in public hygiene, the public toilets, are currently closed, but they are gradually re-opening. The cleaning profession is now much more appreciated; cleaners and intensive care staff were awarded a bonus for their contribution to Corona's struggle in the Netherlands (Rijksoverheid 2020).

The upward trend in the number of passengers using trains has abruptly dropped. The WHO asked the WTO to contribute to the standardisation of public toilets in relation to Corona, including transportation toilets. Our project now shows its true value: the ergonomic research conducted as part of this project has resulted in the functional specifications for improved hygiene of Dutch train toilets.

Epidemics are part of human life. While writing this dissertation, the diseases Sars, MRSA, Zika, and Ebola emerged. In the Middle Ages, communal personal hygiene changed into a private matter, driven by a fear of diseases such as the plague known as the black death that (like Corona) began in Asia. Subsequently, cholera swept through India in the early 19th century; it took at least half a century before it was recognised that the contamination went via water (Germ-theory) and not through the air (Miasma theory).

It is not exactly clear how Covid-19 infection occurs via the air and contact surfaces; this is still a matter of (scientific) research, and new vaccines protecting against Covid-19, have become rapidly available, in comparison with past epidemics. However, the simplest protective advice, keeping a safe distance, seems to be difficult to enforce in western nations.

Thanks to Covid-19, hygiene standards are becoming increasingly stricter, reinforced by the fear of disease. Because of the focus on handwashing, with facilities provided throughout the public space to enable people to disinfect their hands, people are now more likely to wash their hands after using the toilet. It is interesting to observe that, when conducting the study, some participants did not wash their hands after using the train toilet because they wanted to avoid touching anything in the train toilet environment.

Implications for design and Covid-19
From Covid-19 came the idea of three control options as design implications for public toilets. Firstly, to create a touch-free environment, for example, using sensors so that no transmission occurs from touching surfaces (figure 2.17). Secondly, to provide a facility in the public toilet environment so that the user can pre-clean contact surfaces like the toilet seat before use, as introduced in chapter 7, section 7.4.1. This type of facility can be particularly useful for visually restricted people, as they find it difficult to determine the hygienic condition of elements like the toilet seat (chapter 8, section 8.7). Thirdly, to use alternative body parts to operate devices, such as opening the door with an elbow, or using a foot to prevent surfaces being touched with the bare hand.

Given the human and natural nature of toilet use, options 2 and 3 have the best credentials for reducing physical distance while improving usability and the related hygiene. Sensor options are an attractive route, but they increase dependence on technology for basic functions and compromise the usability and related hygiene aspects.

In general, Covid-19 highlights the need for washing hands in the public environment without touching anything afterwards. This promotes the idea of adding a hand wash facility outside the train toilet area for passengers other than toilet users who have their washbasin inside, as suggested in chapter 7.1.2. This will also serve to reduce social distance (S<) between train passengers, which once again improves hygiene as discussed in section 9.5.

9.7 Recommendations for future research

The recommendations for future research are based on the chapters of this dissertation. In addition, general directions for the domain of sanitation are included; these were not specifically addressed in this thesis.

9.7.1 Evaluating the Hygiene Model of Sanitation and the design in the train

The use of the hygiene model of sanitation in the design to improve the hygiene of public toilets needs to be further explored. The model has been refined but not tested, which is difficult in a laboratory setting. The reduction in physical (P) and mental (M) distance

was determined with the mock-up tests in a laboratory environment and supported by the literature study. In particular, the issue of reducing social distance through design during the use of a toilet needs to be further examined to determine whether toilet users experience social pressure to take more care of train toilet's cleanliness.

Furthermore, there is a desire to create a large social distance, i.e., a high degree of privacy when using the toilet; a public toilet is a private public place. Thus, the question is whether people want to be connected in this particular place by reducing social distance. As a result, the see-through door we designed was viewed as being incompatible given the increasing embarrassment people experience about body-toilet practices (see figure 2.6). Hence, users prefer not to be connected to their environment when using the toilet; they gradually develop an increasing need for privacy. In this sense, attention also needs to be paid to the phenomenon of 'parcopresis', i.e., people's reticence to defecate in a public toilet environment.

