Experimental research on the factors which influence the fleeing time and rescue time of people evacuating flooded areas

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(Watersnoodmuseum, n.d.)

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HKV LIJN IN WATER

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Research on the factors which influence the fleeing time and rescue time of people evacuating flooded areas

By

M. J. van den Bulk

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Preface

This thesis is the final product of my master track Structural Engineering with Hydraulic Structures and is written as partial fulfilment for the degree of Master of Science in Civil Engineering at the Delft University of Technology. The research has been performed in cooperation with HKV Lijn in Water. The assistance and facilities provided by HKV Lijn in Water are highly appreciated.

The subject of this thesis is ‘Experimental research on the factors which influence the fleeing time and rescue time of people evacuating flooded areas’. I came across this topic on the site of the Technical University Delft. After reading the description of this topic, I made contact to ask for the possibilities. My background from the Reddingsbrigade emphasizes my interest into this topic and I was happy to start in October 2020. While making this thesis, I received a great deal of support and I want to take this opportunity to thank these persons.

First, I would like to thank my supervisors Jeremy Bricker, Guus Rongen, Bas Kolen, Paul Korswagen Eguren, Bas Jonkman and Pieter van Gelder for their excellent guidance, enthusiasm and support. Your feedback helped me with bringing my work to a higher level. Hereby, special thanks go to Guus Rongen for the time dedicated to help me during weekly meetings.

Secondly, I want to thank several people regarding the experiment. The experiment is carried out at test facility Flood Proof Holland in Delft at which I had contact with Lindsey Schwidder and Jean-Paul de Garde. I would like to thank them in this section for the hospitality, possibilities and the support during my time at Flood Proof Holland. Further, I want to thank Jeremy Bricker and the project partners for the funding made available for purchasing the waders. Also, I would like to thank the following persons for borrowing materials needed for the experiment: Joffrey Post, company Van Etten, Reddingsbrigade Callantsoog Paal 13, my parents and Water lab at faculty Civil Engineering which involves Bas Hofland, Pieter van der Gaag and Jaap van Duin.

Additionally, I am grateful for the help by my father Ron van den Bulk, my brother Mike van den Bulk and Jean-Paul de Garde for the help with making the parcourse. During the experiment my mother Jenny van den Bulk made foods and drinks which is very much appreciated. In order to speed up taking the measurements, my father and brother were of high value. Additionally, I would like to thank Tom Taekema for taking measurements on an experiment day, Joffrey Post and Koen Hufkens for taking measurements at the evening session and Francis van Marrewijk for making foods and drinks during the experiment in the evening. The enormous amount of enthusiasm brought by participants was of high value and I am grateful that they wanted to participate on the experiment.

Further, I would like to thank all experts for filling in the questionnaire and I want to especially thank Joost Bierens and Jakolien Leenders for helping me expanding my knowledge during my literature review.

Finally, special thanks go to my parents Jenny and Ron, brother Mike and dog Thunder because of the countless support and assistance in pursuing my ambition to become a Civil Engineer.

I hope you enjoy your reading.

M.J. van den Bulk
Berkel en Rodenrijs,
August 2021

Abstract

The floods of 1953, 1993, 1995, 2021 and the almost flood in Rivierenland show that floods have major consequences. Before a flood people can evacuate preventively or vertical and during a flood people can flee, being rescued or permanently stay behind. This research focuses on fleeing and being rescued to a safe region.

The research question is: **'How much time does it take to flee to a safe region during a flood, and what are the core factors that determine the success of a rescue operation by a lifeboat in the Netherlands?'**.

To indicate how much time it takes for people to flee to a safe region, an experiment took place at test facility Flood Proof Holland in Delft. During this experiment 25 persons walked or bicycled over a parcourse divided into five rounds with different water depths, namely 0.2, 0.4 and 0.6 meter. Additionally, there were other variations, such as walking with a floating object, bringing luggage, bringing a domestic animal, fleeing during darkness and the addition of debris in the water. Time measurements took place during the experiment. If people cannot flee, rescue is needed. To gain more insight into rescuing of people during floods, a questionnaire is spread among experts.

Relations between time measurements are found with the use of the Pearson moment correlation coefficient, paired t-test and determining the line by using intersept free linear regression. The relations are combined into a flow chart. Further, the time needed during a rescue attempt is combined into a formula. The navigation speed deviates for different water depths and types of lifeboats. Further, it is estimated by the experts that it takes 7½, 30 and 1 minutes from the contact with a person located at respectively a higher floor or attic, collapsed building and out of the water until having this person into a lifeboat.

There is no direct singular answer to the research question, because it depends on the area where the flood takes place and the extent of the flood. Larger water depths increase the fleeing time. If a person decides to flee, it is recommended to walk with a bicycle or bring an air mattress. A stick is useful to check where the road is located. Avoid areas with a lot of debris and do not flee during darkness, except if this is inevitable to survive. People can also wait for rescue at a higher (dry) floor. For the rescue crew, number one priority is safety. Try to avoid to navigate through areas with a lot of debris as this may damage the lifeboat. Search the area systematically and make notes of where people are located.

Summary

The floods of 1953, 1993, 1995, 2021 and the almost flood in Rivierenland show that floods have major consequences. Multi-layer safety is introduced as result of the shift from prevention of floods towards a flood risk-based approach in 2009. Three layers are distinguished: Prevention (I), spatial planning (II) and disaster management (III) (Rijkswaterstaat, 2021).

The aim of evacuation of people during a flood is to limit victims. Before a flood people can evacuate preventively [light green] or vertical [orange] and during a flood people can flee [yellow], being rescued [brown] or permanently stay behind [dark red]. This research focuses on the part of disaster management and especially on fleeing [yellow] and being rescued [brown] to a safe region, see figure i.1.

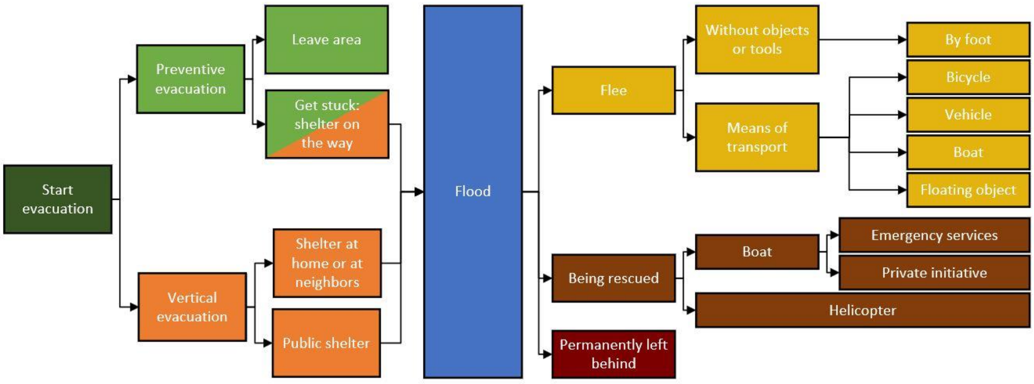


Figure i.1: Parts included in this research given as overview in the evacuation process.

The research question is: **'How much time does it take to flee to a safe region during a flood, and what are the core factors that determine the success of a rescue operation by a lifeboat in the Netherlands?'**.

In the Netherlands, three types of floods can occur, namely coastal floods, river floods and pluvial floods. The flood characteristics are different for each location and per flood scenario. Based on the maximum water depth for a flood scenario with an exceedance probability between 1/300 till 1/3000 year and flow velocity, categories are made, see table i.1. The Netherlands is roughly divided into these categories.

Flood category	Water depth [m]	Flow velocity [m/s]
I.)	0.0 – 0.5	Below 0.5
II.)	0.5 – 1.0	Below 0.5
III.)	Above 1.0	Below 0.5
IV.) Breach location	-	Above 0.5

Figure i.1: Parts included in this research given as overview in the evacuation process.

An average water temperature during a flood in the Netherlands is estimated to be 8 ^{o}C. Further, there is uncertainty about debris as it depends on the area where the debris is located, the displacement, amount and kind of debris.

The following dangers require fleeing from a hiding place: lack of food and drink, medications, outbreak of diseases, hypothermia, collapsing of hiding place and injuries. During fleeing, there is a risk of becoming hypothermic, injured or drown. The ratio between fleeing and being rescued is estimated as:

- Category I and II: 90% can flee and 10% need rescue
- Category III: 60% can flee and 40% need rescue (Kolen, Zethof, Rongen, & Bierens, 2017)

During fleeing, it is rare for people to panic while fleeing to an extent that 'irrational behaviour' is observed (Proulx, 2001). The evacuation after hurricane Katrina shows that people often see pets as part of the family and people would like to bring their pets with them (Animal Welfare Institute, 2017). There are different means of transport, indicated in figure i.1

If people cannot flee, rescue is needed. In the Netherlands the Nationale reddingsvloot (NRV) is focussed on this task and consists of approximately 80 lifeboats of mainly the type Vlet, Tinn Silver and Rescue 3. In this report, a questionnaire is made in which lifeboats of the NRV are considered. The rescue attempt consists of the parts: alarming, loading, navigating, reaching people, transferring people into a lifeboat, unloading people and preparations for the next rescue attempt.

To indicate how much time it takes for people to flee to a safe region, an experiment took place at test facility Flood Proof Holland in Delft. During this experiment 25 persons walked or bicycled over a parcourse divided into five rounds with different water depths, namely 0.2, 0.4 and 0.6 meter. Additionally, there were other variations, such as walking with a floating object, bringing luggage, bringing a domestic animal, fleeing during darkness and the addition of debris in the water.

From the time measurements taken during the experiment, relations between time measurements are found and combined into a flow chart, see figure i.2. Additonally, the fleeing velocities during daylight are added, as well as the 5% and 95% boundary and the number of data points.

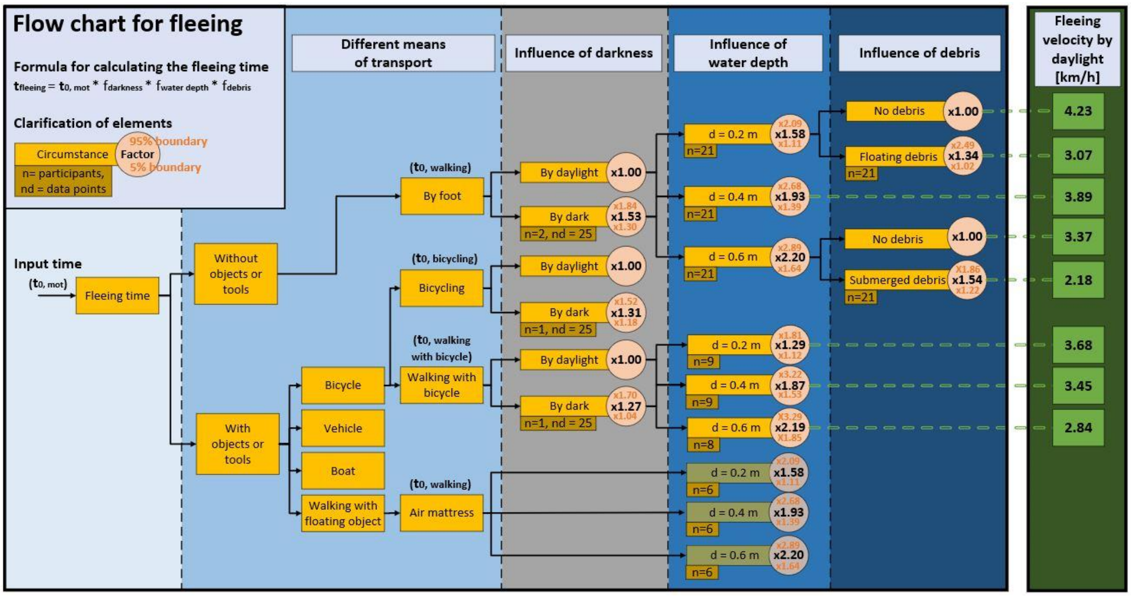


Figure i.2: Flow chart.

The time needed during a rescue attempt is combined into a formula: $t_{\text{rescue attempt}} = t_{\text{alarm}} + t_{\text{loading}} + t_{\text{navigation}} + t_{\text{searching}} + t_{\text{boarding}} + t_{\text{unloading}} + t_{\text{material check}}$. The navigation speed deviates for different water depths and types of lifeboats, see table i.2. Further, it is estimated by experts that it takes 7½, 30 and 1 minutes from the contact with a person located at respectively a higher floor or attic, collapsed building and out of the water until having this person into a lifeboat.

Vlet		Water depth [m]	0.0 – 0.5	0.5 – 1.0	+ 1.0
		Navigation speed [knots]	2.5 (4.6 km/h)	4.7 (8.7 km/h)	6.3 (11.7 km/h)
Tinn Silver		Water depth [m]	0.0 – 0.5	0.5 – 1.0	+ 1.0
		Navigation speed [knots]	2.2 (4.1 km/h)	4.6 (8.5 km/h)	9.5 (17.6 km/h)
Rescue 3		Water depth [m]	0.0 – 0.5	0.5 – 1.0	+ 1.0
		Navigation speed [knots]	1.8 (3.3 km/h)	4.2 (7.8 km/h)	10.5 (19.4 km/h)

Table i.2: navigation speed per water depth (Reddingsbrigade Egmond aan Zee, n.d.), (Schepenkring Yachtbrokers, n.d.). [1 knot = 1.852 km/h].

The discussion consists of several parts, namely the experiment about fleeing, the questionnaire about lifeboat experiences, the placement of results into flood scenarios in the Netherlands, suggestions for future research and a description about a possible setup of a model.

The two most important aspects which should be considered by using the flow chart of figure i.2 or redoing the experiment are the flow velocity and the length of the parcourse. During the experiment the water levels were stable and there was no influence of flow velocity. The length of the parcourse is 40.5 meter, however during a flood the fleeing distance will be larger. For a large fleeing distance, influences of tiredness and hypothermia shall increase the fleeing time. Further, there is a boundary regarding the water depth as people have to swim if the water depth becomes too large. The used data is a small sample of a much larger group, which implies that there is uncertainty in the relations. This uncertainty will decrease if more people complete the parcourse, resulting in a larger dataset. Note that the effect of repetitive learning is taken into account by deviating the round order for each experiment. During a flood, group behavior will play a role in case lots of people walk behind each other and cannot pass each other. This is not included in the experiment. Further, scientific literature on the subject of fleeing after a flood is limited. Because of this, the flow chart shown in figure i.2 gives new insight in the fleeing time.

Regarding the rescue, in this report it is assumed that fuel is unlimited and that the rescue crew and lifeboat can proceed rescuing people during the whole rescue period. This should be the case, but in reality there is a possibility that the supply of fuel forms an issue and the members of the rescue crew can get injured or the boat can get damaged during a rescue attempt. The answers on the questionnaire provides a new insight into the navigation speed in a flooded area as it depends on the water depth and the type of lifeboat. Also, the results are compared with the Model of Matthijsse (2016). The Model of Matthijsse (2016) does not fully fit with the results estimated by experts.

The results of the experiment and the questionnaire are visualized into flood scenarios in the Netherlands. Three categories are made, based on the maximum water depth for a probability of a flood of 1/300 till 1/3000 per year. The maximum water depths will be larger for a scenario with a smaller probability of a flood, however this map is not used as the chance of occurrence is so small it becomes unrealistic. Areas for example along the river Meuse in Limburg have a higher probability of flood, however a rough categorization is made and this is not based on scenarios with the most likeliness of occurrence in each individual area.

It is assumed and in agreement with the results of the flood scenario of Terschelling that at a water level of less than one meter (category I and II) 90% of the people can flee and 10% must be saved. If people decide to flee it is not recommended that people flee at the beginning of the flood, because the water will spread over the area in this phase. The results of the scenario at Dordrecht do not agree of the assumed ratio between fleeing (60%) and rescuing (40%) for a water level above one meter (category III). As the flood depth are too large to walk through and the water does not drop for a larger time period, people can only flee with a boat.

This report is limited to areas in the Netherlands, however the relationships from the experiment may also be of value in flood scenarios abroad. Perhaps the knowledge from this report can provide added value in the event of flood due to dam breaches or volcanic eruptions at glaciers. Note that the relations may be used in flood situations abroad, however the temperature can cause another timeframe in which people are able to flee before getting hypothermic. Also other aspects, like an outbreak of life threatening diseases, should be considered for flood scenarios abroad.

More research should be conducted into which areas in the Netherlands are not suitable to flee and whether the capacity of the NRV is sufficient to rescue all people in this area. An idea for future research is an test street where a flood will be simulated. Additionally, there should be research into the flood of 2021 in Limburg, parts of Belgium and Germany. This is the most recent flood and observations can be useful for gaining more insight of the evacuation of people.

The total evacuation process during a flood can be combined into a model. With the relations from the experiment, there can be determined how much time it takes for people to flee to a safe area. Hypothermia, injuries and tiredness determine the available time a person has to reach a safe location and forms a boundary. Further, with the experts estimations the needed time per rescue attempt can be determined to determine the rescue capacity. Based on the results from the model, the evacuation strategy can be adapted.

With the results of the experiment and the questionnaire, the research question is answered. There is no direct singular answer to the research question, because it depends on the area where the flood takes place and the extent of the flood. However, relations are found to answer the research question per area and flood scenario.

For the first part of the research question, the flow chart given in figure i.2 can be used to find the fleeing time. As concluded from this figure, fleeing during darkness and through debris increase the fleeing time. Also, larger water depths increase the fleeing time. If a person decides to flee, it is recommended to walk with a bicycle or bring an air mattress. A stick is useful to check where the road is located and to notice changes in the bottom profile. Avoid areas with a lot of debris and do not flee during darkness, except if this is inevitable to survive. Wear as much as possible warm and rainproof clothes.

For the second part, core factors are summed into a formula which is used to calculate the total time needed for a rescue attempt. If a person decided to stay and wait for rescue, this can be done at a higher (dry) floor. In order to help emergency services with finding people, the amount of people and the location can be written on the roof by the people who need rescue. For the rescue crew, number one priority is safety. Try to avoid to navigate through areas with a lot of debris as this may damage the lifeboat. Search the area systematically and make notes of where people are located.

Definitions

Term	Definition
Flood	A certain amount of water covers normally dry land.
Preventive evacuation	People evacuate by leaving the area prior to a flood until the start of the flood.
Vertical evacuation	Movement of people toward a location to find shelter prior to a flood. This could be at home, at the home of neighbours, the home of family or friends, in a public shelter or at another dry location in the area.
Acute evacuation	The dike is breached during this stage, however there is not yet interaction with water. Preventive and vertical evacuation is still possible.
Flee	People leaving the flooded area after interaction with water, without the assistance of emergency services.
Rescue	People leaving the flooded area with the assistance of emergency services.
Boarding time	Taking a person into a lifeboat during the rescue process.
Debris	All solid objects within a water flow.
LIWO	National Information system water and floods (In Dutch: 'Landelijk Informatiesysteem Water en Overstromingen')
NRV	Nationale Reddingsvloot which is part of the Reddingsbrigade and the fire department.

Table i.3: Definitions.

Contents

1. Introduction

This chapter provides an introduction to the subject of this report: ‘Research on the factors which influence the fleeing time and rescue time of people evacuating flooded areas’. First some context is given in paragraph 1.1. The next paragraph describes the scope to delineate the boundaries of this research. Paragraph 1.3 describes the research questions and lastly a reading guide is included.

1.1. Motivation

1.1.1. Floods in the Netherlands

The Netherlands is affected by several floods in the past, the most famous of which is the 1953 flood disaster, named ‘De Watersnoodramp’ in which more than 1800 people died. Among the survivors is, for example, Koos Hage who lost his mother and sister as these two persons could not reach the dike in time. Both women died because the way towards the dike was blocked by a large expanse of water and debris (Watersnoodmuseum, 2018).

The magnitude of the flood was enormous as a large part of Zeeland and parts of South Holland and Brabant are flooded due to the north-westerly storm in combination with spring tide, see figure 1.1. This large amount of water caused thousands of people to hide at their attics, on roofs or crammed together on dikes. (Watersnoodmuseum, n.d.-a).

Figure 1.1: Flooded area during the flood disaster of 1953 in the Netherlands (Watersnoodmuseum, n.d.-a).

To visualise the flood disaster on a more local scale, figure 1.2 is added. These images show that the damage was extensive and that the water level differs per area. People travel through the flooded area with different means of transport, such as walking, bicycling and by car.

Figure 1.2: Impression flood disaster Watersnoodramp of 1953 (Watersnoodmuseum, n.d.-b).

As indicated above, the consequences of 'De Watersnoodramp' was enormous, however, the floods in and around Limburg in 1993, 1995 and 2021, and the almost-flood in Rivierenland should not be forgotten either. Prior to these floods in Limburg, preventive evacuation was carried out. For example, in 1995, more than 200 000 people were evacuated from villages and parts of cities along the Maas (Frieser, Vrijling, & Jonkman, 2005; Rijkswaterstaat, 1995). Although the evacuations in 1993, 1995 and 2021 were successful, no dikes breached. Further, the flood disaster of 1953 was more than half a century ago and it is thus unrealistic to compare this flood disaster to a flood situation in the present time. However, these floods do show the significant impact of a flood.

1.1.2. Development after the floods in the Netherlands

After the floods of 1953, 1993 and 1995, flood defences were improved, and the Room for the River plan was drawn up with the primary aim of preventing floods (ENW, 2012). Additionally, the flood disaster of 1953 was the reason to set up the Nationale Reddingsvloot to save as many people as possible after a flood has occurred (NRV, n.d.). Further, in 2009, multi-layer safety was introduced as result of the shift from prevention of floods towards a flood risk-based approach.

1.1.3. Multi-layer safety

Since a large area of the Netherlands is located below sea level, there will always be a risk of a flood. To reduce the risk of a flood and to provide a better overview, the flood risk policy is based on multi-layer safety. Three layers are distinguished: Prevention (I), spatial planning (II) and disaster management (III) (Rijkswaterstaat, 2021).

This report focuses on the part of disaster management and more specifically on the displacement of a person through water and the rescue of a person with lifeboats of the Nationale Reddingsvloot (NRV). The aim of disaster management is to evacuate as many people as possible and to achieve the fastest possible recovery of the affected areas after a flood (ENW, 2012). Disaster management includes a well-functioning plan which consists of several parts, see figure 1.3 (Kolen, Zethof, Rongen, & Bierens, 2017).

Figure 1.3: Timeline of a flood scenario.

1.1.4. Evacuation before and after a flood

The aim of evacuation of people during a flood is to limit victims. The evacuation process around a flood is given in figure 1.4. The evacuation is divided into two main parts, namely the evacuation before the flood [I] (preventive and vertical evacuation) and the evacuation during the flood [II]. During a flood the evacuation is split into acute evacuation [II.1] (acute evacuation) and evacuation after interaction with water [II.2] (fleeing and being rescued).

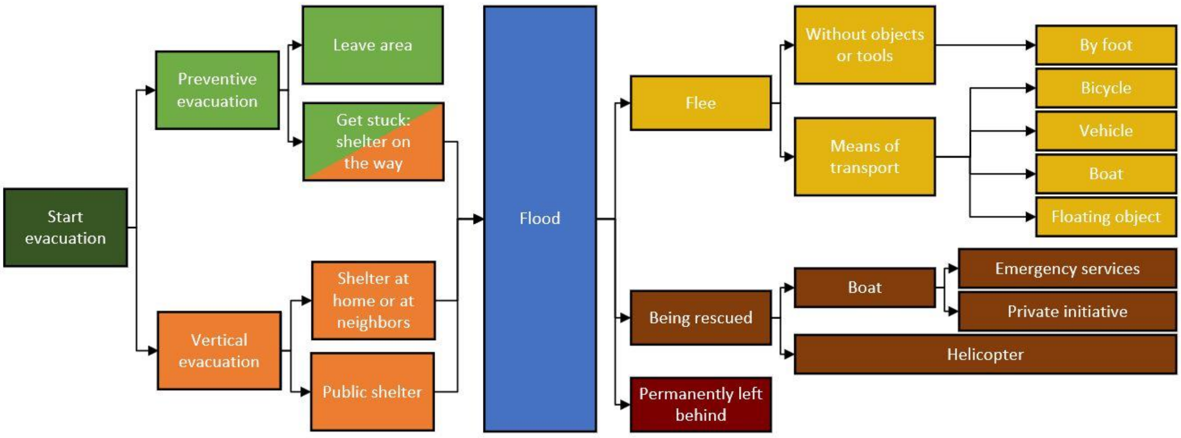


Figure 1.4: Evacuation process concerning a flood.

I.) Evacuation before the flood

It is necessary to make a decision before a flood occurs whether to evacuate or not. A quick decision to evacuate can limit economic and emotional damage. However, an unnecessary evacuation will result in high unnecessary costs (Jonkman, 2007). If it is decided to proceed with evacuation, a decision must be made in which way to evacuate before the flood. This can be preventive evacuation, vertical evacuation or a combination of both.

- Preventive evacuation [light green]: During preventive evacuation, people leave the area before the flood occurs. The preventive evacuation capacity is for a large part determined by the infrastructure and the available time. In addition, the capacity is partly determined by the behavior of people and the weather conditions (Kolen et al., 2017).

- Vertical evacuation [orange]: In this form of evacuation, people move to a place in the area where the risk of dying is reduced. This place can be at home, the house of neighbours or family, a public shelter or at other dry locations. People wait at this location for the flood to pass and then leave the area by fleeing or must be rescued (Kolen et al., 2017).

Parliamentary documents show that particularly for densely populated areas in South Holland and North Holland a complete evacuation of the coastal area is not possible within 48 hours in the event of an imminent flood (Kamerstukken II 2007/08, 30 821, no. 6). To prevent the infrastructure from becoming overloaded in these densely populated areas, 100% vertical evacuation is initially recommended as basic strategy (Kolen, Rongen, & Zethof, 2019). From this strategy it is determined which groups must evacuate preventively and which people will evacuate vertically. The relationship between the available time and the effectiveness of preventive evacuation and vertical evacuation is shown in figure 1.5 (Kolen et al., 2017).

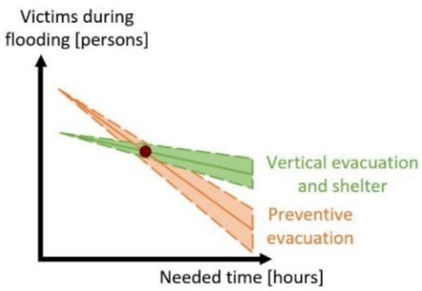


Figure 1.5: Relationship between victims and time required for vertical and preventive evacuation (Kolen et al., 2017).

II.) Evacuation during the flood
II.1) Acute evacuation: During this part the dike is breached, however there is not yet interaction with water. People who are preventive evacuating can get stuck and have find shelter on the way. This situation is risky as people can get surprised by the flood.

II.2) The evacuation after the interaction with water. During this time people can flee, being rescued or permanently stay behind.

- Fleeing [yellow]:
  One person or a group of people leave the area after interaction with water by foot, bicycle, vehicle, floating objects or boat.

- Being rescued [brown]:
  People who cannot flee must be rescued. This can be the case if the water depth becomes too high to walk through or if a person has a limited mobility, is injured or disabled. A specified service in order to rescue people after a flood is the NRV (Nationale Reddingsvloot). The NRV consist of more than 90 lifeboats and is part of the Reddingsbrigade and fire brigade (NRV, 2020).

  In addition, other emergency services are military services, assistance of lifeboats of the Reddingsbrigade and KNRM, medical services, police, international assistance and private initiatives with for example recreational vessels.

- Permanently left behind [dark red]:
  There is a possibility that people want to stay behind or cannot be found.

1.1.5. Evacuation abroad

Earlier in this report, the floods of 1953, 1993 and 1995 in the Netherlands are notified. However, outside the Netherlands more recent floods occurred. Below, two floods are described briefly.

- Katrina (USA): In 2005, Hurricane Katrina affected part of the United States of America, affecting nearly 2.6 km^2 and killing about 1330 people. The evacuation plans failed because it did not account for widespread and simultaneous catastrophes (Townsend, 2006). This indicates that is important to have a large-scale evacuation plan. An impression is attached in appendix A.

- Xynthia (France): In 2010, storm Xynthia caused a series of floods in France. This storm damaged 200 km of sea walls, flooded part of the affected area and killed 47 people. Emergency rescue were of high value as these services rescued more than 1500 people (Jacquet, Kahan, & Lalande, 2006). The affected area in France consist mainly of single-story houses. In the Netherlands, the houses are different. Therefore, this flood situation caused by Xynthia is not comparable to a flood scenario in the Netherlands. (Kolen et al., 2017).

It is difficult to translate these situations into a situation in the Netherlands due to environmental characteristics (Kolen et al., 2019). However, from above two floods it is clear that an evacuation plan and an organized rescue service are of essence to limit casualties.

1.1.6. Topic of discussion

The progress of an evacuation concerning a flood in the Netherlands should be a topic of discussion. Especially, there is still too little attention paid to fleeing to a safe region or the rescue of people out of the flooded area. This is due to the many variables and the absence of a flood in the Netherlands in recent years. Furthermore, the situations abroad are incomparable because of the large amount of people in an area and the limited forecasting time.

1.2. Scope

This report considers the evacuation during a flood in the Netherlands. The evacuation after interaction with water until reaching stable water levels consists of fleeing or being rescued. Hereby, the focus is on the fleeing process or rescue of one person with the aim to find time relations to calculate how long it takes to leave a flooded area. This implies that only non-disabled people are taken into consideration for the part of fleeing as help of others is not included. Further, people who want to permanently stay behind are left out of consideration.

1.3. Research question

This research is about the evacuation of people during a flood in the Netherlands. During a flood people can flee, being rescued or permanently left behind, see figure 1.6. As seen from this figure, the research is focused on fleeing and the rescue of a person after a flood in the Netherlands.

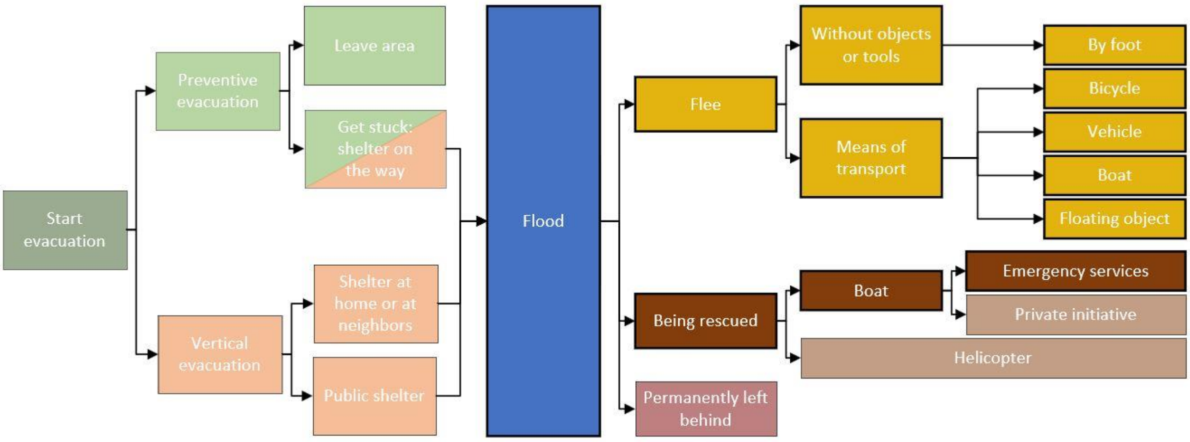


Figure 1.6: Parts included in this research given as overview in the evacuation process. The parts included are: 'Exposure to flood' [blue], 'Flee' [yellow] and 'Being rescued' [brown].

1.3.1. Research question

The research question is: **'How much time does it take to flee to a safe region during a flood, and what are the core factors that determine the success of a rescue operation by a lifeboat in the Netherlands?'**.

The research question consists of two parts indicated in figure 1.6:

1. Fleeing to a safe region [yellow]: this is mostly the initial phase and is from the interaction with water till stable water levels are reached.
2. Being rescued to a safe region [brown]: this is the final phase and at this phase the water levels are generally stable.

1.3.2. Sub-questions

The separation of fleeing and being rescued is also made in the sub-questions, which are given below.

1. How much time is needed for one person to flee through a flooded area?

- What is the influence of different means of transport such as walking, bicycling, with floating objects, by car or navigating with a boat on the fleeing speed?
- What is the influence of water depth on the fleeing speed?
- What is the influence of debris on the fleeing speed?
- What is the influence of bringing a domestic animal on the fleeing speed in case of walking?
- What is the influence of bringing luggage on the fleeing speed in case of walking?
- What is the influence of darkness on the fleeing speed?
- Can the road be followed during fleeing?

2. What are core factors such as navigation speed, time needed to reach one person and boarding time during a rescue operation in a flooded area by a lifeboat?

- Compared to the navigation speed of a lifeboat in an unobstructed waterway, how much is the navigation speed reduced in a flooded area and does this depend on the water depth?
- How can people be found?
- Is it realistic to reach everybody who needs to be rescued?
- How will people be transferred into a lifeboat and how much time does this take?
- Will the rescue equipment remain usable after a rescue in a flooded area?

1.4. Reading guide

Figure 1.7 gives an overview of the reading guide.

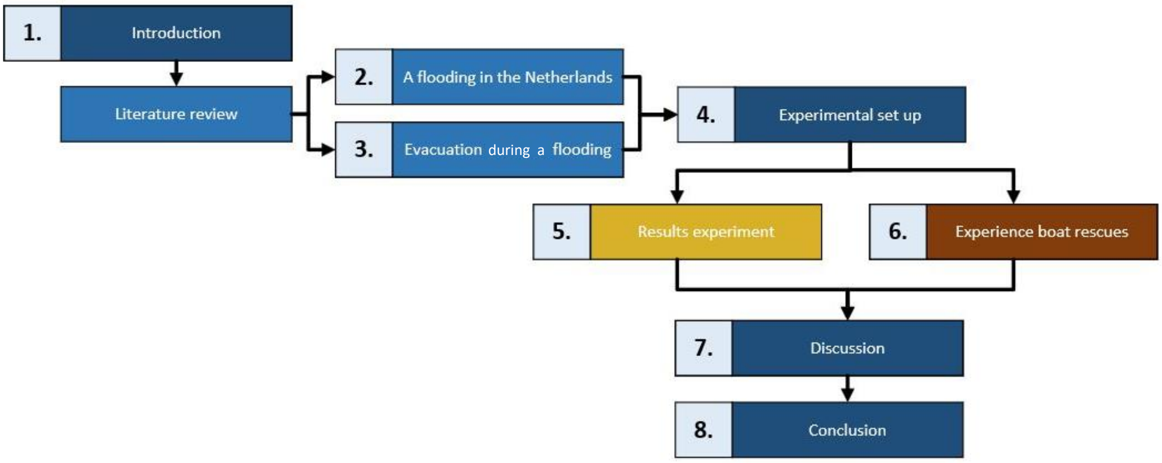


Figure 1.7: Reading guide.

The next two chapters include a literature review. Chapter 2 forms the first part of the literature study. In order to answer the research question, it is first important to know what the characteristics are such as flood depth, time scales, flow velocities and debris, of floods caused by North Sea storm surges or high river discharges in the Netherlands. Chapter 3, which is the second part of the literature review, includes a review about fleeing and being rescued during a flood.

After the literature review, the setup of the experiment and questionnaire are included in chapter 4. For the part fleeing, during the experiment measurements are taken how much time it takes for people to walk and bicycle over a parcourse through different water depths. The results of the experiment are given in chapter 5 [yellow]. Further, the questionnaire is about experiences with boat rescues and the results are shown in chapter 6 [brown].

Chapter 7 includes the discussion of the results. Lastly, chapter 8 adds the conclusion. In this chapter also an advice for a safer evacuation is given and the recommendations for future research.

2. Literature review on floods in the Netherlands

This chapter gives a literature review on the exposure to a flood in the Netherlands, indicated in figure 2.1 in blue. It is important to know what the flood characteristics in the Netherlands are in order to determine how a person can navigate or being saved after a flood in the Netherlands.

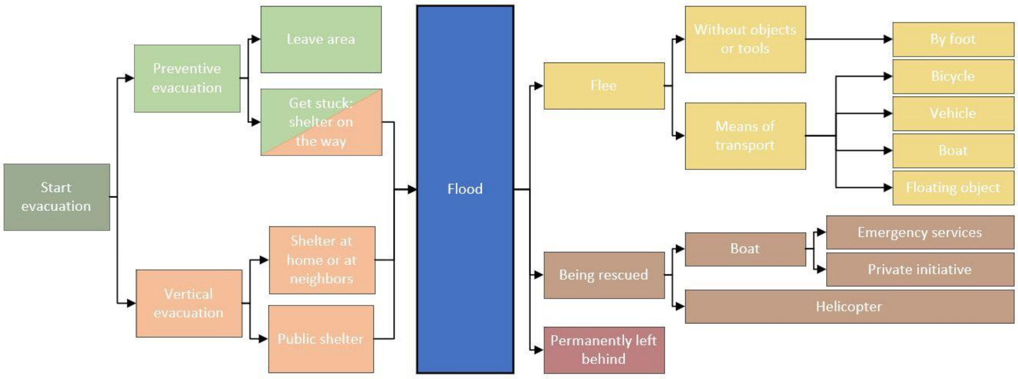


Figure 2.1: Parts included in this research given as overview in the evacuation process. The part included in this paragraph is: 'Exposure to a flood' [blue].

First, the type of floods which can occur in the Netherlands are described in paragraph 2.1. After this, an indication about the characteristics such as flood depth, time scales, flow velocities and debris during a flood in the Netherlands are given in paragraph 2.2. Lastly, flood scenarios are included in paragraph 2.3 in order to visualize a flood scenario in the Netherlands and to place obtained results in this report into context.

2.1. Types of floods in the Netherlands

The number of victims and the damage depends on the type of flood and the affected area. See appendix B for an overview of types of floods. In the Netherlands the following three types of floods and combinations of these floods can occur:

- **Coastal flood (or surge flood):** The high wind speeds from a storm causes the seawater to be pushed up to higher water levels than normal. If this occurs at the same time as high tide, this will result in extra high-water levels in the coastal areas. These high-water levels in combination with the wave loads can cause the coastal protection to break down and flood the area behind. An example of this type of flood in the Netherlands is the 1953 flood disaster.

- **River flood:** If a river is supplied with more water than it can process due to for example extreme rainfall, the water level will rise which can result in a breached dike leading to a flood. Further, for rivers without a dike, an insufficient discharge capacity of the river causes overflow of the river bank resulting in a flood. Examples of river floods in the Netherlands are the floods of 1993, 1995 and 2021.

- **Pluvial flood (or surface water flood):** A pluvial flood is the result of precipitation with a so high intensity that the surface area or water system cannot process the amount of water. This type of flood is independent of an overflowing water body, but often occurs in combination with a coastal and river flood (Maddox, 2014).

2.2. Flood characteristics in the Netherlands

The parameters concerning floods in the Netherlands are described in this paragraph.

2.2.1. Flood depth

A large part of the Netherlands is located below seawater level and protected by coastal flood defences and dikes. Since the water depth during a flood differs per location and per flood, no specific value can be given. However, a categorisation of the flood depth is made in figure 2.2 and table 2.1 where categories are distinguished.

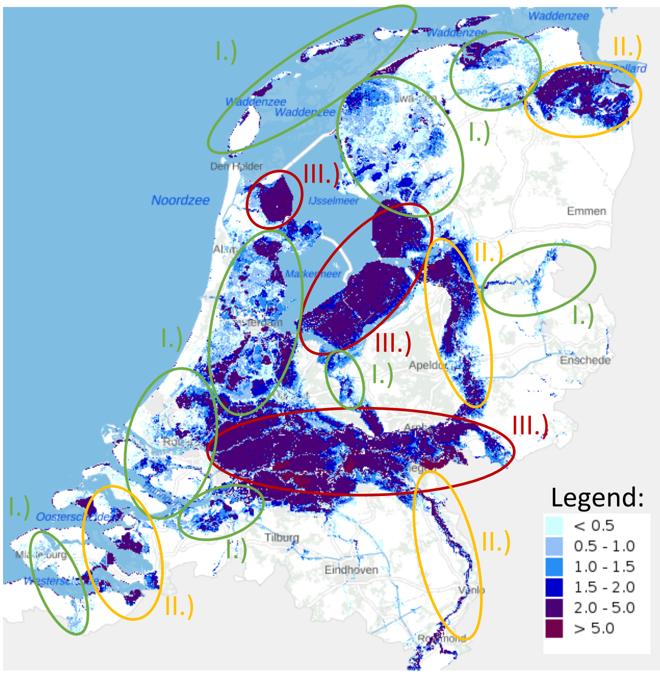


Figure 2.2: Maximum water depth for a small probability of a flood (1/300 till 1/3000 per year). Note that the breach locations are not included in the figure. Map received on the 26th of October 2020 (LIWO, n.d.).

Flood category	Water depth [m]	Flow velocity [m/s]	Expected displacement	Example location in the Netherlands
I.)	0.0 – 0.5	Below 0.5	Fleeing	Amsterdam and surrounding area, Friesland, Waddeneilanden
II.)	0.5 – 1.0	Below 0.5	Fleeing Rescue	Zwolle, East part of Groningen, along river the IJssel at Apeldoorn, parts of Zeeland
III.)	Above 1.0	Below 0.5	Rescue	Dordrecht and other parts of the Randstad, Flevoland
IV.) Breach location	-	Above 0.5	-	-

Table 2.1: Categorization of flooded areas. Note that category IV is not included in figure 2.2.

Several notes are made for this categorisation:

- The categorising of the areas is bases on a rough estimation of the maximum water depths in an area. The water depth in an area can deviate at different time periods after the breach.
- Probability of a flood:
  - At the site of LIWO, five scenarios with different maximum flood depths are given with a probability of occurrence of: extreme small, very small, small, medium and large. The maps with an occurrence of small, medium and large are added in appendix B.
  - In this report the maximum water depth with a small probability of occurrence is visualized, which is 1/300 till 1/3000 per year.
  - The specific probability of a flood is not determined for each flood scenario in this report and the division of areas is a rough estimate. For areas next to rivers, like in Limburg, the probability of a flood will be larger. If a larger probability of a flood is taken into account, the maximum water depth will be less and the flooded area smaller.
  - Background information about the LIWO maps is included in appendix B.

2.2.2. Flow velocity

During a flood, the water flows to lower parts. The flow velocities around places where the dike breached are larger than for the other parts of the relatively flat Dutch landscape. This dichotomy of area is used to categorize the flow velocity into larger than 0.5 m/s for breach locations and smaller than 0.5 m/s for the most parts in the Netherlands.

Notes for the categorisation:

- Breach locations are not taken into account in the categorization.
- The flow velocity is below 0.5 m/s for all three categories in table 2.2.

2.2.3. Time scale

During a flood it can take days to months for the water to disappear. This depends on the extent of the flood and the subsoil.

The time scale is divided in this report into the following sections:

- Breach of dike
- Interaction with water
- Stable water situation
- Recovering of the flooded area

2.2.4. Water temperature

The water temperature is partly of influence on how fast people can become hypothermic. Table 2.2 distinguishes two areas and gives the corresponding range of water temperatures and the period for which it is most likely to have a flood in this area. An average water temperature during a flood in the Netherlands is estimated to be 8 ^{o}C. A more detailed description on the estimation of the water temperature is added in appendix B.

	Range water temperature	Period with higher chance of a flood
River area	5 – 12 ^{o}C	December – April
Coastal area	5 – 17 ^{o}C, with a rapid decrease from 17 ^{o}C in October till below 10 ^{o}C in December	October – March

Table 2.2: Classification of water temperature. (Boardshortz, n.d.; Van der Grinten, Van Herpen, Van Wijnen, Evers, Wuijts, & Verweij, 2008).

2.2.5. Debris

During a flood it is possible that there is debris in the water which can form obstacles during the evacuation of people out of an area. Debris is defined in this report as all solid objects within a water flow and there is a large uncertainty about debris as it depends on the area where the debris is located, the displacement of debris, the amount of debris and which kind of debris.

Location and type

The location and type of debris depends on the specific area which is looked at and the kind of flood. The debris is transported by water from rivers during a river flood and from the North Sea during a storm surge.

- <u>River floods:</u> Rivers transport water, sediment and debris in downstream direction. This debris consists of natural debris, like trees and branches, and human made debris, like waste objects.

- <u>Storm surges:</u> Consists of debris originated from coastal areas, debris from shipping, debris from platforms at sea and debris which is transported by currents out of other areas in the world.

Furthermore, all object on dry land can form debris during a flood. For a forest area, examples of debris are trees and branches. For an urban area, examples of debris are bicycles, building materials, material of damaged houses, shopping charts.

Displacement

The displacement of debris depends on the size and weight of the objects, wind velocities for floating debris and the flow velocity of water. For larger flow velocities it is expected that debris is transported more easily. At the end of a flood, the water is distributed over the flooded area and the flow velocities will be low. For these low flow velocities, the expectation is that debris does not displace much.

Amount

The amount of debris depends on the affected area, storm conditions and is time dependent. Because of this, every area has a different amount of debris.

- Affected area: some areas have more loose and light objects than other areas
- Storm conditions: during a storm, the wind can cause damage in the affected area which results in a large amount of debris.
- Time dependence: During a flood water (and wind) have devastating effects which result in an increase of the amount of debris.

Overview

In order to gain an overview of debris, a categorization is made with the use of estimated dimensions, estimated weight and the buoyancy of objects. The elaboration on the categorization is added in appendix B and table 2.3 gives an overview of a rough categorization.

Category	Estimated dimensions	Estimated weight	Buoyancy	Main expected area
Wood	Very small (branches) till large (trees)	Very light till heavy	Floating	(Nearby) forests and in urban area
Vehicle	Relatively middle to large	Light weight of a bicycle to heavy weight of a truck	Submerged. Note that cars can drift because of an air chamber	Urban area
Garden items, construction materials (this includes not wooden objects), material from damaged buildings, objects from a shopping area	Relatively small	Relatively small A full rain barrel can be an exception	Submerged, unless an air chamber is present	Urban area
Other	Varies form very small till very large	Varies from very light till very heavy	Submerged, unless an air chamber is present. An air chamber can occur for example in a container	No specific area

Table 2.3: Categorization of debris.

2.3. Examples of flood scenarios in the Netherlands

In order to place fleeing and rescuing after a flood into perspective in the Netherlands, three flood scenarios of the project Veiligheid in Kaart (VNK2) are used. As there are many flood scenarios possible with each its own flood characteristics, it is important to indicate which areas are interesting. These are mainly areas which have a primary flood defence and are densely populated because of a high rate of vertical evacuation. Additionally, the type of flood can be distinguished for areas. See paragraph B for an elaboration.

Chosen areas

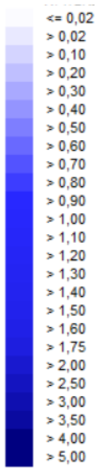
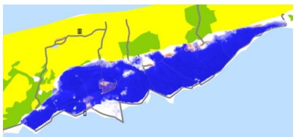
- 1.) Terschelling (category I.): This area is chosen because it is an island with on the North side the North Sea and on the South side the Waddenzee. After a flood people can only escape from the island by boat or helicopter.
- 2.) Zwolle (category II): This city is located in an area with only rivers.
- 3.) Dordrecht (category III): This area consists of many residents on a relatively small area which result in a high amount of vertical evacuation. This area is located a few meters below sea level. Also, there is variety in types of homes, like typical Dutch houses and high-rise buildings.

Figure 2.3: Chosen areas.

Note that the described scenarios have a probability of occurrence of 1/2000 per year, which is the toetspijl.

2.3.1. Terschelling

Table 2.4 visualises the progress of a flood at Kenneth-West in Terschelling. From three days after the breach, the scenario belongs to a caterogy I flood.