On the other hand, design remains a promising intervention for reducing social distance when toileting and increasing the connection with the environment. Moreover, moments of creating a social context and reducing social distance still remain when entering and leaving the (train) toilet. However, while using the train toilet, a large social distance is still guaranteed as the door is closed and locked.

The Covid-19 crisis has increased the three underlying distances in the hygiene model of sanitation. This also occurred in the Middle Ages, when the fear of disease transmission increased the desire for privacy and thus the need for social distance (S>) during sanitary actions (toileting and bathing).

The data has led to the creation of a set of generic knowledge so that other contexts than trains can use the design implications for improving sanitation hygiene. My thesis project's outcome is the proposal for a hygiene model with three different parameters (P, M, S) that influence the hygiene of a sanitary facility. The (P, M and S) values depend on the context in which the sanitary facility is located. It can also be used for public toilet design as a whole. This model needs further research.

Evaluating the design in the train

The new NS train toilet which resulted from this study is currently being implemented and used in VIRM intercity trains, albeit without the children's elements such as the platforms and baby changing table. Still, we hope that the NS will reflect on this. In addition to reducing mental distance related to dirt (M<), the children's platforms also contribute to a child-friendly image for the NS because children can independently use the train toilet without their guardians having to lift them. The study's circle would be complete by assessing how the design improved usability and hygiene-related perception.

9.7.2 Hygienic sanitation

Users and cleaners
Users and toilet cleaners are interconnected and play a key role in the hygiene of toilets. In this dissertation, I focused on how passengers use train toilets and how toilet usage affects hygiene (cleanliness). A hygienic approach towards users in connection with toilet cleaners needs to be further explored. Progress in new cleaning techniques using, for example, ozone without chemical additives and UV-light, monitoring toilets, and apps to control cleaners all fell outside the initial research scope. Furthermore, new materials are available on which dirt cannot adhere and these, combined with toilet usage, also need to be explored.

Hand washing
In addition, handwashing facilities, which we excluded from the research due to its initial focus, need to be further examined. These include features such as comparing the use of electric hand dryers to the use of paper towels to dry hands. An electric hand dryer increases the physical distance (P>) between the human body (hands) compared to a hand cloth and therefore reduces hygienic perception. On the other hand, it is assumed that due to the absence of paper towels, hygienic perception increases because users cannot deposit paper towels on the floor.

In brief, handwashing facilities needs to be further investigated.

Defecation and menstruation
Even though this thesis focuses on urination and the related spillage as an indication of hygiene, we also postulate that a small physical distance for defecation would improve hygiene. Because if people keep a large physical distance (P) from the sit toilet when they defecate, we suppose that faeces that land from a higher distance will stick more to the bowl and be more difficult to flush away.

As a general remark, it is recommended that a small piece of toilet paper be laid in the toilet bowl beforehand so that the faeces that are excreted on the toilet paper can be flushed via the toilet paper without traces.

The many aspects of personal and toilet hygiene in relation to defecation need to be further explored.

Furthermore, the toilet experiments were predominantly concerned with male urination, which indirectly benefits women's hygiene; they then do not need to sit on a toilet seat covered with urine spray. The majority of women recognised the added hygienic value of a urinal (figures 8.30 and 8.31). In addition, menstrual issues have been under-explored in this thesis and require more research.

Encouraging users to leave the toilet clean
Furthermore, as suggested in chapter 3, a facility for users to clean the toilet bowl after usage is unavailable in train toilets, for example, a toilet brush that is usually present in public toilets. Participants of our studies showed that they are willing to leave the toilet clean for the next user.

NS is reluctant to offer a loose cleaning facility in the train toilet because of the possible risk for improper use. Further research is needed to develop and design a facility for cleaning a train toilet for those who have used it and, in a broader sense, how to induce the user to leave the toilet clean for the next user, as we suggested by reducing social distance (S<).