Terschelling – Dike ring 3 – Progress flooded area					
	Kinnum-West (TP)	**Time after breach**	**Water depth (most locations) [m]**	**Max. water depth [m]**	**Notes**
Legend: [m] 		1 hour after breach	1.0	1.8	The village Midsland is indicated with orange in the figure. From this time the water interacts with the village Midsland.
		15 hours	1.6	2.0	Maximum water depth for this flood scenario.
		3 days	0.5	1.1	This timeslot is chosen to further elaborate on for a possible evacuation scenario.
		7 days	0.2	0.9	

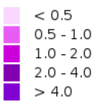
Legend: [m/s] 		**Flow velocity (most locations):** Below 0.5 m/s **Flow velocity at breach:** Up till 5.0 m/s

Table 2.4: Water depths and flow velocity of a flood scenario at Terschelling. The probability of failure is 1/2000 per year (toetspeil).

2.3.2. Zwolle

Table 2.5 visualises the progress of a flood at Zuidwest in Zwolle. Till three days after the breach, the scenario belongs to cateogry II and after three days the scenario belongs to cateogry III.

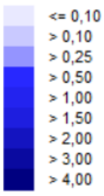
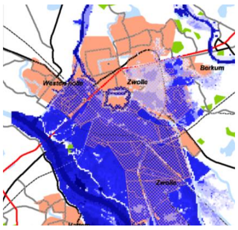
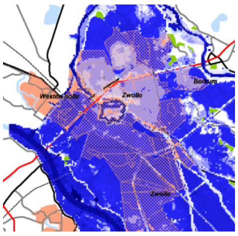
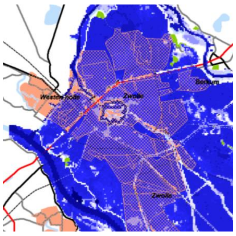
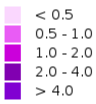
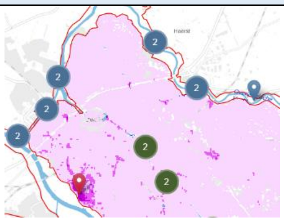
Zwolle – Dike ring 53				
	Zuidwest	**Time after breach**	**Water depth (most locations) [m]**	**Max. water depth [m]**
Legend: 		1 day	1.0	2.0
		3 days	1.0	2.0
		7 days	1.7	3.0
Legend: [m/s] 			**Flow velocity (most locations):** Below 0.5 m/s **Flow velocity at breach:** Up till 3.0 m/s	

Table 2.5: Water depths and flow velocity of a flood scenario at Zwolle. The probability of failure is 1/2000 per year (toetspeil).

2.3.3. Dordrecht

Table 2.6 visualises the progress of a flood at Wantij in Dordrecht. Right after the breach, this area belongs to cateogry III.

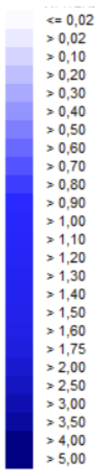
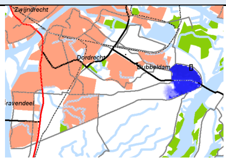
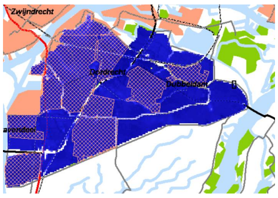
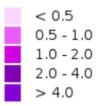
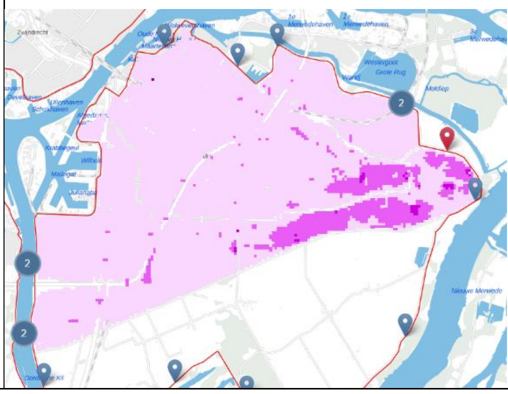
Dordrecht – Dike ring 22 – Progress flooded area					
	Wantij 5	**Time after breach**	**Water depth (most locations) [m]**	**Max. water depth [m]**	**Notes**
Legend: 		1 hour	1.5	1.8	
		38 hours	3.0	4.3	The whole area is under water from this time
		3 days	2.8	4.0	
		7 days	2.0	3.5	
Legend: [m/s] 				**Flow velocity (most locations):** Below 0.5 m/s **Flow velocity at breach:** Up till 2.0 m/s	

Table 2.6: Water depths and flow velocity of a flood scenario at Dordrecht. The probability of failure is 1/2000 per year (toetspeil).

3. Literature review on evacuation during a flood

This chapter includes a literature review about the risks during vertical evacuation and hypothermia. Further, the ratio between fleeing and being rescued is given in paragraph 3.3 and the parts fleeing and being rescued are reviewed in paragraphs 3.4 and 3.5 respectively. Figure 3.1 gives an overview of the relevant parts in the total evacuation process.

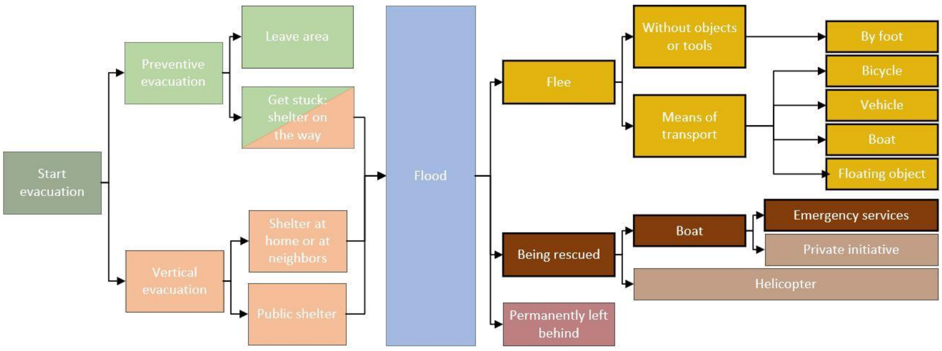


Figure 3.1: Parts included in this research given as overview in the evacuation process. The parts included in this paragraph are: 'Flee' [yellow] and 'Being rescued' [brown].

3.1. Risks during vertical evacuation

To gain insight into how long people can remain vertically evacuated, a survey was conducted among the population of Dordrecht (Kolen et al., 2017). The risks which can cause that people need to flee or rescued are briefly summarized in table 3.1.

Risk	Elaboration
Food and drink	Generally, a person survives for two to three days without food and drink. The survey shows that the stock of food at home is sufficient to survive for several days. However, the shortage of drinking water forms the first bottleneck that causes people to flee or have to be rescued (Kolen et al., 2017).
Medications	The following is concluded in the report 'Storylines voor het redden en vluchten na een overstroming' (2017): "Both people at home as in hospitals have sufficient medications for a period of one to two weeks. This is also confirmed by the association of pharmacists and the population survey" (p. 21). A very limited number of people outside a hospital or shelter require daily care. This are humans for example who depend on kidney dialysis. It is plausible that these people already left the area before the flood in the form of preventive evacuation.
Outbreak of diseases	The outbreak of life-threatening diseases is not realistic in the Netherlands. Further, sewage water is not expected to cause problems with regard to human health during a flood (Kolen et al., 2017).
Hypothermia	During vertical evacuation it is unlikely that people will become hypothermic as there will be sufficient insulating material in the hiding place (Kolen et al., 2017).
Collapsing of hiding place	During storm conditions and the flood, hiding places can collapse. Especially the buildings at a breaching location are at risk.
Injuries	If people save their belongings by bringing them upstairs, people can injure themselves.

Table 3.1: Risks during vertical evacuation.

3.2. Risk of hypothermia during evacuation

After leaving a shelter, people will be exposed to low temperatures, rain and wind. Hypothermia does pose a risk here (Kolen et al., 2017).

Hypothermia can be caused by:

- Immersion in cold water
- Exposure to wind and precipitation, especially in case of wearing wet clothes

In order to gain some insight into hypothermia during fleeing, the purpose of this paragraph is to give an indication about the time scale in which people become hypothermic and to see what the consequences are on the evacuation during a flood in the Netherlands. Hereby, it is important to note that there is a large spread in the time before people get hypothermic and even if a person gets hypothermic the degree differs per person. Further, the likelihood of getting hypothermic increases if more time passes.

3.2.1. Body processes

Hypothermia is the condition where people have an abnormally low body temperature. How fast a person can become hypothermic depends on:

- Thermal factors: weather conditions and water temperature
- Non-thermal factors: body size, body composition, blood glucose, motion illness, racial and sex differences (Tipton, Collier, Massey, Corbett, & Harper, 2017).

The relation of body temperatures and the state of the human body are given in table 3.2.

Core body temperature [^{o}C]	Body state or symptom	Notes regarding traveling through a flooded area
37	Normal body temperature	
36	Shivering	
35	Confusion, disorientation, introversion	People have difficulties with finding the way as people gets disoriented.
34	Amnesia	
33	Cardiac arrhythmias	
30 – 33	Clouding of consciousness Loss of consciousness	- The person will drown during staying in the water as unconsciousness prevents people from undertaking physical activity to maintain their head above the water. - The person is not able to reach a safe location without the help of others. - People with this body temperature need medical care to increase the body temperature.
28	Ventricular fibrillation	
25	Death	

Table 3.2: Relation of body temperature and state of the human body (Tipton et al., 2017).

3.2.2. Walking through flooded area

This part is meant to indicate when a body temperature becomes below 35 ^{o}C and thus have difficulties with finding the way through a flooded area, see table 3.2.

There is no literature found on how fast the body temperature drops by walking through water after a flood in the Netherlands. However, Hayward and Thompson did an experiment in which 18 participants walked for five hours at a temperature of 5 ^{o}C in the rain and with the influence of wind. The specifications of this experiment are given in table 3.3.

Experiment: Wet-cold exposure and hypothermia	
Participants	18 males
Temperature	5 ^{o}C
Time	5 hours
Walking speed	5 km/h
Wind	8.0 km/h, from the 2nd hour till the end
Rain	7.4 cm/h, from the 2nd hour till the end
Results	○ 13 participants failed to proceed after 3 hours of which two participants developed significant hypothermia with a body temperature of 35 ^{o}C. ○ 5 participants completed the experiment, with an average body temperature after the experiment of 36.4 ^{o}C.

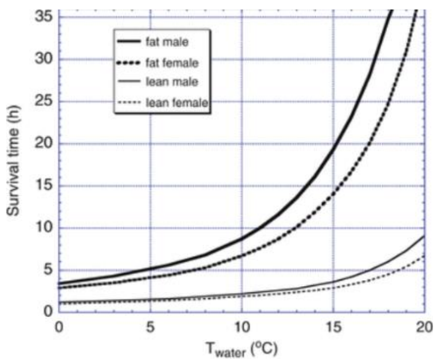
Table 3.3: Experiment: Wet-cold exposure and hypothermia (Thompson, & Hayward, 1996).

The conclusion from this experiment is that 72% did not withstand the wet-cold conditions for more than two hours of exposure to wind and rain.

3.2.3. Swimming during a flood

During a flood, there is a possibility that people will try to swim for a short period to reach a dry area.

Survival time



As mentioned in paragraph 2.2, the average water temperature during a flood is approximately 8 ^{o}C. The survival time for staying unprotected in the water with a water temperature of 8 ^{o}C is maximum six hours for a fat male, five hours for a fat female and two hours for a lean person, see figure 3.2 (Bierens, 2014).

Note that these people become hypothermic (disorientated and then unconscious) at an earlier stage, before eventually dying.

Figure 3.2: Survival time of people at different water temperatures (Bierens, 2014).

Experiment swimming time regarding hypothermia

The relation between swimming time and hypothermia is investigated with a 20 minute flume swim test with athletes in bare skin conditions. Four out of 11 athletes were able to complete the 20 minutes swim at a water temperature of 14 ^{o}C of which two out of these four persons became hypothermic at the end of the experiment with a body temperature below 35 ^{o}C (Saycell, Lomax, Massy, & Tipton, 2018).

Cold shock

Next to hypothermia, people who go into cold water have a risk of getting a cold shock. Cold water shock is a reaction of the human body on a sudden, unexpected immersion into water with a water temperature below 15 $^{\circ}$C. The breathing of people increases abruptly which can lead to a panic reaction. This can cause the victim to involuntarily ingest water and drown (Hof, 2015).

3.2.4. Experiment rescue workers

At the University of Portsmouth in the United kingdom researchers Tipton, Abelairas-Gomez, Mayhew and Milligan preformed an experiment in which the thermal demands of flood rescue and impacts on task performance is investigated.

Participants stood still, knee deep, in water for 1 hour with a water temperature of 4 ^{o}C, flow velocity of 4.8 km/h and with the presence of rain and wind. The clothes consist of a dry suit with underneath a long sleeve thermal vest and trousers. After one hour the grip strength declined by 13%, the manual dexterity declined with 22% and the jump height declined by 20%. The participants did not find it physical demanding, however, did report feeling very cold and uncomfortable by the end of the experiment (Tipton, Abelairas-Gomez, Mayhew, & Milligan, 2019).

3.3. Ratio fleeing versus being rescued

The ratio between the number of people who flee or must be rescued themselves is unknown. An assumption about the percentage of fleeing people is given in the report Storylines for rescue and fleeing after a flood (2017): 'In the upper limit we assume that 90% of the people flee, in the lower limit 60%' (p. 11). This assumption is further specified later in this report:

- For all situations it is assumed that at a water level of less than one meter 90% of the people can flee and 10% must be saved.
- For a water level above one meter, 60% of the people will be able to flee and 40% must be saved (Kolen et al., 2017).

Finally, according to evaluations of the evacuation of people during Hurricane Katrina, it cannot be underestimated that people refused to leave a shelter because animals would be left behind (Animal Welfare Institute, 2017). This appears to be confirmed by images posted on YouTube in which people have posted evacuation messages on roofs, including the amount and kind of animals, see Appendix A. Furthermore, there are people who want to stay behind to protect possessions.

3.4. Fleeing

Little is known about fleeing after a flood. Below are aspects related to fleeing of people shown.

3.4.1. Route

The escape route is determined by environmental aspects and the choice of people. To estimate the route which people will take, the escape behavior during a building fire is looked at. Several studies into the evacuation of buildings during a fire show that people prefer to choose a route which is familiar and do not always follow the escape routes (Sime, 1984; Kobes, 2010).

On the escape route in a flooded area, people encounter fixed and movable obstacles during the flight. The fixed obstacles can help to find the way in a flooded area. Examples of fixed and loose objects are:

- Fixed obstacles: speed bumps, bridges, ditches, lamppost, buildings, trees, tram rails, and holes in the road because a sewer cover has been moved.
- Loose obstacles: parts of trees, garden furniture, shopping trolleys and sewage covers.

3.4.2. Behavior of people

Most people believe that humans panic before and during a flood, however it is the contrary which is true. A person only panics if this person does not see a solution or way out to the situation (U.S. army corps of engineers, 2019). This is also confirmed by research into building fires that shows that it is rare for people to panic while fleeing to an extent that "irrational behavior" is observed (Proulx, 2001). In addition, it emerges that people in a crisis situation are inclined to follow others. Especially when the stress situation increases, people are more likely to imitate other people (Veldhuijzen van Zanten, 2017).

3.4.3. Domestic animals

The evacuation after hurricane Katrina shows that people often see pets as part of the family and people would like to bring their pets with them (Animal Welfare Institute, 2017). In the Netherlands, there were approximately 27 million pets in 2019, see figure 3.3 (Dibevo, 2020).

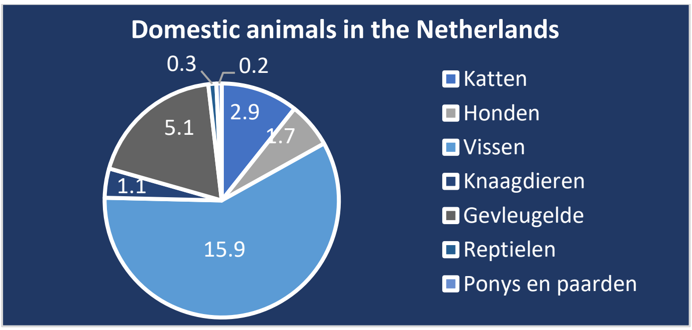


Figure 3.3: Distribution of domestic animals in millions in the Netherlands (Dibevo, 2020).

The small domestic animals can be carried as luggage during fleeing out of the area. The other part, which are too heavy or too large to carry as luggage, are larger dogs, ponies and horses. These animals can walk on their own or on a leash. Larger animals, like a pony or a horse, can be used to ride on or to transport personal belongings. However, no information is found on how this will proceed.

3.4.4. Means of transport

While fleeing, people may use resources available in or near the hiding place. Images posted on YouTube show that people flee by foot or with the aid of moving equipment and floating materials, see the images in paragraph 1.1 and appendix A. However, no information is found how this actually works. Below, an inventory is shown of the available rolling and floating equipment in the Netherlands.

Rolling equipment

Rolling equipment are bicycles, mopeds, cars, and trucks. Table 3.4 provides an overview of contemporary modes of transport.

Rolling equipment	Amount [million]
Bicycles (2018)	23 million
Passenger cars (2017)	8.2 million
Motorcycles and mopeds (2017)	1.8 million

Table 3.4: Part of the rolling stock in 2017 and 2018 (Stichting Bovag-Rai Mobiliteit, 2019), (CBS, RDW, & Statline, 2020).

Bicycle

Table 3.4 shows that there are 23 million bicycles in the Netherlands. With a population of about 17 million people in 2018, this means that there are more bicycles in the Netherlands than people (StatLine, 2020). However, no information is found about the effectiveness of fleeing with a bicycle.

Vehicle

The success of fleeing out of a flooded area with a vehicle depends on the aspects given in table 3.5. Below this table, research on the wading depth is given.

Aspect	Description
Driving behavior	Emotions can impair the driving ability of people. Also, some drivers have more experience with driving than others.
Technical condition	Poorly maintained vehicles have a higher risk of breaking down.
Amount of fuel	Enough fuel is needed to drive out of the flooded area.
Amount of vehicles	If there are one hundred vehicles and the first car breaks down, this car can form a blockage. In this case all other cars cannot drive further and people have to walk to reach a dry area. People become wet and the risk of hypothermia increases.
Wading depth	The wading depth is defined as how deep water can be before a vehicle engine stops working. If the engine stops working the fleeing person(s) get stuck on their way or have to continue fleeing by foot. This is different for each type of vehicle as it depends on: the air inlet height of the car engine, height and weight of the car, generator and ignition system, and the watertightness of electrical equipment and the interior space (Kramer, Terheiden, & Wieperecht, 2016).

Table 3.5: Aspects which determines the success of fleeing with a vehicle.

From manufacturer data and literature, the range of wading depths is found. The wading depths are given in table 3.6.

Vehicle type	Wading depth
Standard cars	0.30 to 0.50 meter (Kramer et al., 2016).
Emergency vehicles	0.60 till 1.20 meter (Kramer et al., 2016).
High riding 4WD cars	0.35 meter for a Volvo XC60-2016 with a driving speed of no more than walking speed (Volvo Car Corporation, 2020), which is approximately 5 km/h, till 0.60 meter for a Mercedes Benz G280 CDI (Ministerie van Defensie, n.d.).

Table 3.6: Wading depth per vehicle type.

Furthermore, researchers at the UNSW Water Research Laboratory did an experiment about how cars behave during a flood regarding the water depth and flow speed. Note that this is not the wading depth of a vehicle but the water depth where a vehicle moved. The researchers conclude that vehicles are vulnerable to flowing water once the depth reaches the floor of a vehicle, which is approximately 0.20 meter for standard cars (WRC, 2016). The results are added in table 3.7.

Type	Weight [ton]	Flow speed [m/s]	Water depth where the vehicle moved [m]	Water depth of completely floating away [m]
Toyota Yaris	1.1	1	0.15	0.60
Nissan Patrol 4WD	2.5	1	0.45	0.95

Table 3.7: Results experiment about the behaviour of cars during a flood (WRC, 2016).

The risk of driving faster than walking speed in relation to water depth are:
- Aquaplaning: the tyres lose its contact with the road and the vehicle becomes unmanageable.
- The bow wave produced by car becomes too large resulting in a higher risk of water into the engine inlet resulting is a broken engine (ANWB, n.d.).

Floating equipment
Floating equipment means all objects that floats sufficiently to transport a person. Examples of objects referred to here are a surfboard, boat, canoe, air mattress and other inflatable objects.

<u>(Small) floating objects</u>
There is no information found on how people flee with the help of small floating material, such as a surfboard, an air mattresses or other inflatable objects.

<u>Boat</u>
In case of fleeing with a vessel there is an inventory available of the HISWA. In 2015 there were approximately 500 000 recreational vessels in the Netherlands. These recreational vessels are divided into the following categories: sailing boats, motorboats, rowing boats, canoes and surfboards. Some of these vessels are at fixed locations, such as harbors, and the remainder at residential locations. The number of recreational vessels available depends on each area (Waterrecreatie Advies BV, 2015). If the number of recreational vessels is compared with the number of inhabitants in the Netherlands, less than 3% of the Dutch citizens have their own recreational vessel. Although several people can fit in a boat, the percentage of recreational craft available to flee remains limited. In addition, a person can be in possession of several recreational vessels.

However, if a person flees with a boat, the aspects given in table 3.8 can influence the effectiveness.

Aspects	Description
Draft	Raised parts, such as speed bumps, can form obstacles as the draft is temporarily reduced at this point. The draft depends on the type of boat and engine. The required draft can be estimated at a minimum of 0.5 meters to sail at a low speed. Some boats can navigate in shallower depths and small boats can be pushed by a person who walks next to the boat.
Currents	This can have a beneficial and detrimental effect during fleeing with a boat. It depends on the type of boat and engine, engine power, current speed and direction of flow when leaving an area.
Debris	The influence of debris on the fleeing speed depends on the type of boat and the propulsion. Type of boat: • Boats made of polyester, steel or wood will not be easily damaged as this material is hard. • Boats with an inflatable part, such as ribs, can be more easily damaged by sharp objects and this will lead to a reduction in sailing speed. Propulsion: • Outboard engine: this engine can be raised to check for debris on the propeller. • Inboard engine: if debris wraps around the propeller, it will not be possible to continue navigating and the ship will become rudderless. • Jet engine: this type of engine has the advantage to be able to navigate at very small water depths. However, just like the inboard engine, if debris wraps around the propeller, it will not be possible to continue navigating and the boat will become rudderless.

Table 3.8: Aspects which influence the effectiveness of sailing through a flooded area.

3.5. Being rescued by lifeboats of the NRV

As mentioned in paragraph 1.1, the NRV was established after the 1953 flood disaster especially to safe people after a flood in the future. Since 2018, the NRV is the responsibility of the 25 security regions in the Netherlands, of which 22 regions have a flood risk (NRV, n.d.). The total amount of lifeboats of the NRV are 38 red units (Fire brigade) and 56 orange units (Reddingsbrigade) (NRV, 2020).

3.5.1. Types of NRV lifeboats

1.) Reddingsbrigade: the lifeboats of the orange units in the NRV consists of several boat types, namely a Vlet, Tinn Silver 550 Rescue and the Rescue 3. See figures 3.4, 3.5 and 3.6.

Figure 3.4: Vlet.
Figure 3.5: Tinn Silver 550 Rescue (Reddingsbrigade Egmond aan Zee, n.d.).
Figure 3.6: Rescue 3 (Schepenkring Yachtbrokers, n.d.).

2.) Fire brigade: the lifeboats of the red units of the NRV consists mainly out of the boat type Tinn Silver, see figure 3.7. In Dordrecht a larger vessel named Zuid-Holland-Zuid is part of the NRV, see figure 3.8.

Figure 3.7: Tinn Silver (Boonstra, 2018).
Figure 3.8: Zuid-Holland-Zuid (Van Straten, 2019).

3.5.2. Equipment in NRV lifeboats

Overall, the equipment of the lifeboats of the NRV consists of:

- Fire extinguisher
- Flares
- Signal horn
- Sidelights and top light
- Paddles and prong hook
- Plastic bailer
- Anchor with line
- Mooring line
- First-aid kit
- Lifebuoy
- Flashlight/hand searchlight
- Communication set (C2000) and VHF radio
- Crew: wears a survival suit and a lifejacket (Reddingsbrigade, 2015)

3.5.3. Navigation speed

The factors that influence the velocity of boats are listed below.

- Swell and waves
- Currents can have a negative effect on the sailing speed.
- The ambient temperature has an influence on the speed when victims are on board
- At night it is estimated that the effectiveness of the rescue is reduced to 50% compared to the rescues during the day
- Reduced sailing speed during rain and fog (CBR, 2008)

It is not clear at which velocity a lifeboat can travel in flooded areas. Assumptions are made about the average velocities of lifeboats in a flooded area, namely 4 to 6 km/h for a lifeboat from the NRV and 3 km/h for the gray fleet (CBR, 2008; Matthijsse, 2016; Kolen et al., 2017; Kolen et al., 2019).

3.5.4. Boarding time

- In Matthijsen's model, 10 minutes is taken as a starting point, but can also be entered as a variable (Matthijsse, 2016).
- In the reports relating to the Sloegebied, Dordrecht and the Randstad, an average boarding time of 20 minutes is used. In addition, there is made a distinction between disabled and non-disabled people and the use of the Nationale Reddingsvloot or the gray fleet (Kolen et al., 2017; Kolen et al., 2019). Table 3.9 gives an overview of the assumed boarding times.

Assumed boarding time				
		Favorable [min.]	**Expected [min.]**	**Unfavorable [min.]**
Nationale Reddingsvloot	Non-disabled	15	20	25
	Disabled	30	40	50
Gray fleet	Non-disabled	30	40	50
	Disabled	60	80	100

Table 3.9: Boarding time (Kolen et al., 2017; Kolen et al., 2019).

3.5.5. Number of rescued people during a rescue attempt

There is an uncertainty about how many people are rescued at each rescue attempt. The following two assumptions are found in reports:

- Five people are rescued during one rescue attempt (Matthijsse, 2016; Kolen et al., 2017; Kolen et al., 2019).
- Two to four persons are rescued during one rescue attempt, depending on the area type (CBR, 2008).

3.5.6. Employability

The following aspects influence the employability:

- Availability of sufficient fuel
- Number of available rescue workers
- Fatigue of rescue workers
- Any damage to lifeboat or rescue equipment

4. Experimental set up

This chapter describes the method to answer the research question. The relevant parts in this research, fleeing [yellow] and being rescued [brown], are indicated in figure 4.1.

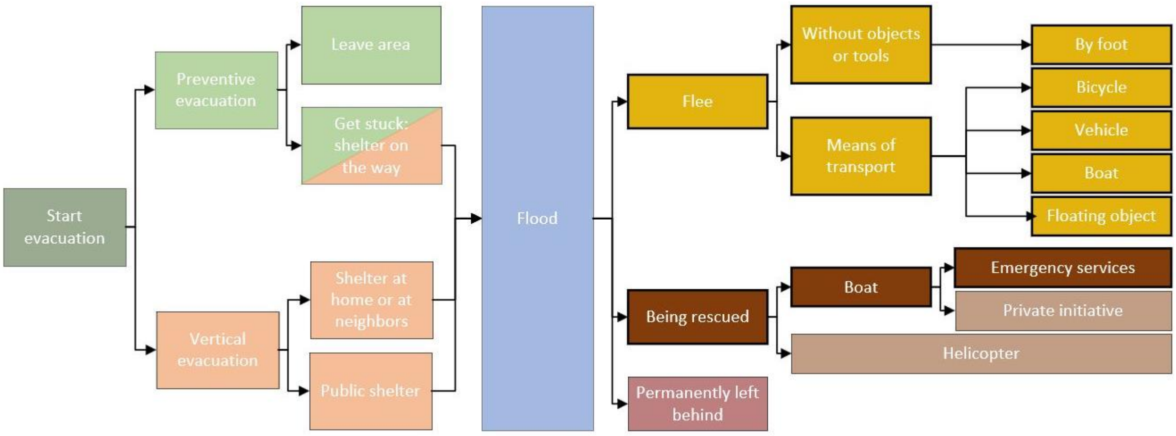


Figure 4.1: Parts included in this research given as overview in the evacuation process. The parts included in this paragraph are: 'Flee' [yellow] and 'Being rescued' [brown].

In order to give some insight in the fleeing process, an experiment is carried out. The set-up, expectations and the method of processing data of the experiment are described in paragraph 4.1. For the rescue process during a flood, a questionnaire is spread among experts who have experiences with boat rescues. The set-up of the questionnaire and expectations are added in paragraph 4.2.

4.1. Experiment fleeing

In order to determine how long it takes for people to flee out of a flooded area and thereby answering the sub question **'How much time is needed for one person to flee through a flooded area?'**, an experiment took place at test facility Flood Proof Holland in Delft. During this experiment 25 persons were walking or bicycling over a parcourse divided into five rounds with different water depths, namely 0.2, 0.4 and 0.6 meter. Additionally, there were other variations, such as walking with a floating object, bringing luggage, bringing a domestic animal, fleeing during darkness and the addition of debris in the water. Figure 4.2 and figure 4.3 give an impression of the parcourse which consists of three basins. The parcourse is approximately 40 meter and includes several slopes, a stair and a bend. See appendix C for a more detailed description.

Figure 4.2: Overview parcourse.

Figure 4.3: Impression of the parcourse.

4.1.1. Measurements

The parcourse is divided into five parts, indicated with the use of Jalon piles. For each part of the parcourse a time measurement with the use of a stopwatch takes place. Additionally, two GoPro Hero 4 camaras are placed between the basins. The video material can be used in case a time measurement is missing or aberrant.

4.1.2. Dimensions parcourse

- Length: An indication of the length of each part is given in table 4.1.
- Width: Parts of the parcourse consist of a width of 0.6 meter and the other parts of 2.0 meter, see figure 4.4.
- Bottom profile: The bottom profile consists mostly out of concrete plates and pavement stones. Only basin 3 has a deviating bottom profile, see figure 4.4.

	Part 1 (basin 1)	Part 2	Part 3 (basin 2)	Part 4	Part 5 (basin 3)
Length [m]	12.0	6.9	8.6	7.5	5.5

Table 4.1: Length of parcourse in meter.

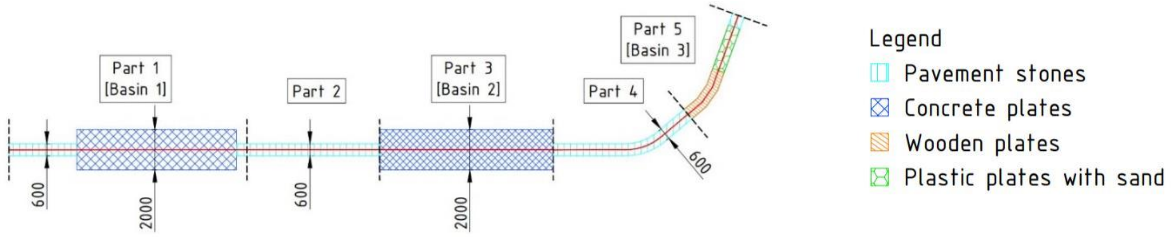


Figure 4.4: Top view parcourse. The dimensions are expressed in millimeter. Note that this is a standard way of expressing these measurements but should not be interpreted as an accuracy.

4.1.3. Participants

25 Persons participated in the experiment divided over several days. The participants of which 12 males and 13 females are in the age of 13 till 64 years old with an average age of 33 years. During the experiment the participants wore a wader. All participants are non-disabled and able to walk without the help of others or tools.

4.1.4. Human research ethics

It is important to protect the dignity, rights and welfare of humans participating the research.
By conducting this research, the ethical procedures are followed and the application is approved by the Human Research Ethics Committee of the TU Delft.

4.1.5. Rounds

The experiment consists of five rounds with each its own deviations, see table 4.2. Except for round 4, each participant will walk twice over the parcourse and bicycle once at each round.

Round	Water depth Basin 1 [m]	Water depth Basin 2 [m]	Water depth Basin 3 [m]	Detail
0	0.0	0.0	0.0	Normal clothes, no wader
1	0.0	0.0	0.0	-
2	0.2	0.4	0.2	-
3	0.2	0.6	0.4	-
4	0.2	0.6	0.4	Walking with an air mattress, bag or dog
5	0.2	0.6	0.4	Basin 1 with floating debris Basin 2 with submerged debris

Table 4.2: Specification of rounds.

- **Round 0:** This round is intended to see whether there is an influence of wearing a wader instead of normal clothes. Only a few participants will complete round 0.

- **Round 4:** During round 4 participants walk two times over the parcourse with an air mattress, a bag or with a dog.
  - Air mattress: This is chosen because it is expected that this object is compared to other floating objects the most present in households in the Netherlands. Further, an air mattress has in comparison to other floating objects a large floating surface area and can therefore be useful.
  - Domestic animal: During the experiment, it is investigated how much extra time it takes to bring a dog. The dog is a 35 kg Labrador, not afraid of water and used to walk on a leach.
  - Bag: two types of bags are used: one of 10 kg and one of 20 kg.

- **Round 5:** Basin 1 consists of floating debris and basin 2 of submerged debris.
  - Basin 1 (floating debris): five brances, beam, plank and two bocks aerated concrete, see figure 4.5.
  - Basin 2 (submerged debris): wheelbarrow, two PVC tubes, bucket and a watering can, see figure 4.6.

Figure 4.5: Floating debris.

Figure 4.6: Submerged debris.

To avoid repetitive learning, the order of round deviates at each experiment, see table 4.3.

Experiment	Participant	Round order
I	1 – 8	1 – 2 – 3 – 4 – 5
II	9 – 11	1 – 4 – 5 – 2 – 3
III	12 – 15	1 – 3 – 4 – 5 – 2
IV (in the dark)	16 – 19	1 – 2 – 3 – 4 – 5
V	20 – 25	1 – 2 – 3 – 4 – 5

Table 4.3: Participants with different round order.

4.1.6. Experiment in the dark

During a flood it is possible that people must flee in the dark. To gain insight in the influence of darkness, one experiment with four participants takes place in the evening when it is dark.

4.1.7. Expectation

In this section, the expectations are described for the main factors. Note that the expectations are not based on scientific literature because this is limited.

- **Water depth:** The expectation is that it takes more time to move along the course as the water depth increases. The bottom will not be visible for water depths above 0.2 meter and this can cause people to walk next to the parcourse. In terms of time required per water depth, the forecast is that the time increase is linear. Further, the expectation is that a water depth of 0.2 meters will not have a big influence on the time compared to walking without water, because this is only a small layer of water.

- **Walking with an air mattress, dog or bag:** It is expected that walking with an air mattress, dog or a bag will take a little bit longer than walking without an object or dog. This is expected because bringing extra weight takes more effort and the dog needs directions.

- **Bicycling:** It is expected that bicycling is faster than walking. However not everyone shall be able to bicycle during all water depths as more water increases the resistance. More resistance takes more effort of people, and this will most likely takes time.

- **Debris:** Moving through debris will most likely result in a time delay. People can be surprised especially by debris located under the water level and have to walk or bicycle over or around the debris which takes time.

- **Darkness:** Due to the reduced visibility, it is expected that people will take longer to complete the course in the dark. The greatest reduction in time is expected for the part of completing the parcourse with the influence of debris during darkness.

4.1.8. Method for processing data

The time measurements are compared to each other with the use of the Pearson product moment correlation analysis, the paired sample t-test and in case of a clear relation there is tried to fit a line through the data in order to find a relation. The relations will be combined into a flow chart with which the fleeing time can be calculated.

Below, a description is given about the Pearson product moment correlation, the t-test and linear regression. Further, an elaboration of this analysis is added in appendix D. Note that the Pearson product moment correlation analysis and the paired t-test should only be used if the variables are normally distributed.

- **Pearson product moment correlation**
  This method denotes the strength of the correlation between time measurements with correlation coefficient r. The range for this coefficient is $-1 \leq r_{XY} \leq 1$ and to classify the correlation the following boundaries are used:
  - $0.00 < r_{XY} \leq 0.30$; Indicates a very weak correlation
  - $0.30 < r_{XY} \leq 0.50$; Indicates a weak correlation
  - $0.50 < r_{XY} \leq 0.70$; Indicates a moderate correlation
  - $0.70 < r_{XY} \leq 0.90$; Indicates a strong correlation
  - $0.90 < r_{XY} \leq 1.00$; Indicates a very strong correlation (Calkins, 2005)

  The significant relation boundary of 5% is used in this report and note that r squared (r_{XY}^2) gives the percentage of explanation of the variance by known factors.

- **Paired sample t-test**
  As the correlation coefficient r does not indicate whether there is a difference between two sets of time measurements, the paired sample t-test is used to determine if there is a large enough difference between two sets of measurements. It tests whether two samples differ enough (significantly) to be considered from a different statistical population.

- **Linear regression**
  If there is a significant correlation and there is a difference between the time measurements, a line can be fitted through the data. The line through the data is a matter of choice for modelling the relation. In this research three lines are plotted through the data to see what the best fit is:
  - Least squares linear regression: This method works by making the total of the squares of the difference between variables, named errors, as small as possible. By doing this the variables which are located further away from the line count more heavily than the points which are closer to the line.
  - Least squares intercept free linear regression: This method is the same as the least squares linear regression model, only in this case the line goes through the origin.
  - Mean slope linear relation: This model is the same as the least squares intercept free linear regression, only in this case the error is not squared.

  Although the line through the data is just a matter of choice for modelling the relation, the least squares intercept free linear regression is used as best fit through the data. Compared to the least squares linear regression, the lines from the least squares intercept free linear regression and the mean slope linear relation are easier to scale over a longer timescale as it is a direct relation between two variables. Additionally, these two relations start at the origin, which is more logical than the case in which one variable starts at zero and the other variable at a non-zero time. Furthermore, the relationships of the least squares intercept free linear regression, and the mean slope linear relation are in most cases almost the same. There is chosen for the least squares intercept free linear regression over the mean slope linear relation because this method takes error better into account by making them as small as possible.

4.2. Experiences boat rescues

In order to determine how a person can be saved after a flood and thereby answering the sub question **'What are core factors such as navigation speed, time needed to reach one person and boarding time during a rescue operation in a flooded area by a lifeboat?'**, a questionnaire is made. An overview of the steps of a rescue attempt is given in figure 4.7. After unloading, the rescue equipment must be checked and replenished if necessary, before the start of the next rescue.

Figure 4.7: Steps during a rescue attempt.

4.2.1. Assumptions

For the rescuing part of the evacuation during a flood, the following assumptions are made:

- The water levels will be stable, and the area is completely flooded.
- The flow velocity is below 0.5 m/s (1.8 km/h).
- The wind speed is low during the rescuing of people
- There is enough fuel available.
- The rescue crew does not get tired or injured during the rescue attempts.
- The water depth is divided into three categories, namely I.) 0.0 – 0.5 meter, II.) 0.5 – 1.0 meter, and III.) above 1.0 meter. The water depth varies only in the given category.

In the questionnaire the three different boat types of the NRV are distinguished. These are given in table 4.4.

1.) Vlet 9.9 – 15 pk	2.) Tinn Silver 50 – 60 pk	3.) Rescue 3 ~ 70 pk
	 (Reddingsbrigade Egmond aan Zee, n.d.)	 (Schepenkring Yachtbrokers, n.d.)

Table 4.4: Boat types of the Reddingsbrigade of the NRV ('Nationale ReddingsVloot').

4.2.2. Questionnaire

The questionnaire consists of six parts. Below, each part is described briefly. The questionnaire is enclosed in appendix E.

1.) Introduction

In this question the experience of the participant is asked to verify the experience of the participant with boat rescues.

2.) Navigation speed
This part of the questionnaire is included to obtain an answer on the following question: 'How much is the navigation speed reduced in a flooded area, compared to the navigation speed of a lifeboat in a waterway?'

An estimation regarding the navigation speed in a non-flooded area and an estimation regarding the navigation speed in a flooded area for different water depths will be asked. The values will be compared to the assumption described in paragraph 3.5 which is that lifeboats of the NRV navigate with a speed of 4 to 6 km/h (which is 2.2 – 3.2 knots) in a flooded area.

Furter, a description of the influence of debris and the influence of waves from lifeboats is asked in this part.

3.) Transferring people into a lifeboat
In this part, there are questions about how people are transferred into a lifeboat during a flood. The answers contain a description of method(s) and will answer the question: 'How are people transferred into a lifeboat?'.

For this question, three different situations are distinguished:
- Evacuation from a higher floor, which is expected to be the most common during a flood.
- Evacuation from a collapsed building.
- Evacuation out of the water.

Furthermore, a time indication is asked about how much time it takes to transfer one person from the hiding place into a lifeboat. This time period is defined as the time between making contact with the person till the moment that the person is in the lifeboat.

Lastly, the needed equipment is asked to transfer a person into a lifeboat.

4.) Employability of rescue equipment and rescue crew
The following question will be answered: 'Will the rescue equipment remain usable after a rescue in a flooded area?'.

In order to answer this question, fist there will be asked how a lifeboat can be damaged during navigating in a flooded area. After this, the likeliness of damage to the lifeboat and how many times a lifeboat can be deployed during a flood is asked. Further, the materials or specifications will be asked which can prevent damage to lifeboats and thus increase the usability of a lifeboat during a flood.

5.) Reaching people
In this part the participants will be asked to think of a way to systematically search the flooded area for survivors and if it is realistic to find every person after a flood. This part will answer the question: 'Is it realistic to reach everybody who needs to be rescued?'.

6.) Experience
Lastly, in this part the participants are asked to write down experiences of boat rescues. For example, the experience of participants during the deployment of lifeboats in 1993 and 1995 or during other rescues with a life boat. This is asked in order to gain more information about situations in which people needs to be rescued and to confirm the value of the answers.

4.2.3. Experts

Twelve persons are asked to participate in this questionnaire. All participants have a background in rescue operations with lifeboats. In the first part of the questionnaire a distinction between rivers and sea is asked and between the different organisations, namely Reddingsbrigade en KNRM.

4.2.4. Human research ethics

By conducting this research, the ethical procedures are followed and the application is approved by the Human Research Ethics Committee of the TU Delft.

4.2.5. Expectation

The expectation on the results of the questionnaire is given below. Note that the expectations are not based on scientific literature because this is limited.

- **Response:** It is expected that at least the six participants of the twelve asked persons will fill in the questionnaire. However, this will depend on work obligations and private circumstances of the experts.

- **Navigation speed:** The expectation regarding the navigation speed is that in a flooded area the speed will be low due to debris in the water. It is expected that there will be a difference in navigation speed for different water depths and different types of lifeboats. A Vlet will navigate slower as the engine power is lower compared to a Tinn Silver and a Rescue 3.

- **Boarding time:** The boarding time will be different for each circumstance. If a person is located on a higher floor, it expected that this will take some time to help this person into a lifeboat. If a person is located in the water, this can be done within five minutes as this person only has to be transported from the water into the lifeboat. Bringing people into a lifeboat from a collapsed building brings other difficulties as a person could be stuck.

5. Results of the experiment

This chapter describes the results of the experiment for the part fleeing, see figure 5.1, in order to answer the following question: ‘**How much time is needed for one person to flee through a flooded area?**’. The relations from the intercept free linear regression as described in paragraph 4.1 are given in tables and, below the tables, the advantages and disadvantages are described. The data from the experiment and the analysis which results in the relationships is included in the appendices. Note that, from the data, a first remark is made which is wearing a wader does not influence the traveling time during the experiment and that there were no extreme weather conditions. See appendix F and M for a substantiation.

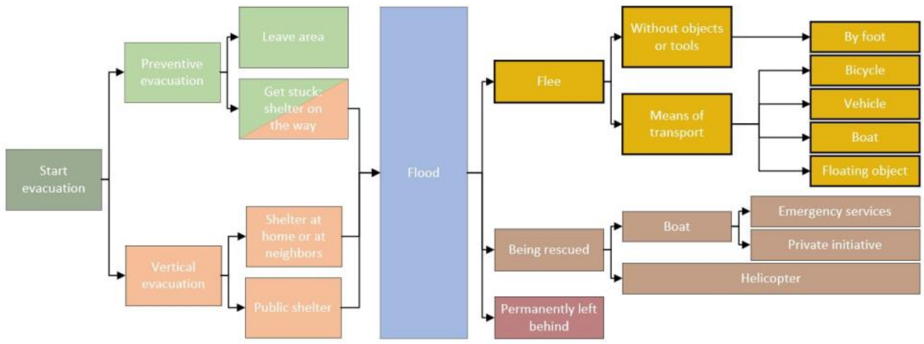


Figure 5.1: Parts included in this research given as overview in the evacuation process. The part included in this paragraph is: ‘Flee’ [yellow].

Paragraph 5.1 describes the influence of different water depths on the fleeing speed. The results of the influence of debris, bringing an animal or luggage are described in paragraph 5.2, 5.3 and 5.4 respectively. Paragraph 5.5 shows the influence of darkness and paragraph 5.6 describes how well the road can be followed during a flood. Paragraph 5.7 gives a comparison between the different means of transport and an overview of the results is given in paragraph 5.8. Lastly, paragraph 5.9 elaborates on a visualization of the data.

5.1. Influence of water depth

In this paragraph the question **‘What is the influence of water depth on the fleeing speed?’** is answered with the use of the experiment. The relations for walking, bicycling and fleeing with a floating object at water depths of 0.2, 0.4 and 0.6 meter are given and the advantages and disadvantages of each means of transport are described.

5.1.1. Walking

Relation between walking through water depths of 0.0 and 0.2, 0.4 or 0.6 meter				
	Relation	**Correlation**	**Participants**	**Significant**
Straight part	$t_{d=0.2\ m} \approx 1.58\ t_{d=0.0\ m}$	r = 0.80 (strong)	n = 21	$r_{\alpha=0.05} > 0.43$
	$t_{d=0.4\ m} \approx 1.93\ t_{d=0.0\ m}$	r = 0.45 (weak)	n = 21	
	$t_{d=0.6\ m} \approx 2.20\ t_{d=0.0\ m}$	r = 0.45 (weak)	n = 21	
Bend	$t_{d=0.2\ m} \approx 1.55\ t_{d=0.0\ m}$	r = 0.74 (strong)	n = 21	$r_{\alpha=0.05} > 0.43$
	$t_{d=0.4\ m} \approx 1.97\ t_{d=0.0\ m}$	r = 0.65 (moderate)	n = 21	

Table 5.1: Relation between walking through water depths of 0.0 and 0.2, 0.4 or 0.6 meter.

Table 5.1 gives relations which indicates that the increase in time for the walking is respectively 58%, 93% and 120% for the water depths 0.2, 0.4 and 0.6 meter in respect to the mean times without water. A division is made between relations at a straight part and at a bend. However, the differences are very small:

- Walking at a water depth of 0.2 meter compared to walking without water during one hour takes 94.8 minutes for a straight part and 93 minutes for a bend. The difference is 1.8 minutes.
- Walking at a water depth of 0.4 meter compared to walking without water during one hour takes 115.8 minutes for a straight part and 118.2 minutes for a bend. The difference is 2.4 minutes.

The data and derivation of the relations can be found in appendix G.

5.1.2. Bicycling

During the experiment 25 persons used different ways of fleeing with a bicycle, namely:

- Bicycling (9 persons)
- Walking with a bicycle (10 persons)
- Carrying the bicycle
- Using the bicycle as a step (1 persons)
- Combination of the above (5 persons)

Note that five persons used a combination of different ways of fleeing for each round. These are persons 1, 2, 10, 11 and 13. Below, for each way of fleeing with a bicycle the relation is given (if there is one) and then the advantages and disadvantages. The corresponding calculation is added in appendix N.

I) Bicycling

From the 25 participants, nine persons were bicycling over the parcourse of which most were males. Three of these persons were bicycling by darkness. Overall, there is a time delay during bicycling over the parcourse with water in comparison with bicycling without water, see figure 5.2. However, no significant correlation is found between the measurements of bicycling with and without water, which implies that no clear relation can be found for bicycling at different water depths from this experiment. A possible reason for finding no clear relation is that some participants had to step off the bicycle at some point and walked a short distance before getting on the bicycle again. For example, some participants walked on the slope at the end of basin 1 and basin 2 because these participants were not having enough speed to reach the top of the slope by bicycling.