9.7.3 Limited technology in public toilet environments versus smart sanitation

In figure 2.6, we show that practicing personal hygiene will become increasingly technical and inclusive by 2050. This poses a dilemma; more research is needed regarding usability and inclusiveness of technological ingenuity in public toilet environments, such as designing a touch free environment, and an automatic mechanical toilet seat cleaning device. For example, automatic sensors are ergonomically adapted to the 'average person'; someone who does not practically exist. Moreover, an automatic approach to train toilets has already been implemented in India: www.youtube.com/watch?v=faFPT_vR7MA.

On the other hand, it may be desirable to be less dependent on technology so that users remain autonomous and in control of how they clean their body and toilet environment, particularly when using the toilet. We have already accepted autopilot car driving, robotic mowers, hoovers, and car washes, however the context of toilet usage is different because it is something basic and natural, with a need for a shorter physical distance which may contradict the use of technology.

ProRail switched from automatic station toilets due to insufficient customer assessment to toilets cleaned by cleaners. Technology such as apps supports cleaners in 'just in time cleaning'; dirty toilets are traced and can be cleaned sooner (information provided by ProRail).

In brief, further research is needed into how the operation of a public toilet environment (on the street, or in airport/railway station) can be made more intuitive, and user-friendly. It is worth noting that the (semi) public toilet is a place where people can relax and slow down when they are in public and can have contact with themselves and perceive their own bodies while escaping from social duties.

Smart sanitation
However, APC's technical ingenuity has the advantage that toilets are cleaned after each usage, immediately reducing the mental distance between dirt (M<). Nevertheless,

both their interior and exterior design needs to be more user-friendly and less 'techno-automatic'; they need a warmer, human design approach.

In Japan, people are more familiar with the automatic toilet operation, figure 9.7 shows a public sit-toilet with extra functions such as music and a bidet; these prevent sharing intimacy with others in our private toilet usage. It is a way to increase privacy and thus increase social distance (S>).

Figures 9.7 Public toilet Japan International Airport: Photo: Chen Hao

Furthermore, future scenarios include health monitoring of urine and faeces. In that way, people's most intimate functions can be inspected in public facilities. The ethical context of these scenarios should be considered and further researched.

9.7.4 Lighting

Independent of our train toilet research, NS removed the standard train toilet window because of the cost and user's privacy. People standing on the platform can no longer see through the toilet window. In modern trains, the toilet can also be used when the train is stationary due to the new closed flushing system (see section 2.4.2).

This means that train toilet lighting is now artificial, without any daylight. In our research, some mock-up test 2 participants experienced natural light capture through the see-through door as pleasant. The perception of daylight in the train toilet can make users feel more connected to the surroundings rather than experiencing a situation in an enclosed bastion. This feeling of connectedness can reduce a degree of anonymity and thus social distance (S<).

Lighting supports eyesight, including its perception, and is a way of creating a pleasant atmosphere, but we excluded this effect in our research. An additional lamp was placed above the urinal to visually support a man when directing the urine stream. Louts proposed a circular occupation light on the floor of the train toilet (figure 7.18) to reduce social distance (S<).

The influence of artificial and natural lighting on the perception of hygiene needs to be further investigated.

9.7.5 Autonomous sanitation, gender neutrality, and sustainable sanitation

Autonomous sanitation

Sanitation for the very young and for older adults needs further research. In addition, there is a task for parents and guardians who could teach their children to leave the toilet clean for the next user after use. This would be an ideal second nature development as everyone prefers a clean toilet.

The hygiene of school toilets needs further research. Dirty school toilets confront children with a negative experience with public toilets from an early age. Accordingly, they try to avoid them instead of being able to use them without any concerns. Toilet solutions adapted for use by older adults, helps them retain their interdependence and remain longer at home.

Gender neutrality

Public toilet design expresses gender because they are generally separate for men and women. Gender-neutral people want to feel welcome in public toilets. Gender-neutral toilets prevent confusion and stress among gender users about which toilet to choose, and contribute to gender-neutral people's acceptance and well-being (Dujardin 2017).