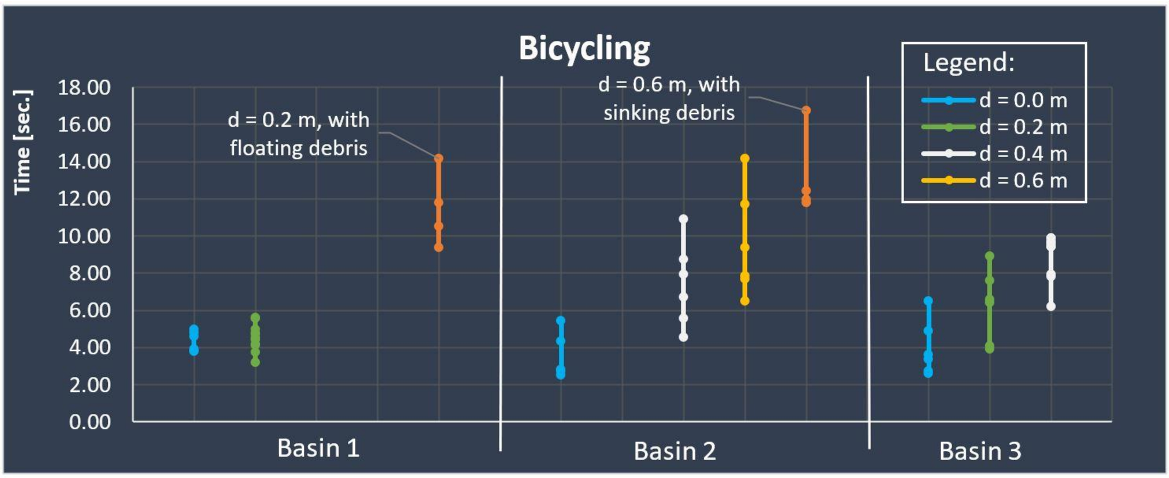


Figure 5.2: Time measurements of bicycling over the parcourse.

Advantages of bicycling:

- Bicycling is faster than walking for small water depth at a straight part, see paragraph 5.7.

Disadvantages of bicycling:

- It is not possible to bicycle over all kinds of surfaces.
- Time delay during getting on and off a bicycle.
- Higher risk of falling in the water. If a person gets wet, the change on hypothermia increases.

Note that persons 1, 10, 11, and 13 bicycled over the parcourse without water. However, with the addition of water at the parcourse, these participants did not bicycle anymore.

II) Walking with a bicycle
From the 25 participants, ten persons walked with a bicycle over the parcourse of which overall females. One out of the ten participants completed the experiment in the dark. Table 5.2 gives relations which indicates that the influence of water for the walking time with a bicycle is an increase of respectively 29%, 87% and 119% for the water depths 0.2, 0.4 and 0.6 meter in respect to the mean times without water.

Relation between walking with a bicycle through water depths of 0.0 and 0.2, 0.4 or 0.6 meter				
	Relation	**Correlation**	**Participants**	**Significant**
Straight part	$t_{d=0.2\ m} \approx\ 1.29\ t_{d=0.0\ m}$	r = 0.83 (strong)	n = 9	$r_{\alpha=0.05} > 0.67$
	$t_{d=0.4\ m} \approx\ 1.87\ t_{d=0.0\ m}$	r = 0.69 (weak)	n = 9	$r_{\alpha=0.05} > 0.67$
	$t_{d=0.6\ m} \approx\ 2.19\ t_{d=0.0\ m}$	r = 0.87 (strong)	n = 8	$r_{\alpha=0.05} > 0.71$

Table 5.2: Relation between walking with a bicycle through water depths of 0.0 and 0.2, 0.4 or 0.6 meter.

For the bending part there is no significant correlation found and thus no relation. A possible reason for this is that participants used the bicycle to test where the parcourse was located, which took some time, see paragraph 5.6.

Advantages of walking with a bicycle:

- A bicycle can be used as support during walking.
- A lot of bicycles have a luggage rack which can be used to transport luggage or a slightly injured person.

No disadvantages are noticed during the experiment.

III) Carrying the bicycle
Three out of 25 persons carried the bicycle during one round.

- Person 2:
    - Walked over the parcourse without water
    - Walked with the bicycle over the parcourse at water depths of 0.2, 0.4 and 0.6 meter and also carried the bicycle at the water depths 0.2, 0.4 and 0.6 meter.
    - This person did not complete the round with the addition of debris in the water.
- Persons 11 and 13:
    - Bicycled over the parcourse without water
    - Walked with the bicycle through different water depths
    - Carried the bicycle during the round with the addition of debris in the water.

IV) Using the bicycle as a step
One person completed the parcourse by stepping with the bicycle. This means that this person is on one side of the bicycle with one foot on the pedal. The other foot is used to push off on the ground in order to move forward.

The time measurements of this person are in the range of bicycling over the parcourse. The same advantages and disadvantages will hold as for bicycling over the parcourse, except from the time delay of getting on and off a bicycle.

5.1.3. Walking with a floating object

During the experiment, participants showed that there are several ways to bring the air mattress with them, namely;

- Dragging the air mattress behind or next to the participant as a kind of boat on the water
- Carrying the air mattress on the head of the participant
- Carrying the air mattress under one arm of the participant

Relation between walking with an air mattress through water depths of 0.2, 0.4 and 0.6 meter				
	Relation	**Correlation**	**Participants**	**Significant**
Straight part	$t_{d=0.2\text{ m; air mattress}} \approx t_{d=0.2\text{ m}}$	r = 0.86 (strong)	n = 6	$r_{\alpha=0.05} > 0.81$
	$t_{d=0.6\text{ m; air mattress}} \approx t_{d=0.6\text{ m}}$	r = 0.97 (very strong)	n = 6	$r_{\alpha=0.05} > 0.81$
Bend	$t_{d=0.4\text{ m; air mattress}} \approx t_{d=0.4\text{ m}}$	r = 0.86 (strong)	n = 6	$r_{\alpha=0.05} > 0.81$

Table 5.3: Relation between walking with an air mattress through water depths of 0.2, 0.4 and 0.6 meter.

Table 5.3 gives the relations of walking with an air mattress and walking without an air mattress at different water depths. Walking with an air mattress and walking without an air mattress takes approximately the same time. See appendix I. for the data of walking with an air mattress and the derivation of the relations.

Advantages of bringing a floating object:

- Several participants indicated that a floating object can be useful to transport luggage.
- A floating object can be used to stay above the water to prevent drowning.

Disadvantages of bringing a floating object:

- None of the participants used the air mattress to sit or lay on. Some participants indicated that the risk of getting wet or tilting of the air mattress is too high.

5.2. Influence of debris

During fleeing people can come across many objects of which a categorisation is made in paragraph 2.2. In this section the following question is answered: **'What is the influence of debris on the fleeing speed?'**. See appendix C.3 for the dimensions and an impression of the used debris.

5.2.1. Walking

Relation between walking through water depths of 0.0 and 0.2 meter with floating debris or 0.6 meter with submerged debris					
		Relation	**Correlation**	**Participants**	**Significant**
Straight part	Floating debris d = 0.2 m	$t_{d=0.2\ m;\ floating\ debris} \approx 1.34\ t_{d=0.2\ m}$	r = 0.66 (moderate)	n = 21	$r_{\alpha=0.05} > 0.43$
	Submerged debris d = 0.6 m	$t_{d=0.6\ m;\ submerged\ debris} \approx 1.54\ t_{d=0.6\ m}$	r = 0.74 (strong)	n = 21	

Table 5.4: Relation between walking through water depths of 0.0 and 0.2 meter with floating debris or 0.6 meter with submerged debris.

Table 5.4 gives relations which indicate that the increase in time for walking due to debris is respectively 34% for a water depth of 0.2 meter with floating debris and 54% for a water depth of 0.6 meter with submerged debris in respect to the mean times without debris.

During the experiment, five participants used floating debris, e.g. a stick, to locate the position of debris. Furthermore, the floating debris was used as a walking stick. The data and the analysis are added in appendix H.

5.2.2. Bicycling and walking with a bicycle

Relation between bicycling and walking with a bicycle through water depths of 0.0 and 0.2 meter with floating debris or 0.6 meter with submerged debris						
			Relation	**Correlation**	**Participants**	**Significant**
Straight part	Floating debris d = 0.2 m	Bicycling	-	r = 0.85 (strong)	n = 4	$r_{\alpha=0.05} > 0.95$
		Walking with bicycle	-	r = 0.74 (strong)	n = 5	$r_{\alpha=0.05} > 0.88$
	Submerged debris d = 0.6 m	Bicycling	$t_{d=0.6\ m;\ submerged\ debris} \approx 1.44\ t_{d=0.6\ m}$	r = 0.95 (strong)	n = 4	$r_{\alpha=0.05} > 0.95$
		Walking with bicycle	-	r = -0.33 (weak)	n = 5	$r_{\alpha=0.05} > 0.88$

Table 5.5: Relation between walking through water depths of 0.0 and 0.2 meter with floating debris or 0.6 meter with submerged debris.

Table 5.5 shows that there is a large uncertainty in the time measurements. The only relation ($t_{d=0.6\ m;\ submerged\ debris} \approx 1.44\ t_{d=0.6\ m}$) which is just significant is for bicycling through submerged debris at a water depth of 0.6 meter. The analysis and data are added in appendix O.

During the experiment the following notes are made:

- Nobody reached the other side by bike without getting off the bicycle.
- Some participants tried to lift the bicycle over the debris, and others walked around the debris.

5.3. Bringing a domestic animal

During fleeing, it is not likely that people leave their domestic animal(s) behind, because of the emotional bond, see paragraph 3.4. This paragraph indicates the influence of fleeing with a domestic animal in order to answer the question: '**What is the influence of bringing a domestic animal on the fleeing speed in case of walking?'**

Of the seven persons, three persons were used to the dog, one is the owner and the other two also have a dog at home. These three persons did not have a noticeable delay with bringing the dog compared to walking without a dog. The other four persons did have a delay with bringing the dog as the dog did not follow these persons as good as the with the other three persons who are used to the dog. No significant relation was found, however if the dog does not want to go into the water or walk easily with a person, the fleeing time will increase compared to walking without a dog. See appendix K for more information about the data and the analysis.

5.4. Bringing luggage

This paragraph answers the question: **'What is the influence of bringing luggage on the fleeing speed in case of walking?'** When people flee, the following belongings can be considered: Valuable possessions, clothes, domestic animals and food and drinks.

To see how luggage influences the fleeing time, participants walked over the parcourse with a bag of 10 kg or 20 kg. The difficulty of walking the parcourse with a backpack differs from person to person as it depends on how strong a person is.

Relation between walking with luggage through water depths of 0.2, 0.4 and 0.6 meter				
	Relation	**Correlation**	**Participants**	**Significant**
Straight part	$t_{d=0.2\ m;\ luggage} \approx t_{d=0.2\ m}$	r = 0.95 (very strong)	n = 8	$r_{\alpha=0.05} > 0.71$
	$t_{d=0.6\ m;\ luggage} \approx t_{d=0.6\ m}$	r = 0.90 (strong)	n = 8	
Bend	$t_{d=0.4\ m;\ luggage} \approx 1.25\ t_{d=0.4\ m}$	r = 0.91 (very strong)	n = 8	$r_{\alpha=0.05} > 0.71$

Table 5.6: Relation between walking with luggage through water depths of 0.2, 0.4 and 0.6 meter.

From table 5.6 it appears that taking luggage with you on a straight stretch has a negligible reduction in time. The delay was slightly greater when walking with luggage in a bend. It is not exactly clear from the results why people walked slower on this part, however the participants walked more cautiously in the bend with a backpack. The bottom was not visible, making it more difficult to follow the curve.

5.5. Fleeing in the darkness

During fleeing at night, the visibility is reduced. This influence is investigated by doing the experiment in the evening in order to answer the question: **'What is the influence of darkness on the fleeing speed?'**. Fleeing during darkness takes more time than fleeing during daylight. However, if the water levels become too high to stay dry or the shelter collapses, a person must flee in the dark to a safe location in order to survive.

Four persons successfully completed the parcourse in the dark of which two persons completed the parcourse during daylight as well. The data is attached in appendix L for walking and appendix P for bicycling and walking with a bicycle. The time measurements from the two persons who completed the parcourse during daylight and darkness can be compared to each other to see what the influence of the darkness is on the fleeing speed.

Two notes are made for this part:

- In a flood situation, it is likely that there is no electricity, so the surroundings are completely dark. During the experiment this was not fully the case as there is a highway located nearby and light from a nearby building.
- There is assumed that the difference in time measurements is the same between daylight and darkness for each part and round.

5.5.1. Walking

The relations of walking during darkness compared to daylight is given in table 5.7. Additionally, the data points are given in figure 5.3 and there is a relation given for the merged data from person A and B which is $t_{darkness} \approx 1.53\ t_{daylight}$.

Relation between walking during daylight and darkness				
Person	**Relation**	**Correlation**	**Measurements**	**Significant**
A	$t_{darkness} \approx 1.51\ t_{daylight}$	r = 0.88 (strong)	n = 25	$r_{\alpha=0.05} > 0.40$
B	$t_{darkness} \approx 1.57\ t_{daylight}$	r = 0.92 (very strong)	n = 25	

Table 5.7: Relation between walking during daylight and by darkness.

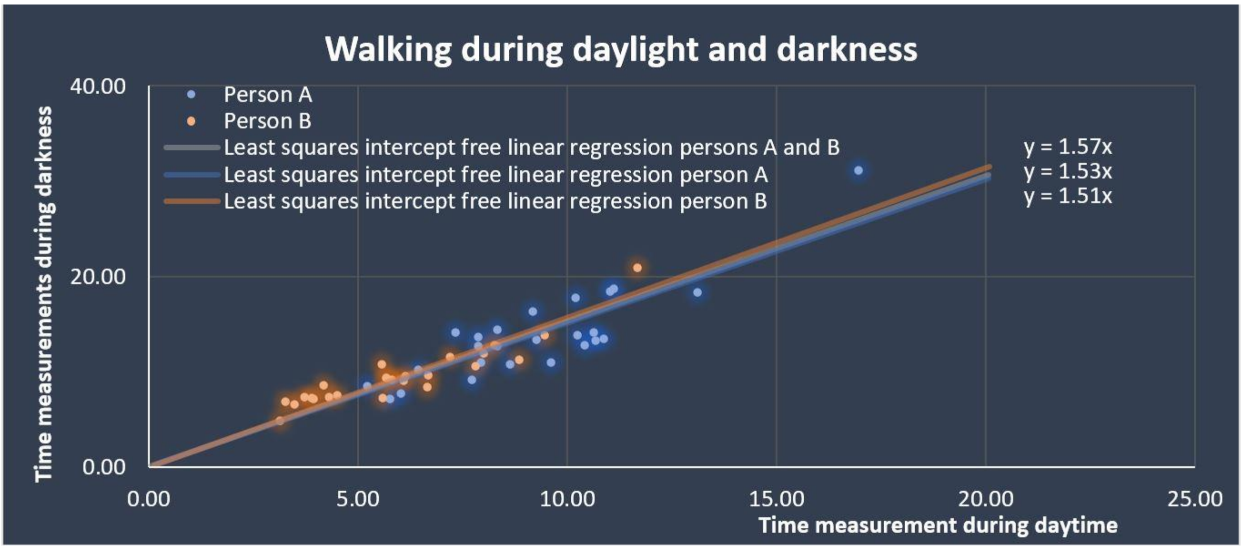


Figure 5.3: Walking during daylight and darkness for persons A and B.

5.5.2. Bicycling and walking with a bicycle

Person A walked with the bicycle and person B bicycled over the parcourse. Table 5.8 gives the relations. Note that these relations give a smaller difference in time between daylight and darkness than the relation for walking ($t_{darkness} \approx 1.53\ t_{daylight}$).

Relation between bicycling and walking with a bicycle during daylight and darkness				
Person	**Relation**	**Correlation**	**Measurements**	**Significant**
A: Walking with bicycle	$t_{darkness} \approx 1.27\ t_{daylight}$	r = 0.91 (Very strong)	n = 25	$r_{\alpha=0.05} > 0.40$
B: Bicycling	$t_{darkness} \approx 1.31\ t_{daylight}$	r = 0.94 (Very strong)	n = 25	

Table 5.8: Relations of walking with a bicycle and bicycling between daylight and by darkness.

5.6. Following the road

As described in paragraph 3.4, it is expected that people prefer to take their usual route to another area. During this displacement it is important that people do not:

- Injure themselves
- Trip over or fall
- Lose track of the road

The risk of getting injured, trip over or fall, or gets lost increases if someone steps next to the road. A person can injure themselves by stepping for example into a hole or a ditch. A person with a sprained ankle may not be able to continue fleeing and needs to be rescued or moves more slowly. This can result into a time delay or if a person falls and becomes wet, the risk of hypothermia increases. If a person becomes hypothermic the risk of dying increases. Further, there is a chance of losing the track and getting lost during fleeing out of the flooded area by stepping next to the road.

During the experiment the following observations were made regarding the risks describes above:

- Injure themselves: nobody injured themselves during the experiment.
- Trip over or fall: one participant tripped over at the straight part with a water depth of 0.6 meter and was completely wet.
- Gets lost by walking off the road: every participant was able to follow the parcourse.

Furthermore, this paragraph describes how often participants stepped next to the parcourse at different water depths during day and by night, and for a straight part and a bend. This in order to answer the question: '**Can the road be followed during fleeing?**'. An elaboration on the data is included in appendix Q.

For the part below, note the following:

- 'n' represents the number of participants.
- Walking with an object includes walking with a dog, bag and an air mattress.
- The parts without measurements from the experiment are not considered. For example, walking through debris without water is not included as there is no data for this from the experiment.

5.6.1. Following the straight road

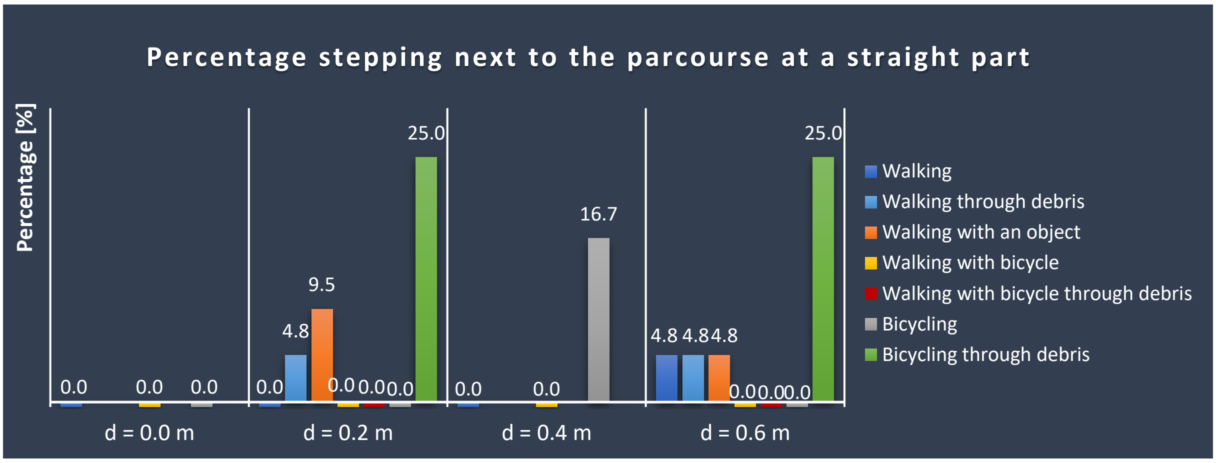


Figure 5.4: Walking (n = 21), walking through debris (n = 21), walking with an object (n = 21), walking with bicycle (n = 9), walking with bicycle through debris (n = 5), bicycling (n = 6), bicycling through debris (n = 4).

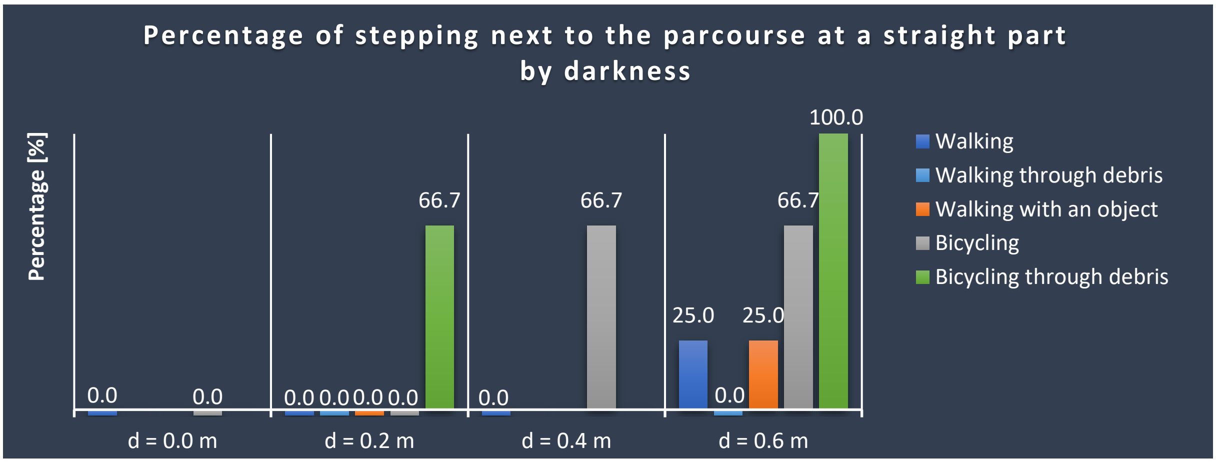


Figure 5.5: Walking (n = 4), Walking through debris (n = 4), Walking with an object (n = 4), bicycling (n = 3), bicycling through debris (n = 3). Walking with a bicycle in darkness is only carried out by one person, this is not taken into account in this figure.

Figure 5.4 shows that without water on the parcourse, nobody stepped or bicycled next to the parcourse. Below, the most important results related to “following the road” are given. The categories walking, bicycling and walking with a bicycle are distinguished.

The most important results are:

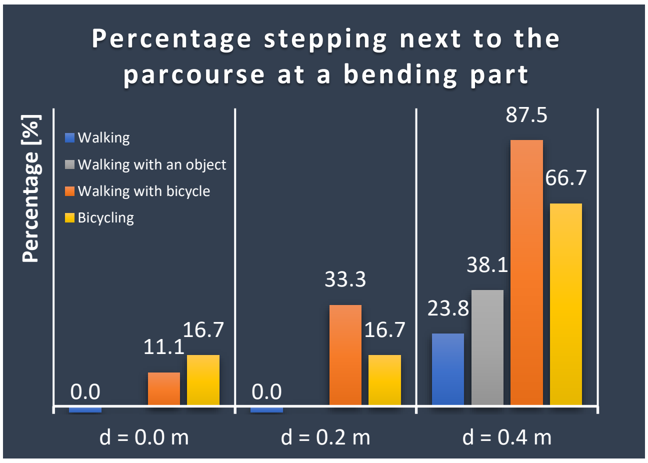
- Walking:
  - One of the 21 participants walked next to the parcourse at a water depth of 0.2 meter and 0.6 meter during daylight.
  - During darkness only at a water depth of 0.6 meter one persons out of the four participants stepped next to the parcourse.

- Walking with bicycle:
  - Nobody walked next to the parcourse with a bicycle during daylight.
  - The participant who walked with the bicycle during darkness only stepped or bicycled next to the parcourse at a water depth of 0.6 meter.

- Bicycling:
  - With the exception of one person, the participants walked with the bicycle at a water depth of 0.6 meters or did not reach the other side of the basin and has to walk further. These participants walked with the bicycle during a water depth of 0.6 meter. This could be an explanation why participants did not stepped next to the parcourse at a water depth of 0.6 meters, while at a water depth of 0.4 meters participants did during bicycling.
  - One out of four participants stepped next to the parcourse because of debris in the water.
  - Participants were more likely to get off the track when bicycling both during daylight and darkness, and especially in the presence of debris.

Note that four participants carried out the experiment by darkness of which only one person chose to walk with a bicycle and this result is therefore not included in figure 5.5.

5.6.2. Following a bend in the road



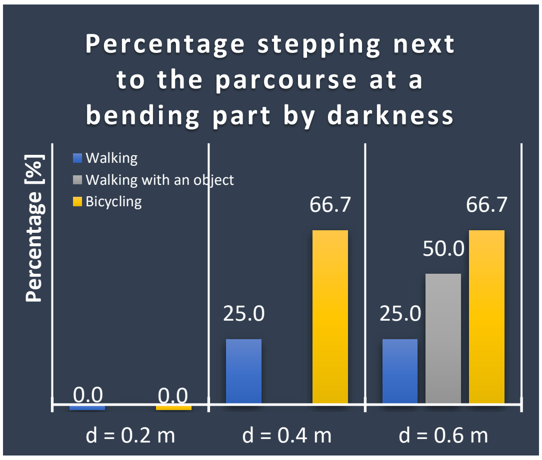


Figure 5.6: Walking (n = 21), walking with an object (n = 21), walking with bicycle (n = 9), bicycling (n = 6).
Figure 5.7: Walking (n = 4), Walking through debris (n = 4), Walking with an object (n = 4), bicycling (n = 3), bicycling through debris (n = 3). Walking with a bicycle in darkness is only carried out by one person, this is not taken into account in this figure.

Figures 5.6 and 5.7 show that at a water depth of 0.2 and 0.4 meters, there is a higher percentage of people who stepped or bicycled next to the parcourse in comparison with no water at the parcourse. At 0.4 meters of water, the bottom was no longer visible and at this water depth more participants stepped or bicycled next to the parcourse.

The most important results for walking with bicycle:
- In contrast with walking with a bicycle over a straight part by which nobody stepped next to the parcourse, walking with a bicycle in a bend is different. Figures 5.6 and 5.7 show that participants stepped next to the parcourse more often. However, in almost all cases only the bicycle went next to the parcourse as participants used the bicycle to indicate where the parcourse was located by pushing the bicycle in front of them. Additionally, note that the width of the parcourse at the straight part is 2.0 meter and at the bend 0.6 meter. This causes that the two parts of the parcourse are not fully comparable as a narrower course increases the risk of stepping off the track.
- During darkness, the only participant who walked with a bicycle walked next to the parcourse at a water depth of 0.2 meter.

5.7. Different means of transport

In this paragraph the following question is answered: **'What is the influence of different means of transport such as walking, bicycling, with floating objects, by car or navigating with a boat on the fleeing speed?**', except from the part fleeing by car or boat as this is excluded from the experiment.

Figure 5.8 shows that finishing the parcourse by walking (indicated with a '1') takes slightly more time than finishing the parcourse by walking with a bicycle (indicated with a '2'). Especially at basin 3, for walking through the bend at a water depth of 0.4 meter, there is a larger difference in time. Walking with a bicycle takes more time at this part than walking without a bicycle.

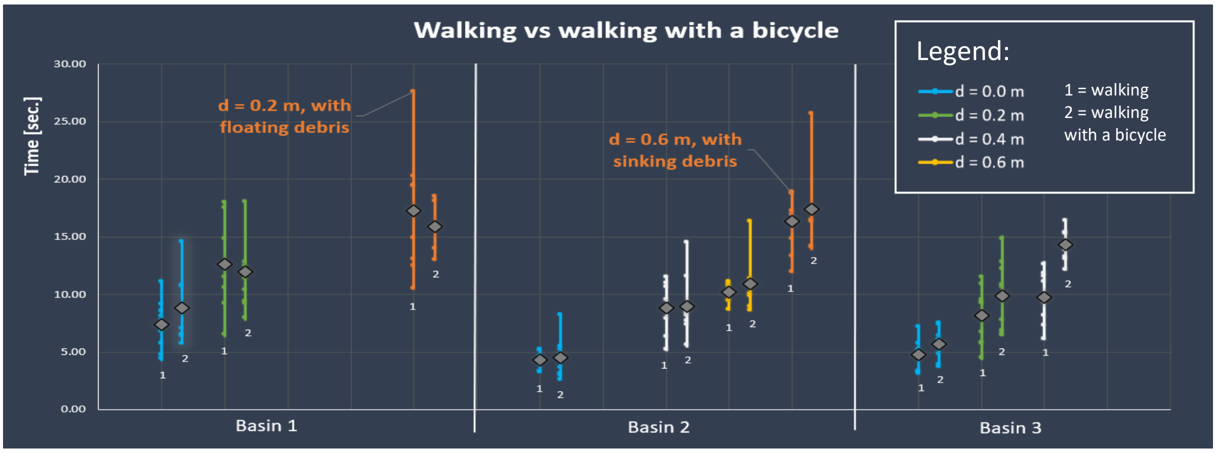


Figure 5.8: Time comparison for walking and walking with a bicycle for each basin, n = 9 (persons 3, 6, 7, 9, 20, 22, 23, 24 and 25). The dots on the lines are individual realizations.

For the straight part, bicycling over the parcourse without water and with a water depth of 0.2 meter is faster than walking, see figure 5.9. Additionally, it is observed that participants did not step off and on the bicycle.

As shown in figure 5.9, walking is faster than bicycling through a water depth of more than 0.2 meter. During the experiment it became clear that stepping on and off the bicycle takes time. Note that everyone except one person had to step off the bicycle at the bend and continue walking with the bicycle.

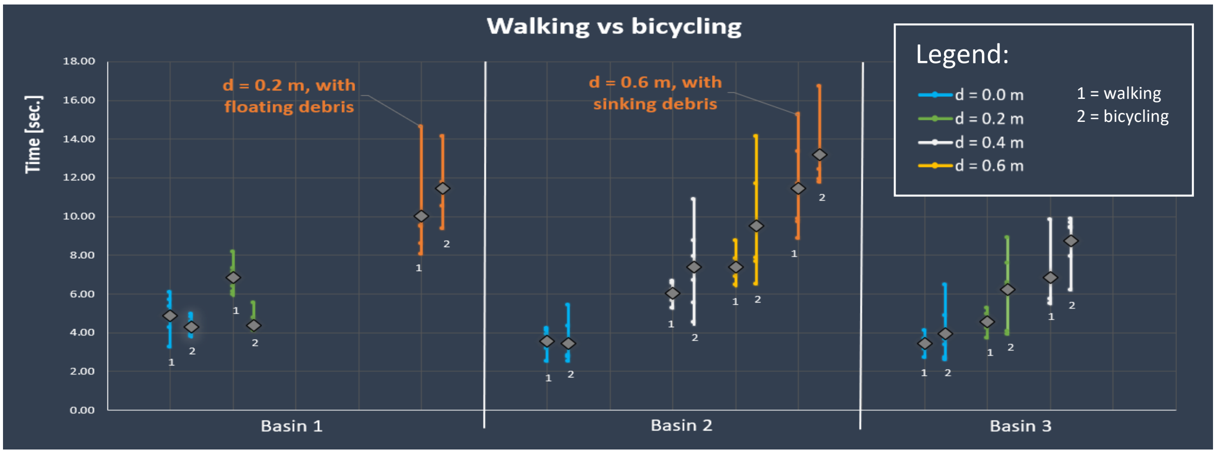


Figure 5.9: Time comparison for walking and bicycling for each basin, n = 6 (persons 4, 5, 12, 14, 15 and 21). The dots on the lines are individual realizations.

5.8. Overview experimental results

This paragraph gives an overview of the results combined into a flow chart. The flow chart includes also the fleeing velocities. Below the flow chart, the use of the flow chart is explained and an example of using the flow chart is given. Additionally the spread, check of normality of the variables and cross correlations are included. Further the relations are visualized in this section and lastly the advantages and disadvantages of each means of transport are described.

5.8.1. Flow chart

The relations given in this paragraph for the straight parts of the parcourse are combined into a flow chart, see figure 5.10. By following the flow chart, the fleeing time is calculated. Additionally, the fleeing velocities are given at the right side of the graph [green]. Further, the 5% and 95% boundaries are visualized above and below each factor [orange text] and the number of participants which give the data points are included for each relation [golden].

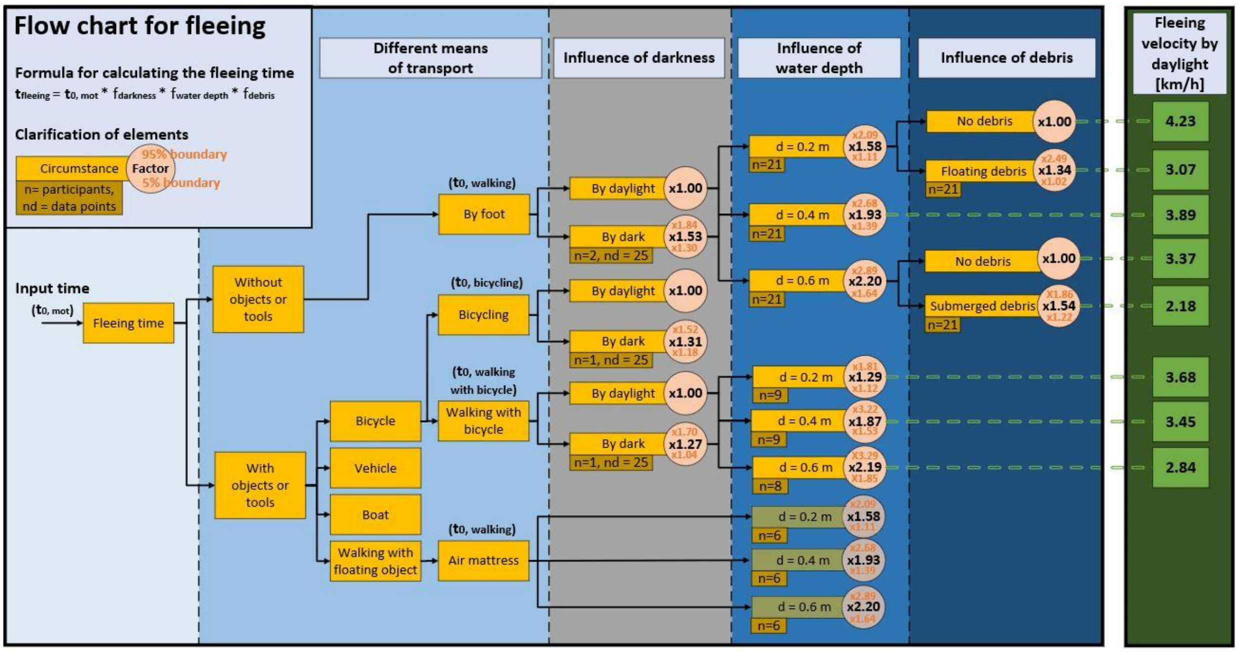


Figure 5.10: Relations regarding the fleeing time combined into a flow chart.

Use of flow chart

The use of the flow chart is explained with the following formula:

$$t_{fleeing} = t_{0,mot} * f_{darkness} * f_{water\ depth} * f_{debris}$$

Parameters:

- $t_{0,mot}$ = time it takes to travel over a distance without a flood for a means of transport (m.o.t.).
- $f_{darkness}$ = factor indicating the influence of darkness
- $f_{water\ depth}$ = factor indicating the influence of the water depth
- f_{debris} = factor indicating the influence of debris

Fleeing velocity

Additionally, from the time measurements the fleeing speed is calculated and added in the flow chart, see figure 5.10. The calculation is attached in appendix R. The velocities are added as these are generically applicable in other situations whereas the fleeing times are not.

Spread and check of normality of the variables
As described in paragraph 4.1, the Pearson product moment correlation analysis and the paired sample t-test should only be used if the variables are normally distributed. For the relations used in the flow chart, the normal distribution is visualized and compared to the data in graphs added in appendix S. The cumulative distribution function (cdf) is used as the probability density function (pdf) can be influenced by the number of chosen bins. This appendix also includes the mean, standard deviation and, visualization of the 5% and 95% boundaries for the relations in the flow chart of figure 5.10.

It is difficult to indicate if the data is normally distributed because of the relatively small data set. From the graphs in appendix S, it seems like the data is following a normal distribution. However, the distributions for walking through debris and walking with a bicycle compared to the normal distribution differ a bit more. Nevertheless, the Pearson moment correlation coefficient and the t-test are still be usable as a violation of the assumption of normality is usually not that bad.

Cross correlations
To see how the data set compares to each other, the cross correlations of the data used in the flow chart of figure 5.10 are calculated and added in appendix T. From this calculation it can be be seen that the correlation for walking with a bicycle through debris shows some low values. This indicates that a person is slower at this part than the mean. It is possible that this has to do with de limited amount of data points for walking with a bicycle through debris, which is four.

Notes
- Walking with an air mattress: There is no significant difference in time measurements between walking with and without an air mattress at water depths of 0.2, 0.4 and 0.6 meter. This means that the same relations of walking without objects or tools are used for walking with an air mattress. By using the flow chart, this means that in case of walking with an floating object, $\mathrm{t}_{0,\mathrm{walking}}$ must be used as $\mathrm{t}_{0,\mathrm{mot}}$.
- Number of data points:
  - Walking with a bicycle: For water depths 0.2 and 0.4 meter, there were 9 participants. At a water depth of 0.6 meter, there were 8 participants as person 7 did not complete this round. This person fell in the water during walking at a water depth of 0.6 meter in basin 2 and had to change clothes first.
  - Darkness: For walking in the darkness, there are 25 mean factors based on factors between daylight and darkness for two participants. For walking with a bicycle and bicycling, the data are based on time measurements from one person.

Example use of flow chart
Further, to clarify the use of the flow chart the following example is used:
During normal conditions it takes for example 60 minutes (t_0) to walk over a certain distance. Now, this same person walks during daylight through a water depth of 0.2 meter with floating debris.

By following the flow chart, this takes:
$\mathrm{t}_{\mathrm{fleeing}} = \mathrm{t}_{0,\mathrm{walking}} * \mathrm{f}_{\mathrm{darkness}} * \mathrm{f}_{\mathrm{water\ depth}} * \mathrm{f}_{\mathrm{debris}} = 60 * 1.00 * 1.29 * 1.34 \approx 104$ minutes.

The extra time needed during walking through this example flooded area is $104 - 60 = 44$ minutes. Note that this is the minimum extra delay for walking through the flooded area.

Visualization relations
The relations from the tables in this chapter are also visualized into figure 5.11. The lines are extended transparent towards the factor of 1.0. Further, two lines are dashed as these lines are relations for debris with missing data for a water depth of 0.4 meter. Additionally, note that at a water depth of 0.2 meter there was floating debris and at a water depth of 0.6 meter there was submerged debris.

Furthermore, the green solid lines represent the upper and lower boundary of the factor without the influence of debris. An example on how these boundaries are calculated is given in case of a water depth of 0.2 meter:

$$f_{\text{upper boundary},d=0.2m} = f_{\text{dark},95\%} * f_{d=0.2m,95\%} = 1.84 * 2.09 = 3.85$$
$$f_{\text{lower boundary},d=0.2m} = f_{\text{daylight}} * f_{d=0.2m,5\%} = 1.00 * 1.11 = 1.11$$

The dashed green line represents the upper boundary in case debris is taken into account. However, this line is based on the 95% boundary for the factor at a water depth of 0.2 meter with floating debris and 0.6 meter with submerged debris. The data for a water depth of 0.4 meter with debris is missing. Note that this is the really worst case scenario as for all three factors individually (f_{dark}, $f_{\text{water depth}}$, and f_{debris}) the 95% boundary of the data is used and multiplied with each other.

As the water depth increases there is a point where people are no longer able to walk and start to swim. It is not exactly known at which water depth this is. However, to indicate that there is a boundary, the blue dashed line is added at the right side of figure 5.11.

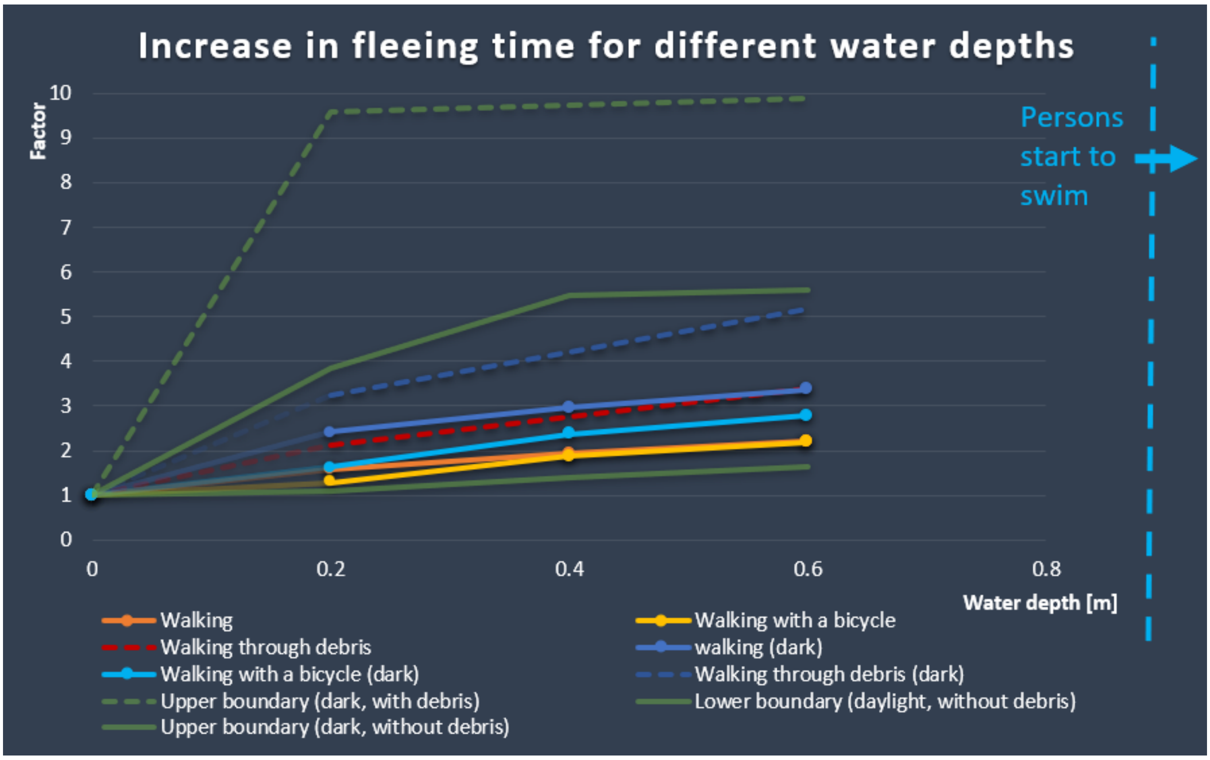


Figure 5.11: The increase in fleeing time for walking. Note that for walking through debris, the line is dashed because there is no data available for walking through debris at a water depth of 0.4 meter. Additionally, at a water depth of 0.2 meter the debris was floating and at a water depth of 0.6 meter the debris was submerged.

From figure 5.11 it seems like the lines are flattening for an increasing water depth.

5.8.2. Advantages and disadvantages of different means of transport

The advantages and disadvantages in case of walking and using a bicycle is given in an overview at table 5.9.

		Advantages	Disadvantage
Walking	-	Some participants used a stick to locate other debris and to check where the way is located.	-
	With bag	-	Slight delay for walking over a bend at a water depth of 0.4 meter.
	With dog	-	If the dog does not want to walk with a person, it causes a time delay.
	With air mattress	• Several participants indicated that a floating object can be useful to transport luggage. • A floating object can be used to stay above the water to prevent drowning.	None of the participants used the air mattress to sit or lay on. Some participants indicated that the risk of getting wet or tilting of the air mattress is too high.
Bicycle	Bicycling Stepping	For a straight part, bicycling till a water depth of 0.2 meter is faster than walking.	• It is not possible to bicycle over all kinds of surfaces. • Time delay during getting on and off a bicycle. • Higher risk of falling in the water. If a person gets wet, the change on hypothermia increases. • People have to lift the bicycle over the debris or walk around it.
	Walking with bicycle	• A bicycle can be used as support during walking. • A lot of bicycles have a luggage rack which can be used to transport luggage or a slightly injured person.	• People have to lift the bicycle over the debris or walk around it.
	Carrying the bicycle	-	-

Table 5.9: Overview advantages and disadvantages per means of transport.

5.9. Reflection on case Terschelling

In an actual evacuation situation after a flood longer distances need to be covered than by the experiments. Therefore, the context of a potential flood at Terschelling will be used to show how these results relate to longer distances. Terschelling is an interesting area for this because:

- It is categorized into category I, which has a flood depths between 0.0 and 0.5 meter, see paragraph 2.3. At this range of water depth, people can flee.
- It is an island surrounded by the Wadden Sea and the North Sea. A large part of the residents will not want to leave the island behind. However, in case people want to flee to the main land, a boat is needed.

An indication of how the flow chart with the relations of the experiment is used in the event of a flood is visualized in this paragraph.

5.9.1. Location

Place: Terschelling, Midsland
Breach location: Kinnum-West

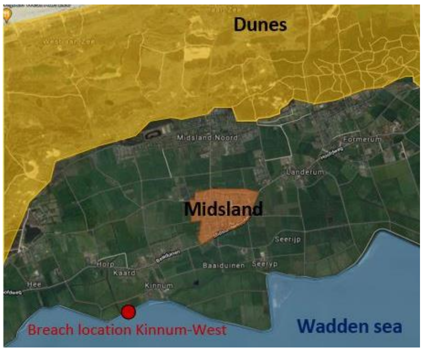


Figure 5.12: Overview of Terschelling (Google, n.d.-b).
Figure 5.13: Zoomed overview of Terschelling (Google, n.d.-b).

5.9.2. Fleeing route

As concluded from paragraph 3.4, people prefer to take the usual route. The route from Midsland towards the dunes is one straight head road and it is expected that this is the usual route for people to transport themselves to the dunes, see figure 5.14.

Route: Midland towards dunes, see figure 5.14
Fleeing distance: 800 meter

Figure 5.14: Fleeing route from Midsland towards the dunes (Google, n.d.-b).

5.9.3. Debris

The first 400 meter, the road lays between meadows, see figure 5.15. It is assumed that there is no influence of debris at this part. At the last 400 meter, the road is located between trees, see figure 5.16. As categorized in paragraph 2.2, this area is a forest area and thus there is influence of floating debris.

Figure 5.15: Impression of surrounding at the fleeing route at the first 400 meter (Google, n.d.-b).
Figure 5.16: Impression of surrounding at the fleeing route at the last 400 meter (Google, n.d.-b).

5.9.4. Flood depth

After three days, the flood depth at the route from Midsland towards the dunes deviates between 0.0 and 0.6 meter, see detail A at figure 5.17. The timescale of three days is chosen because the water level declines and after three days it is assumed that people will undertake a fleeing attempt when these people are not rescued yet by then.

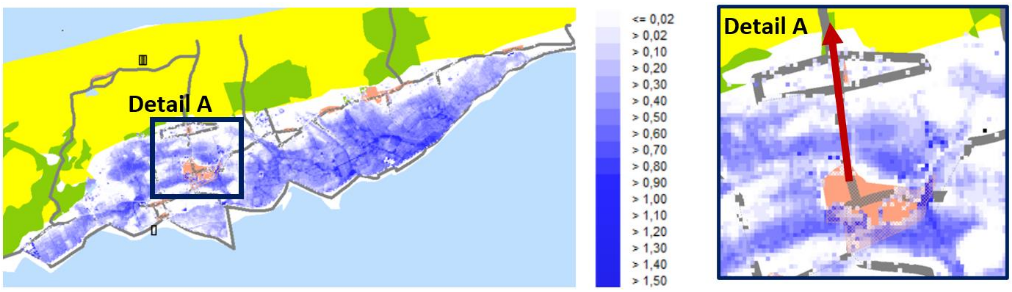


Figure 5.17: Flood depths at three days after a breach at Kinnum-West.

The SOBEK model in figure 5.17 has a grid size of 25x25 meter. Every square has its own constant flood depth rounded to a decimal and this is given with round bullets for the route from Midsland towards the dunes in figure 5.18. Further, as these bullets each have a water depth with a corresponding distance of 25 meter, the distances are assembled into categories into table 5.9. The categories consist of flood depths of 0.2, 0.4 and 0.6 meter.