Design is an instrument with which to address gender-neutral issues of public toilets. A public toilet can provide an enclosed space with a urinal and sit-toilet combination which integrates gender neutrality and provides a communal area with handwashing facilities. Gender neutrality in the context of public toilets needs further research. The privacy needed by women for menstruation and applying make-up needs to be included.

Sustainable sanitation for the environment

Currently, 40% of the world population lack basic sanitation, greatly undermining their quality of life. The state of sanitation reveals the difference between developed and less developed countries where open defecation is practiced by 892 billion people (chapter 2, figure 2.3). Sustainability issues are a theme in the sanitation domain which have hardly

been explored in this thesis. In chapter 7, section 7.1.2, we proposed reducing potable flushing water to flush the toilet by (re)using handwashing water.

We advocate the concept of reuse and reduce. Moreover, in a circular economy, using dry toilets without water and eventually using human waste as a source of energy needs to be explored further. Drug residues entering the sewage system through the toilet are causing increasing filtration issues for water treatment plants; this would be avoided with a composting dry toilet process. More research is needed to reuse human waste in a cost-efficient way accepted by users. These techniques are most promising in contexts with a scarcity of (drinking) water.

Much remains to be done in the field of design for sanitation. I will continue to do my part to achieve a cleaner world. The availability of (clean!) toilets will make the train, the city, the world more pleasant and liveable: in Dutch: “gezellig”.

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Terms and acronyms

Terms

Excrete/excrements, Defecate/defecation
Scientific terminology for (to) poo.

Family sit-toilet
Sit-toilet wheelchair-accessible environment with additional support options for hands, including horizontal and vertical support bars and family facilities such as children's platforms and a baby changing table.

Frequent train travellers (denoted in chapter 3 as NS)
Travellers who travel more than 1-3 times a month by train.

Gender-neutral toilet
Unisex toilet designed for use by all: men, women, trans-and gender-neutral people.

Human dirt
Faeces, urine and blood (from menstruation).

Human waste
Remains of faeces, urine drops and spray, sanitary pads and tampons, (pieces of toilet and hand paper.

lady p.
Female urinal designed by the author for her master's thesis project. It is a urinal that women use to urinate while hovering, or less commonly in a sitting posture (with their back to the wall). It is equipped with partition walls and provides toilet paper, which can be flushed with 4 litres of water.

Non-frequent train travellers (denoted in chapter 3 as NSnf)
Travellers/people who travel by train less than once a month, or never.

Private toilet
Toilet environment for users who are familiar with it.

Public toilet
Toilet environment equipped with toilet-related and personal hygiene facilities, which provides privacy through door(s) that can be locked. It refers to shared usage with 'strangers'; there is no relationship between users of the toilet and they are available 24 hours a day. Public toilets are commonly separated, enclosed sit-toilets with toilet paper dispensers, or male urinals separated by partition walls and without toilet paper dispensers. Furthermore, the public toilet environment provides washbasins with a tap, soap dispensers and hand drying facilities for personal hygiene practices. In this study, the focus is on public toilets in the Western situation, where people in general use sit-toilets in a seated or hovering position in combination with wiping, and using toilet paper for perineal cleansing.

Semi-public toilet
A public toilet environment that is not fully public, and their users and accessibility are related to their location, such as restaurants, libraries, supermarkets, and train stations.

Train toilet
A train toilet is a form of public toilet under moving conditions. It is a wheelchair-accessible space equipped with toilet-related and personal hygiene facilities, offering privacy through a door that can be locked. It is commonly a sit-toilet providing personal care facilities such as a toilet paper dispenser, a mirror, support options, a bin and facilities for hand hygiene; washbasin, tap, soap dispenser and hand dryer. It has a hook to hang a coat and bag and its door can be locked. It is a unisex toilet for use by men, women and gender-neutral people (de Bruin and Loth 2013, 19).

Sit-toilet
Toilet equipped with a toilet seat and lid that is generally used in a sitting or hovering position in combination with wiping, using toilet paper for perineal cleansing.