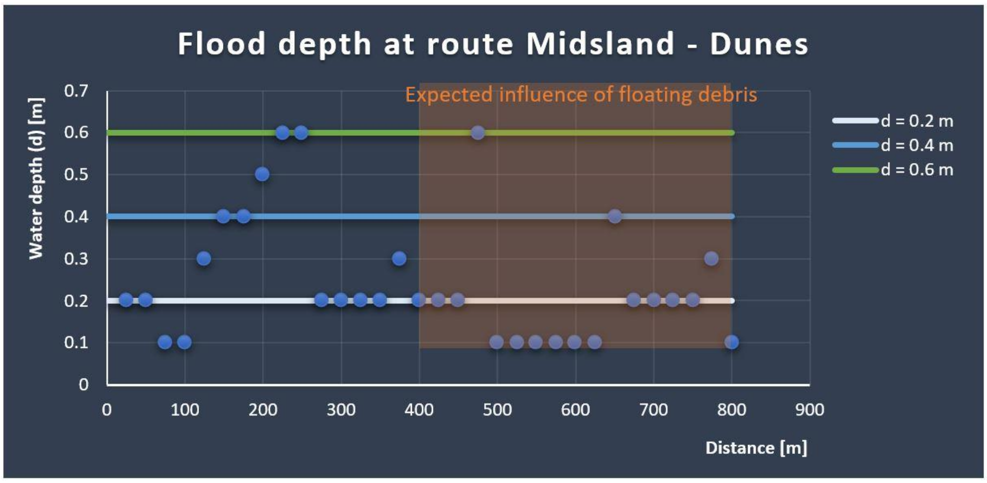


Figure 5.18: Flood depth at route Midsland to the dunes.

In figure 5.18 is the flood depth at the route from Midsland towards the dunes categorized into 0.1 till 0.6 meter. The distances are devided into:

- Water depth of 0.1 and 0.2 meter: (9+13)*25 = 550 meter
- Water depth of 0.3 nad 0.4 meter: (3+3)*25 = 150 meter
- Water dpeht of 0.5 and 0.6 meter: (1+3)*25 = 100 meter

5.9.5. Parameters

Hypothermia	As concluded from the experiment where people walked in a temperature of 5 ^{o}C and with the exposure to wind and rain in paragraph 3.2, 72% of the people cannot withstand the wet-cold conditions for more than two hours because of hypothermia. This gives a limit for the fleeing time, which will be assumed as two hours at this paragraph.
Distance	The distance of 800 meters used in this paragraph is from the edge of Midsland towards the first dry location, which is the dunes. Note that the time from a home towards the edge of Midsland is not taken into account. Furthermore, if a person reaches the dunes, this person needs some facilities such as a shelter to warm up. The facilities and further evacuation of the dune location is not included in this paragraph.

(Table proceeds on the next page).

Daylight	In this paragraph it is assumed that people flee during daylight.
Flow velocity	The flow velocity for category I. will be below 0.5 m/s, except for a breach location which is not the case here, and therefore the influence of flow velocity is neglected in this section.
Flood depth	The grid size in the SOBEK model is 25x25 meter. The deviations in these 25 meter zones are neglected. Furthermore, the flood depths are categorized into 0.2, 0.4 and 0.6 meter. If a flood depth is in between these values, it will be rounded up.
People	It is assumed that the individual who flees has a sufficient enough physical condition to walk without the help of others and tools. In this section the influence of fleeing in a group is not taken into account.

Table 5.10: Assumptions.

5.9.6. Calculation fleeing time

The fleeing time will be calculated with the relations from the experiment. The relations shown in figure 5.10 in paragraph 5.8 are used for the calculation of the fleeing time.

Fleeing by foot

Fleeing by foot			
	t0 [s]	**Time with influence of water depth: t1 [s]**	**Time with influence of water and debris: t2 [s]**
	$\frac{525}{1.39} \approx 378$	$t_{d=0.2\ m} \approx 1.58 * 378 \approx 597$	$t_{d=0.2\ m} \approx 1.34 * 597 \approx 800$ (Expected floating debris)
	$\frac{150}{1.39} \approx 108$	$t_{d=0.4\ m} \approx 1.93 * 108 \approx 208$	$t_{d=0.4\ m} \approx 208$ (No expected influence of debris)
	$\frac{100}{1.39} \approx 72$	$t_{d=0.6\ m} \approx 2.20 * 72 \approx 158$	$t_{d=0.4\ m} \approx 158$ (No expected influence of debris)
Total:	558 (9 min.)	963 (16 min.)	1166 (19 min.)

Table 5.11: Calculation of fleeing time.

Table 5.11 shows that the fleeing time by foot of 19 minutes is approximately two times larger than the travel time of 9 minutes for walking over the same route without a flood.

Notes on the results from table 5.11:

- The calculated fleeing time of 19 minutes is the fleeing time if everything goes as planned. In reality the fleeing time will be more because of unexpected situations, such as roadblocks by trees.
- The part of fleeing from the hiding place till the edge of Midsland is not included even as the part from just reaching the dry area. This will increase the total fleeing time.
- People can get injured along the way or tired. This is not taken into account.
- The fleeing time of 19 minutes plus some extra (unexpected) delay is less than two hours which is assumed to be the limit before people get in trouble regarding hypothermia.

Other means of transport

Fleeing by bicycle is not included because it is equally fast or slower. The water depths are too deep to drive through by car and most water depths are too shallow to navigate through by boat.

6. Experience of boat rescues

This chapter describes the results of the questionnaire about the rescue of people from a flooded area in order to answer the sub-question: **'What are core factors such as navigation speed, time needed to reach one person and boarding time during a rescue operation in a flooded area by a lifeboat?'**, see figure 6.1 which indicates the relevant part for this chapter.

Twelve experts were asked to fill in the questionnaire, of which six responded. The responses of these experts are included in appendix U. Two experts did not answer the questionnaire due to private circumstances. Three other experts confirmed receiving the questionnaire however did not respond after a reminder and one expert did not respond at all.

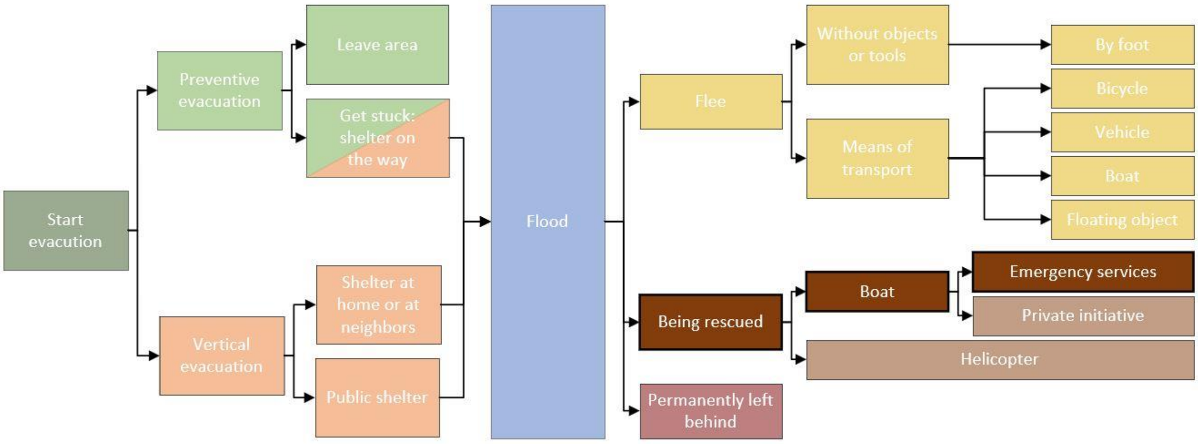


Figure 6.1: Parts included in this research given as overview in the evacuation process. The part included in this paragraph is: 'Being rescued' [brown].

6.1. Navigation speed

This paragraph is meant to answer the following question: '**Compared to the navigation speed of a lifeboat in an unobstructed waterway, how much is the navigation speed reduced in a flooded area and does this depend on the water depth?'**. In order to answer this question, experts estimated the navigation speed of three types of lifeboats which will be used during a flood by the NRV.

Table 6.1 gives ranges and the mean value of the given answers per lifeboat type. All experts made a distinction in sailing speed for different water depths. The visualization of this data is made in figure 6.2. For figure 6.2 notes are made:

- The dots on the lines are the individual realizations.
- For category I, there shall be a minimum water depth which is equal to the draft of the lifeboats and is larger than 0.0 meter. If a lifeboat just floats, it can easily be pushed by people walking next to the lifeboat.

		Vlet: 9.9 – 15 pk 		Tinn-Silver: 50 – 60 pk  (Reddingsbrigade Egmond aan Zee, n.d.)		Rescue 3: ~ 70 pk  (Schepenkring Yachtbrokers, n.d.)	
		Range [knots]	Mean [knots]	Range [knots]	Mean [knots]	Range [knots]	Mean [knots]
Non-flooded area		5 – 10	7.6	22 – 33	27	25 – 30	27.8
Flooded area	I.) 0.0 – 0.5 m	1 – 4	2.5	1 – 3	2.2	1 – 3	1.8
	II.) 0.5 – 1.0 m	3 – 7	4.7	1 – 10	4.6	1 – 9	4.2
	III.) 1.0+ m	3 – 9	6.3	1 – 15	9.5	1 – 16	10.5

Table 6.1: Estimation from expert on the navigation speed. Units are in knots. [1 knot = 1.852 km/h].

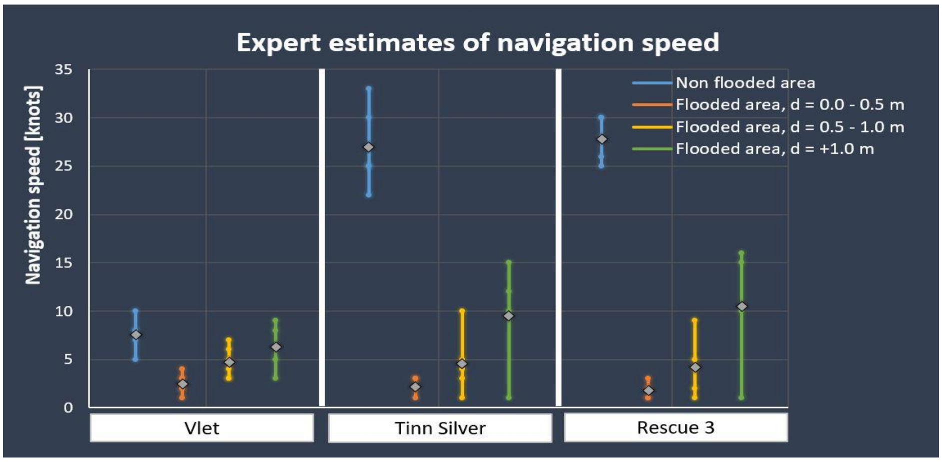


Figure 6.2: Estimation from expert on the navigation speed. The mean values are indicated with the diamond. Units are in knots. (1 knot = 1.852 km/h). The dots on the lines are individual realizations.

As seen from figure 6.2 the navigation speed is approximately 2 knots for navigating in an area with a flood depth below 0.5 meter. For a larger water depth in a flooded area, the navigation speed is larger. The maximum estimated navigation speed (averaged for all responds) for the Tinn Silver and the Rescue 3 is 10 knots in a flooded area.

The reduction of navigation speed in a flooded area compared to a non-flooded area per boat type is calculated with: $\text{Speed reduction}[\%] = \frac{\text{flooded area} - \text{non flooded area}}{\text{Non flooded area}} * 100\%$. The results are given in table 6.2. This table concludes that the faster two boat types have a large reduction in navigating speed compared to the Vlet.

		Vlet: 9.9 – 15 pk 	Tinn-Silver: 50 – 60 pk  (Reddingsbrigade Egmond aan Zee, n.d.)	Rescue 3: ~ 70 pk  (Schepenkring Yachtbrokers, n.d.)
		Reduction [%]	Reduction [%]	Reduction [%]
Flooded area	I.) 0.0 – 0.5 m	-67.1	-91.9	-93.5
	II.) 0.5 – 1.0 m	-38.2	-83.0	-84.9
	III.) 1.0+ m	-17.1	-64.8	-62.2

Table 6.2: Reduction in percentages of navigating in a flooded area compared to navigating through a waterway for different lifeboat types.

The experts are asked what the influence is of debris on the navigation speed and if waves on the environment cause a reduction in navigation speed. The experts indicated that it is a matter of safety to reduce the navigation speed in a flooded area, because:

- Rescue workers are unfamiliar with the situation and do not know what exactly the circumstances are in a flooded area.
- Debris can cause damage to the boat and engine. One expert claims that the lifeboats are fairly resistant to light floating debris. However, all agree that debris decreases the navigation speed as the rescue crew cannot take the risk of damaging the boat and engine.
- Waves produced by the lifeboat:
    - Expert 1 and 4 answered that waves caused by lifeboats may cause hinder to other lifeboats operating in the same area. One expert notes that it is possible that waves could hinder the rescued people in the lifeboat and even create instability of the affected lifeboats. The other expert mentioned that people can become wet and the risk of hypothermia increases.
    - Expert 3 describes that waves produced by the lifeboat could be hindering the own lifeboat when navigating through narrow streets with houses or walls on both sides.
    - Expert 5 and 6 indicate that these waves can unnecessarily damage the environment.
    - Expert 2 answers that waves produced by the lifeboat will not reduce the sailing speed as the speed during a rescue operation in a flooded area is already low.

6.2. Reaching people

During a rescue attempt it is not immediately known where people are located in an area and who needs to be rescued. In this section the following questions are answered: **'How can people be found?'** and **'Is it realistic to reach everybody who need to be rescued?'**.

6.2.1. Systematically searching an area

The experts are asked to think of a way to systematically search a flooded area for survivors. The experts give approximately the same descriptions for searching a flooded area and a separation between an urban and a less populated area is made.

- Urban area: house to house check. The lifeboat will sail to every house and knocks on the door or window to get a response if someone needs rescue.
- Less populated area: search patterns are needed and additionally expert 5 answered that assistance of a helicopter is required.

Experts 2 and 6 point out that the rescue crew should make notes on maps where humans are located. Further, experts 3 and 6 indicate that communication with a central command post should be used to record which areas have been searched and which areas still need to be searched.

6.2.2. Realistic or unrealistic to find every person

All experts indicate that it is not realistic to reach every person during a flood. People will go missing and depending on the time between action and the flood, people could have died.

Expert 5 mentions that 95% of the population in a flooded area can be found. The success of finding all people depends on the passed time, area size and number of lifeboats. This expert notifies hereby that the type of boat is less decisive during the search as the speed will be approximately equal. The coordination and an efficient search pattern are more important.

6.3. Transferring people into a lifeboat

This paragraph answers the question: **'How will people be transferred into a lifeboat and how much time does this takes?'**. In this paragraph three situations are distinguished, namely:

- Rescue from a higher floor
- Rescue from a collapsed building
- Rescue out of the water

After gaining insight how people can be rescued from these locations, an indication is given on how long it will take to transfer a person from its location into a lifeboat.

6.3.1. Rescue from a higher floor

It is expected that the majority of people who needs rescue are vertically evacuated at a dry floor. This can cause a height difference between the surface of a rescue boat and the location of a person who needs rescue. Below the answers of experts are summarized which indicate how a person can be transported into a lifeboat from a higher floor. A distinction is made for people who can move by themselves and evacuees who cannot move by themselves. These last group of people will consist of injured, elderly or handicapped people.

Evacuees who can move by themselves:

- Evacuees can climb down and enter the lifeboat by themselves via the bow. This can be done with the use of a ladder. However, a ladder is not standard equipment in a lifeboat of the NRV.
- A person can fall in the water and become wet. This increases the risk of hypothermia.

Evacuees who cannot move by themselves:

- A person can be hoisted from the roof by a helicopter and then descend into a lifeboat.
- Transport on a stretcher. This is not very comfortable for the patient, and it does take multiple lifeguards. It is not preferred, but the stretcher could be lowered into the lifeboat by rope if necessary.

6.3.2. Rescue from a collapsed building

As mentioned in paragraph 3.1, there is a possibility that a hiding place will collapse. If a person is vertically evacuated in this hiding place, this person is at risk of getting stuck, injured or die.

During the rescue of people, the top one priority of the rescue workers is safety. The experts all indicated that a collapsed building gives several risks and it is possibly unsafe to enter the (partly) collapsed building. Generally, the crew of the lifeboats are not allowed to enter a collapsed building as these rescue workers are not qualified. Searching collapsed buildings is a task for the USAR (Urban Search and Rescue).

6.3.3. Rescue out of the water

During a flood there is a possibility that a person needs rescue out of the water. This can be the case if a person gets lost, injured or stuck in the water during fleeing out of the flooded area.

In paragraph 3.2 there is described that the survival time for staying unprotected in the water with a water temperature of for example 8 ^{0}C is maximum six hours for a fat male, five hours for a fat female and two hours for a lean person. Before reaching these survival times, a person gets hypothermic and unconscious. To prevent drowning this person has to stay afloat. So, in order to rescue a person out of the water, there is only a limited time before this person dies.

Experts describe the following ways to get a (unconsciousness) person into a lifeboat:

- Pulled on board vertically by lifeboat crew.
- Pulled on board horizontally by lifeboat crew, this is recommended for people who are hypothermic. However, it is difficult to pull somebody horizontally on board into a Vlet or Tinn Silver due to the weight of the person who needs rescue and the number of rescuers in the lifeboat.
- Pulled on board by lifeboat crew using a Jason’s cradle rescue net. This is a special net in which a patient can be pulled on board, see figure 6.3. Note that this is not standard equipment in a lifeboat of the NRV.
- Pulled on board by using a salvage stretcher, see figure 6.4. Note that this is not standard equipment in a lifeboat of the NRV and more than one rescue worker is needed.
- The Tinn Silver lifeboats has an opening on starboard side to take easily poeple on board, see figure 6.5. Other lifeboat types of the NRV do not have this option.



Figure 6.3: Jason’s Cradle (Jason’s Cradle, n.d.).
Figure 6.4: Salvage stretcher (Ants medical, n.d.).
Figure 6.5: Tinn Silver with opening on starboard, indicated with the blue circle (Reddingsbrigade Egmond aan Zee, n.d.).

6.3.4. Timeframe of boarding into the lifeboat

The timeframe, estimated by the experts, from making contact with the person who needs rescue until this person is in the lifeboat is indicated in table 6.3.

	Range	Mean
Higher floor/attic	3 – 15 min.	7½ min.
Collapsed building	3 min. till hours	30 min.
Water	0.5 – 1 min. (Till 10 min. with the use of a stretcher)	1 min.

Table 6.3: Timeframe estimated by experts of boarding into the lifeboat.

6.4. Employability of rescue equipment

After a rescue a lifeboat will be used in a new rescue attempt. This paragraph gives insight into the employability of rescue equipment and answers the following question: **'Will the rescue equipment remain usable after a rescue in a flooded area?'**.

6.4.1. Number of deployments

If handled properly, it is expected by experts that a lifeboat can be used numerous times and be operational for 24 hours a day as long as there are enough crew members. Another aspect which is important is the availability of sufficient fuel. The operating time depends also on whether a lifeboat gets damaged or not during a rescue. If there is damage of vital elements it is not safe for the lifeboat and its crew, the lifeboat must be repaired immediately to be deployable again.

6.4.2. Damage

The experts described the following causes of damage:

- Debris
- Obstacles under water and shallow water
- Collision with another boat
- Taking wrong or contaminated fuel
- Chemicals in the water

During a rescue operation in a flooded area the following equipment and modifications are described by the experts to prevent damage:

- Using a gauging rod to check for obstacles in front of the boat and to investigate the draft.
- Use propellor protection
- Notes on the type of boat: use a hard material for the hull of a lifeboat, like aluminum or polyester, and use a suitable shape. Additionally, the type of engine and cooling system is of influence by preventing damage.

The experts are asked how likely it is that a lifeboat during a rescue operation in a flooded area gets damaged. The outcomes of the answers are summarized below.

- 4 out of 6 experts think that it is likely that a lifeboat is damaged due to navigating in a flooded area and cannot proceed to rescue people during the flood.
- One other expert answered that it is not likely that a lifeboat of the NRV gets damaged as the lifeboats are made of strong material. However, if a lifeboat gets damaged it is most likely loss of propulsion. Then the lifeboat cannot proceed with rescuing people.
- One other expert answered that the risk is high but will decrease if the speed reduced. A lifeboat got only one engine, when this is broken down, the lifeboat crew needs to be rescued.

6.4.3. Needed crew members per 24 hours and available space for people

Table 6.4 shows that a crew of eight till 12 persons and one chauffeur is needed to have one lifeboat operational for 24 hours during a flood.

Expert	Persons per crew	Number of shifts	Total needed person per 24 hours
1	3	3	10 – 12
2	4	2	8
3	2 – 3	3	9
4	3	3	9
5	3	3	9
6	3	4	12

Table 6.4: Needed crew members during a flood.

It is indicated by experts that the available space in a lifeboat depends on the boat type. For a Vlet and a Tinn Silver, the maximum number of people in the boat is seven persons. This means if a boat crew of three persons is present, there is room for four persons who needs to be rescued during one rescue attempt. For the Rescue 3 type of boat, in total only six persons can be transported.

6.5. Overview results

Calculation time needed during a rescue attempt:

The time needed for a total rescue attempt is the summation of several parts and given in the following formula: $t_{\text{rescue attempt}} = t_{\text{alarm}} + t_{\text{loading}} + t_{\text{navigation}} + t_{\text{searching}} + t_{\text{boarding}} + t_{\text{unloading}} + t_{\text{material check}}$.

Parameters:

- t_{alarm} = time needed from the call or command until informing the rescue crew.
- t_{loading} = launching the lifeboat into the water and the time needed for the rescue crew to put on a survival suit and stepping on board of the lifeboat. For a second rescue attempt in the same area, directly after a first rescue attempt, this parameter only represents a change of crew members if necessary.
- $t_{\text{navigation}}$ = the timeframe to travel from an assembly point into a flooded area where the search starts and the time needed to travel back to the assembly point if a person is boarded. The navigation time is calculated with: $t_{\text{navigation}} = \frac{x}{v}$ with v = navigation speed in a flooded area, given in table 6.5.
- $t_{\text{searching}}$ = time needed to find someone in a flooded area.
- t_{boarding} = the timeframe from making contact with the person who needs rescue until this person is in the lifeboat.
    - Higher floor/attic: $t_{\text{boarding}} = 7.5$ min.
    - Collapsed building: $t_{\text{boarding}} = 30$ min.
    - Water: $t_{\text{boarding}} = 1$ min.
- $t_{\text{unloading}}$ = time needed for the rescued people to step out of the boat.
- $t_{\text{material check}}$ = time needed to check the material and refill equipment if necessary.

Vlet		Water depth	0.0 – 0.5 m	0.5 – 1.0 m	+ 1.0 m
		Navigation speed (v)	2.5	4.7	6.3
Tinn Silver		Water depth	0.0 – 0.5 m	0.5 – 1.0 m	+ 1.0 m
		Navigation speed (v)	2.2	4.6	9.5
Rescue 3		Water depth	0.0 – 0.5 m	0.5 – 1.0 m	+ 1.0 m
		Navigation speed (v)	1.8	4.2	10.5

Table 6.5: navigation speed per water depth (Reddingsbrigade Egmond aan Zee, n.d.), (Schepenkring Yachtbrokers, n.d.).

Dependency between parameters
There are too few datapoints to obtain a good overview of cross correlations in order to determine if the parameters are dependent on each other or not. Also, only values are estimated by experts for the navigation speed and the boarding time.

Most likely the following parameters are independent of each other: t_{alarm}, $t_{loading}$, $t_{navigation}$, $t_{searching}$ and $t_{boarding}$. If for example the time for making the alarm time takes very long, this does not mean that the navigation time increases. However, the time to needed unload poeple ($t_{unloading}$) depends on the time it takes to take people on the lifeboat ($t_{boarding}$). This is the case if for example a person is injured. It takes then longer to take this person into the boat and out of the lifeboat. Further, the time needed to check and refill the material ($t_{material\ check}$) increases as well. Additionally, refilling material ($t_{material\ check}$) depends on the navigation time. If the distance to navigate is larger, more fuel is needed and it thus takes more time to refill the fuel tank.