Squat-toilet
Unisex toilet generally for use in a squatting posture, and the related perineal cleansing actions are water, or using toilet paper.

Urinal
A urinal is a toilet used by men who urinate in standing position. It is commonly fitted with partition walls and does not provide toilet paper.

Urinary Hygiene Actions
Using toilet paper by wiping, blotting or dabbing for perineal cleansing in connection with urination.

We
Doctoral candidate Loth and the TU-Delft PhD team working with NS, represented by promotor Daan van Eijk, copromotor Johan Molenbroek, and Mirjam Meier for the NS.

Acronyms

H	Hygiene perception of the user
P	Physical distance between human body and toilet or other sanitation amenities
M	Mental distance related to sanitary dirt
S	Social distance between the user of the sanitary amenity and other people in the vicinity
AED	Applied Ergonomics and Design
BTA	British Toilet Association
BTF	from Back To Front
DOS	Design, Organisation and Strategy
DTO	Dutch Toilet Organisation
FTB	from Front To Back
GNT	Gender Neutral Toilet
HCD	Human-Centered Design
HREC	Human Research Ethics Committee of Delft University of Technology
HTT	Hygienic Train Toilet
IDE	Industrial Design Engineering
KTO	Klant Tevredenheids Onderzoek [Customer Satisfaction Survey]
MDG	Millennium Development Goal
NS	Dutch National Railways
PhD	Doctor in the Philosophy
RTCC	Reinvent the Toilet Challenge
RtD	Research through Design
RVO	Rijksdienst voor Ondernemend Nederland [Netherlands Enterprise Agency]
SDE	Sustainable Design Engineering
TUD	Delft University of Technology
UNICEF	United Nations International Children's Emergency Fund
UH	Urinary hygiene practices
UN	United Nations
WHO	World Health Organisation
WTO	World Toilet Organisation

Acknowledgements

My PhD project has been an "exhilarating journey, during which I had to overcome many challenges" (Luyben & van der Hagen in Doctoral regulations 2018). As I write this, even the nature of the ceremony that will mark the end of my journey is uncertain due to the Covid-19 situation.

Many people have supported me on my journey. However, it is inevitable that I may forget to thank some of those, if so please forgive me. In the meantime, some of you may have even found another job. Nonetheless, these acknowledgements are addressed to everyone (PhD team, NS staff, participants, students, colleagues, friends and family) whose support has contributed my growth in the profession I love most: doing design research in the sanitation domain.

First and foremost, I will start with my PhD team to whom I owe a huge debt of gratitude, Daan and Johan:

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These extremely difficult processes of innovations in research method (to receive ethical approval for chapter 5) and in design took a lot of my energy, pleasure and time. Nevertheless, Daan, Johan and Mirjam remained at my side (Appendix A.8.1.1).

I was able to start the project with the start-up funding (found by Greet Vink and Johan) from the Ministry of Infrastructure and Water Management. I would like to thank Rick Lindeman and Klaartje Arndzen for exchanging thoughts and Monique Huizenga of the NS for her useful explanation how to write the proposal.

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In the same period, the research on 'reinvent the toilet challenge' also took place, which was a pleasant period for me to interact with fellow researchers, such as JC Diehl in the field of sanitation.

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The story behind the message on the sign (arranged by Johan): "only to look at, do not use". One day, when I was preparing the mock-up for an important NS visit (when the urinal was under discussion), I smelled something strange. Very early in the morning, when I lifted the toilet, 4 litres of urine spilled onto the floor! It seemed that people had really used the mock-up toilet! So, together with a cleaner, we mopped up the urine and I emptied half a perfume bottle into the now clean toilet! The NS said after their visit, 'it smelled a bit strange'. Fortunately, the urinal itself had not been used, otherwise I may have been in real trouble.

Later on I moved from the toilet laboratory to StudioLab. Dear Studiolabbers (some of you have found another job in the meantime): Adriaan, Alev, Astrid (thank you for your yoga lessons), Berit, Caiseal, Carlita, Corrie, Deger, Dongjuan, Eefje, Elif, Evert, Fenne, Froukje, Haian, Jantine, Jay, Jie, Haian, Ianus, Iskander, Jantine, Jasper, Jarry, Katinka, Laura, Lavender, Lenneke (thank you for sending me interesting toilet-literature), Lorenzo, Maarten, Marco, Mailin, Matthijs, Martin, Makiko, Maria, Marieke, Marijke (with you delicious cakes), Natalia, Nazli, Niko, Nynke, Panote, Pelin, Reinier, Ricardo, Richard, Sam, Stella, Steven, Susanne, Tal, Taylor, Tomasz, Willem, Wim, Wonsup (thank you for your excel-help). You all helped to create a pleasant and safe atmosphere in which we could blossom and I could be Marian. Thank you.
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About the author

Marian Loth was born in Bunnik, the Netherlands. After finishing high school at Utrecht's Stedelijk Gymnasium, she moved to Amsterdam to study Economics at the University of Amsterdam where she obtained her propaedeutic degree. She then switched to study Industrial Design Engineering at TU Delft where she graduated with her Master's degree. For her master's graduation project she worked on the design of a female urinal at the design department of Sphinx.

lady p. Logo design by Studio Dumbar

This experience stimulated her interest in human sanitation. Marian then became project and design manager of the *'lady p.'* at Sphinx Maastricht *The lady p.* was launched at the ISH'99, Sanitation fair in Frankfurt where it won the Design pl+s award. Subsequently, at Sphinx, she became Innovation Manager and developed sanitary ware concepts for the 'best age' generation of 65+.

Marian then founded her own design studio, but returned to TU Delft when asked to work on a research program in line with *lady p.* In 2009, she started her PhD project

partly funded by the Ministry of Infrastructure and Water Management and Nederlandse Spoorwegen (Dutch Railways; NS). The project aim was to improve the hygiene of NS train toilet facilities through ergonomic design research. In 2016, Dutch Railways implemented Marian's new toilet design concept in the model of their intercity trains.

The new train toilet was rewarded with the Pieter Rookmaaker's award for mobility at Human Factors NL. Furthermore, Marian's work has led to many publications and interviews in newspapers, on radio and television and she has become known as the 'Dutch toilet expert'. She is still regularly consulted about her research and her views on the topic of sanitation. In 2020, under the impetus of Covid-19, she was appointed member of the core team of the WTO compendium for the global standardisation of (transportation) toilets.

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2020 Presentation and workshop at Marian's former high school to inform high school students about the field of industrial design engineering.

2021-2020-2019
Master research day. To inform master students of the Faculty of Industrial Design Engineering about the applied research methods in Marian's research.

2019-2018
Guest lecture at HU Utrecht. To inform HU students about different research methods at TU Delft's research.
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https://www.mediamatic.net/en/page/89089/marian-loth
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2012 **Mini-symposium Sanitation**
Key-note: Jack Sim (who was in Europe) founder World Toilet Organisation (WTO)
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Paper 'Male urination in the train' presented at 11th WTO summit in China
Expositions

2017 **Cube design museum, Kerkrade**
lady p. and train toilet
Exhibition on the themes of toilet and hygiene: "Everything You Always

Wanted to Know About Toilets*But Were Afraid to Ask"
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http://dig-it.tudelft.nl/2014/#project/a6fff9
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https://www.kunsthal.nl/en/plan-your-visit/exhibitions/made-holland/

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https://research.tudelft.nl/en/publications/rein-treintoilet

Foto: Sam Rentmeester

Public sanitation is an essential feature of modern society, and people are dependent on it for their mobility. More specifically, train travellers are used to having free access to train toilets, certainly on long journeys. However, train toilets are perceived as being dirty by travellers in need and are greatly underused.

Marian Loth did extensive research on this topic and worked together with NS to conduct unique observations inside moving trains. She designed a 'clean' multi-user train toilet by reducing the underlying physical, mental, and social distances between toilet, dirt, and train travellers.

This train toilet design is currently being implemented in NS intercity trains.

TU Delft