6.6. Reflection on case Dordrecht

In an evacuation situation after a flood a part of the population needs rescue. Therefore, the context of a potential flood at Dordrecht will be used to show how the results from the experts relate to a rescue attempt. Dordrecht is an interesting area for this because the water depth after approximately 1.5 days is overall approximately 3.0 meter and after 7 days the overall water depth is still 2.0 meter, see paragraph 2.3. At this water depth people cannot stand with their head above the water and the only possibility to leave the area is by boat or helicopter.

6.6.1. Location and route

In this scenario the evacuation route from Dubbeldam to Papendrecht is used, see figure 6.6. The distance is approximately 4 km in this scenario, see figure 6.7.

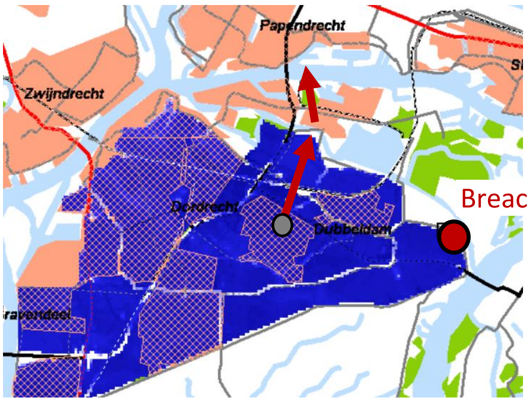


Figure 6.6: Evacuation from Dubbeldam in Dordrecht to the edge of the flooded area.
Figure 6.7: Distance from Dubbeldam to Papendrecht (Google, n.d.-c).

6.6.2. Definitions and assumptions

Navigation time	This is the time it takes to sail from Papendrecht to Dubbeldam and back for the Vlet, Tinn Silver and Rescue 3. The time is calculated by dividing the distance by the navigation speed. The distance is 8 km in this scenario and the navigation speed is estimated by experts, see table 6.1 in paragraph 6.1. From this table the mean navigation speeds are used, which are: 6.3, 9.5 and 10.5 for respectively the Vlet, Tinn Silver and the Rescue 3.
Searching time	This is the time duration to find one person who needs rescue. In this scenario, it is assumed that it takes 10 minutes to find one person who needs rescue in a flooded area.
Boarding time	This is the time between the contact with a person until the person is in the lifeboat. The mean boarding time is estimated by experts, see paragraph 6.3, and divided into three situations: 1.) From a higher floor or attic which takes on average 7.5 minutes 2.) From a collapsed building which is takes average 30 minutes 3.) From the water which takes on average 1 minute
Getting off the lifeboat and checking the material	This is the time needed for people to get out of the lifeboat and to transfer them to the shore crew. Additionally, the rescue equipment must be checked to make sure it is safe to start a new rescue attempt. In this scenario it is assumed it takes 10 minutes to do this.

Table 6.5: Definitions and assumptions.

6.6.3. Calculation time needed for a rescue attempt

	Alarm and loading [min.]	Navigation time [min.] • t = x/v • x = 8 km	Searching time [min.]	Boarding time [min.]	Getting off the boat and checking of material [min.]	Total time [min.]
Vlet v = 6.3 knots v = 11.67 km/h	(5)	41	(10)	$t_{1;\text{ higher floor}} = 7.5$ $t_{2;\text{ coll.building}} = 30$ $t_{3;\text{ water}} = 1$	(10)	$t_1 = 68.5$ $\mathbf{t_2 = 91}$ $t_3 = 62$
Tinn Silver v = 9.5 knots v = 17.59 km/h		27				$t_1 = 54.5$ $t_2 = 77$ $t_3 = 48$
Rescue 3 v = 10.5 knots v = 19.45 km/h		25				$t_1 = 52.5$ $t_2 = 75$ $\mathbf{t_3 = 46}$

Table 6.6: Calculation time needed for a rescue attempt. X = distance, which is 8 km. V = navigation speed with 1 knot = 1.852 km/h.

From table 6.6 the total time of rescuing a person till a possible start of a new rescue attempt is minimal 46 minutes and maximal 91 minutes. Most likely the majority of people who need rescue are located at a higher floor. It takes approximately 50 to 70 minutes to bring someone from a higher floor into safety out of the flooded area.

Notes on the results from table 6.6:

- In this example it is not the intention to see how many people needs rescue and if there are sufficient homes high enough to have a dry floor. The information regarding buildings with a dry floor during a flood is shown in the LIWO map: ‘Beschikbaarheid droge verdiepingen per gebouw’.
- For a scenario with a water depth less than 1.5 meter, the navigation speed is estimated by experts to be less, see paragraph 6.1. Note that the navigation speed is dependent on the water depth and debris. Also, the navigation speed can deviate due to unforeseen circumstances, for example too much debris or a blockage.
- The time of getting off the lifeboat can increase in case a person is badly injured which complicates getting a person out of the lifeboat. Also, if the rescue equipment is damaged and some small repairs are necessary or in case of replenishment of material there will be a delay.

6.6.4. Amount of people that needs rescue out of Dubbeldam

As the water depth is too large to walk through and the water does not drop for a larger time period, (almost) all people who are vertically evacuated need to be rescued. The capacity of transporting rescued people in a lifeboat of the NRV is four persons at a time, see paragraph 6.3. With the information from LIWO maps of how many people are vertically evacuated and information about how many lifeboats are available, the total needed rescue capacity can be calculated.

For this area a special note should be made as in the area of Dordrecht a larger lifeboat of the NRV is available, namely the Zuid-Holland-Zuid, see figure 6.8 and paragraph 3.5. During a flood scenario, this ship lays in a tactical place. Because of the larger capacity, this ship can take over the rescued people from the smaller lifeboats, like the Vlet, Tinn Silver and the Rescue 3. This will reduce the navigation distance and thus the time for each rescue attempt.

Figure 6.8: Zuid-Holland-Zuid (Van Straten, 2019).

7. Discussion

Paragraph 7.1 discusses the results of the experiment about fleeing. First, the results of the experiment are repeated. Then, the aspects for using the flow chart are given, the results are compared to literature and expectations. After this, in paragraph 7.2, the results from the questionnaire are discussed, beginning with the experts and data. Then the assumptions are discussed and the results are compared to literature and expectations. Lastly in this paragraph, suggestions on improvement of rescue equipment are given. Further, paragraph 7.3 discusses the visualisation of the results of the experiment and the questionnaire into flood scenarios in the Netherlands and abroad. Paragraph 7.4 gives suggestions for future research and paragraph 7.5 elaborates on a setup of a model.

7.1. Experiment fleeing

The flow chart, see figure 7.1, is a tool to answer the question **'How much time is needed for one person to flee through a flooded area?'** for different means of transport by following the chart from left to right. The chart starts with the input time $t_{0,mot}$, which is the time it normally takes for a certain means of transport to leave the area. Then for this same means of transport the flow chart is followed resulting in the calculation of the fleeing time. Additionally, the 5% and 95% boundaries, the number of participants and the fleeing velocity by daylight are given.

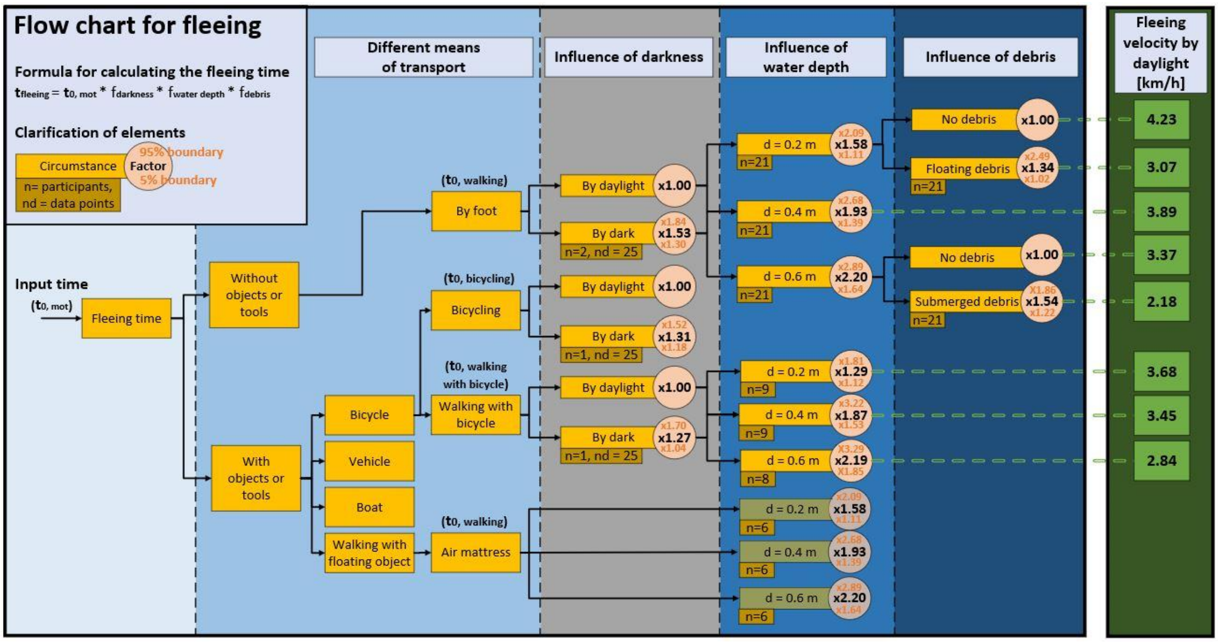


Figure 7.1: Flow chart.

7.1.1. Important aspects for using the flow chart

The two most important aspects which should be considered by using the flow chart or redoing the experiment are the flow velocity and the length of the parcourse. During the experiment the water levels were stable and there was no influence of flow velocity. This means that by using the flow chart given in figure 7.1, the flow velocity should be low enough to not influence the fleeing time during a flood. However, during a flood there are locations at which the flow velocity is of influence on the fleeing speed. The other aspect is the length of the parcourse, which is 40.5 meter. During a flood, the distance that a person flees is larger than 40.5 meter. If hypothermia and tiredness is taken into account the fleeing time based on the flow chart shall increase. Especially for hypothermia, there is a large spread in the time delay. As more time passes the likelihood of getting hypothermic increases and if a person get hypothermic, it takes longer to displace themselves. When the body temperature drops even more and reaches a higher state of hypothermia, people are unable to leave the area by themselves and the risk of dying increases.

Further, there is a boundary regarding the water depth. The water depths of 0.2, 0.4 and 0.6 meter are small enough to walk through, however there is a boundary at which people are no longer able to walk and start to swim. If a person starts to swim, the available fleeing time before getting hypothermic decreases. During this experiment it was not the aim to determine this boundary. However, this boundary is important to know as this is of influence by determining the possibility for a person to flee to a safe area or that rescue is needed.

25 participants completed the parcourse which represent a large part of the population in the Netherlands. Disabled humans are not included in the experiment, because it is likely that these people cannot flee and need to be rescued. Further, for walking over the parcourse, the relations are based on 21 time measurements and for walking with a bicycle on eight or nine time measurements. Deviations due to measurement errors will be minimal as deviating times are compared to video images. However, the used data is a small sample of a much larger group, which implies that there is uncertainty in the relations. This uncertainty will decrease if more people complete the parcourse, resulting in a larger dataset. To check what the probability is of finding correlated samples by change, the Pearson moment correlation coefficient is compared to the values in the table of critical values. All relations used in the flow chart have a significant correlation which indicate that the data has a high enough correlation.

The effect of repetitive learning is taken into account by deviating the round order for each experiment. No increase nor decrease is seen in time for a group of people with the same round order compared to another group of people with a different round order.

During a flood, group behaviour will play a role in case lots of people walk behind each other and cannot pass each other. This is not included in the experiment. The fleeing speed of a group is determined by the slowest person and this slower moving person can cause a congestion. A congestion increases the fleeing time and if the fleeing time increased, the risk of hypothermia will increase. Further, people can learn from each other. If one person steps into a hole, it is likely that the next person does not step into this particular hole.

For the experiment in the dark, the relations in the flow chart can deviate from a flood situation. There was light from the surroundings that will not be present in case of a flood, as the electricity will probably be cut off. Additionally, four persons completed the experiment in darkness. By redoing the experiment, the results will become more reliable if more participants participate. Further, the influence of bringing a flashlight or torch can be considered during a next experiment.

7.1.2. Comparison of results to literature

Scientific literature on the subject of fleeing after a flood is limited. Because of this, the flow chart shown in figure 7.1 gives new insight in the fleeing time. Unfortunately, the results cannot be compared to available data as there are no relevant data found.

7.1.3. Review on the expectations given in paragraph 4.1

In general, the results met the expectations described in paragraph 4.1. The most interesting differences between the expectations and the results are given below with an explanation. Note that the expectations are not based on scientific literature.

It is interesting to see that a water depth of 0.2 meter gives a larger time delay than expected. At a water depth of 0.2 meter, the bottom profile is visible. The expectation is based on only the physical ability and not including the mental part of humans. For an increasing water depth, the factors shown in the flow chart given in figure 7.1 between traveling without water and with water increase less and less. This is different from the expected linear increase, however, may be explained by the following. People have the least resistance if they get their legs out of the water while taking a step. With an increasing water depth, this becomes more and more difficult and eventually it is no longer possible to take a leg out of the water during a step. Additionally, there is an upper boundary for the relations as for a particular water depth people cannot stand anymore and start to swim.

7.2. Questionnaire about lifeboat rescues

The core values during a rescue attempt are asked in the following question: **'What are core factors such as navigation speed, time needed to reach one person and boarding time during a rescue operation in a flooded area by a lifeboat?'**. In order to answer this question, in paragraph 6.5 the core values are combined to the formula: $t_{\text{rescue attempt}} = t_{\text{alarm}} + t_{\text{loading}} + t_{\text{navigation}} + t_{\text{searching}} + t_{\text{boarding}} + t_{\text{unloading}} + t_{\text{material check}}$ and a questionnaire is spread among experts.

7.2.1. Experts and data

The core factors are estimated by experts, which all have at least ten years of experience with boat rescues, and are divided over various rescue brigades within the Netherlands. Six experts answered the questionnaire of which three experts took part in the deployments during 1993 or 1995 and two experts are also active at the KNRM. The results are therefore based on the estimations of six experts and this creates uncertainty. This uncertainty can be reduced by increasing the number of experts and by using other methods, like the classical model for expert judgement. Nevertheless, based on the experience of experts with lifeboat rescues it is stated that the results are valid for this study. However, note that the experts do not have experienced a flood disaster like 'De Watersnoodramp' of 1953.

7.2.2. Review on assumptions made in paragraph 4.2

In paragraph 4.2 assumptions are made and these will be discussed in this section. First of all, in this report it is assumed that there is enough fuel available for all lifeboats during the total rescue. This should be the case, but in reality there is a possibility that the supply of fuel forms an issue. Especially if the rescue takes a longer period. If there is not enough fuel, the rescue cannot proceed until there is enough fuel.

Another important aspect is that members of the rescue crew can get injured or the boat can get damaged during a rescue attempt. In this case the rescue attempt cannot proceed and the rescue capacity reduces.

The water depth in the areas with category I (0.0 till 0.5 meter) can be a limitation for the navigation because of the draft of the lifeboats. If a lifeboats floats, but it is too shallow to sail, members of the rescue crew can walk next to the boat in order to move.

7.2.3. Comparison of results to literature

In this section the results of the questionnaire are compared the Excel model of Matthijsse (2016).

Navigation speed

The navigation speed described in paragraph 3.5 is 4 to 6 km/h (which is 2.16 to 3.24 knots) for a lifeboat of the NRV. The answers on the questionnaire provides a new insight into the navigation speed in a flooded area as it depends on the water depth and the type of lifeboat.

Boarding time

While the data from paragraph 3.5 differentiate between boarding times for non-disabled (20 min.) and disabled (40 min.) humans, the experts make a difference in time estimations between shelter locations.

Model of Matthijsse

The following assumptions are made in the model of Matthijsse (2016) for the calculation of rescue time during floods:

- The navigation speed is 5 km/h (2.70 knots).
- Boarding and unloading time is 10 minutes.
- Five persons are rescued per rescue attempt.

The Model of Matthijsse (2016) does not fully fit with the results estimated by experts. With the expert estimations, this model can be complemented and be more elaborate by:

- Differentiating the navigation speed for different water depths and types of boats.
- Making a difference in the location of people
- Adding the time it takes to find a person and to check the rescue equipment and the time needed to process the alarm.
- Considering the maximum amount of people in a lifeboat.

7.2.4. Review on the expectations given in paragraph 4.2

Almost all expectations are in line with the results from the questionnaire. The only expectation which deviates from the answer is about the navigation speed. It is expected that a Vlet will navigate slower than a Tinn Silver and a Rescue 3 because of the limitation in engine power. However, the mean estimated navigation speed of a Vlet is higher than the mean navigation speed of a Tinn Silver and a Rescue 3 for water depths till 1.0 meter.

7.2.5. Improving rescue equipment

The time needed at each rescue attempt can maybe be reduced if the rescue equipment is improved. However, it is not exactly sure in what extent this will decrease the total time needed for each rescue attempt. The following possibilities regarding the transportation of people into a lifeboat can be considered:

- Scramble net
- Ladder
- Swim-ladder
- Breeches buoy system
- Bow- or stern visor
- Hypothermic stretchers
- Different types of ropes

Figure 7.2: Breeches buoy (Wikipedia, n.d.).

Furthermore, the following improvements can be considered regarding reaching people:

- Tools to open up a house; a crowbar, big hammer, bolt cutter and a knife.
- Nightlights and flashlights during the rescue in the dark.
- Depth indicator.

And lastly some improvements regarding the lifeboat crew:

- Personal protective equipment for the lifeboat crew: GPS trackers, helmets and more lifelines.
- Add paddles in the lifeboat for the case the engine does not work anymore and the crew is stuck in the flooded area.

7.3. Results in the context of a flood situation typical for the Netherlands

This paragraph is added to provide a review of the results for flood scenarios in the Netherlands. The first part is about the categorization of areas in the Netherlands. Then, the assumption made in literature about the percentage of people who can flee or need to be rescued will be compared to the flood scenarios of Terschelling (category I) and Dordrecht (category III). A division per category is used for this. Lastly, a small section is added which describes the value of the results from the experiment in flood scenarios abroad.

7.3.1. Flood scenarios in The Netherlands

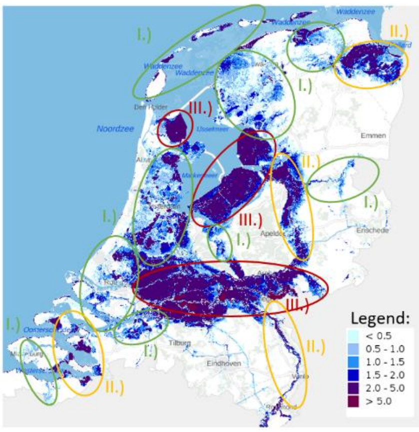


Figure 7.3: Maximum water depth for a small probability of a flood (1/300 till 1/3000 per year). Category IV 'breach locations' is not included in the figure. Map received on the 26th of October 2020 (LIWO, n.d.).

The results of the experiment and the questionnaire are visualised into flood scenarios in the Netherlands. In order to do so, in this report the Netherlands is divided into three main categories mainly based on the maximum water depth for a probability of a flood of 1/300 till 1/3000 per year, see figure 7.3.

The maximum water depths will be larger for a scenario with a smaller probability of a flood, however this map is not used as the chance of occurrence is so small it becomes unrealistic. For a scenario with a larger probability of a flood, like 1/30 till 1/300 per year, the maximum water depth will be less and the flooded area will be smaller. This flood scenario will be more realistic for example at an area along the river Meuse in Limburg. However, figure 7.3 gives a rough categorisation and is not based on scenarios with the most likeliness of occurrence in each individual area. Further, the water depth in an area can deviate at different times per area after a breach for each flood scenario and can exceed the limits of a category.

Three flood scenarios are described in paragraph 2.3 of which Terschelling (Category I) is elaborated in paragraph 5.9 and Dordrecht (Category III) in paragraph 6.6. In this section it is discussed whether it is realistic to flee or if rescue is needed per flood scenario and how the flood scenarios may represent other areas in the Netherlands of the same category.

Category I

From the vertically evacuated people, which can be determined with the use of LIWO maps, it is assumed that at a water level of less than one meter (category I and II) 90% of the people can flee and 10% must be saved, see paragraph 3.3. It is expected that the 10% who need to be rescued are injured, elderly or handicapped humans.

There is a distinction between fleeing at the beginning and at the end of the flood. At the beginning of the flood, people may be surprised by the water during acute evacuation. It is therefore not recommended that people flee during this phase.

If the water is spread over the area, there is a possibility that people decide to flee. The calculated fleeing time in case of walking from Midsland till the dunes at Terschelling, three days after the breach, over 800 meter is 19 minutes. This fleeing time can be discussed as it is the fleeing time based on the assumption that everything goes as planned. In reality the fleeing time is a bit larger because of group behavior, stepping next to the parcourse (or in a sewage hole) at which a person can get injured, weather circumstances, road blockages and the uncertainty in debris. Also, if a dog does not want to go into the water or does not walk easily on a leash the fleeing time will increase. The part of going out of a hiding location which take some time is not included. Furthermore, in a fleeing scenario at night, the visibility is reduced which increases the fleeing time.

After two hours of exposure to a wet environment, see paragraph 3.2, people get hypothermic which forms a limitation to the fleeing time. This limitation is not taken into account in the flow chart of figure 7.1. Caution is important and attention must be paid to awareness of the risks of getting hypothermic, tired, injured or getting lost during fleeing. There is also a possibility to wait for rescue. However, as the difference between 19 minutes plus some extra delay and two hours is sufficiently large, all non-disabled physical fit people are able to flee over this distance. If the injured, elderly and handicapped humans are 10% of the vertically evacuated people, 90% can flee and 10% must be rescued. This confirms the above assumption for this area and will hold for all areas in the Netherlands belonging to category I.

Category II
The flood scenario Zwolle which belongs to category II is not used to visualize the results. However, at this flood scenario the water depths are between category I, where people are able to flee, and category III, where people need to be rescued. It is not exactly clear when people are no longer able to walk, but this will be approximately above 1.0 meter. The fleeing time will be larger than for a category I and depends on the distance to a dry location.

Category III
As the water depth at Dordrecht is too large to walk through and the water does not drop for a larger time period, (almost) all people who are vertically evacuated need to be rescued. This is not in agreement of the assumed ratio between fleeing (60%) and rescuing (40%) for a water level above one meter, see paragraph 3.3. A possibility that 60% of the vertically evacuated people can flee is when these people have a boat at home. However, this is not the case as indicated in paragraph 3.4 in which is described that less than 3% of the Dutch citizens have their own recreational vessel. Another possibility is to build a raft and paddle out of the area. This is unlikely as there is a limited amount of floating materials available and people need to paddle over a long distance at which people are exposed to the environment.

The time needed to rescue a person from a higher floor is calculated at Dordrecht between Dubbeldam and Papendrecht is 46 minutes for a Rescue 3 till 91 minutes for the Vlet. The calculated rescue time over a distance of 8 km is approximately the same for another area of category III with the same navigation distance.

Breach location
At the categorisation of areas, the flow velocity is below 0.5 m/s. However, at breach locations the flow velocity is larger. For the breach locations, the flow velocity can cause instability of humans, people can get hurt or drown. The flow chart and the estimations from the experts are not usable for category IV.

7.3.2. Usage of results abroad

This report is limited to areas in the Netherlands, however the relationships from the experiment may also be of value in flood scenarios abroad. Perhaps the knowledge from this report can provide added value in the event of flood due to dam breaches or volcanic eruptions at glaciers. Also, if stable water levels are reached after a flash flood or tsunami, the flow chart can be used.

Note that the relations may be used in the above situations, however the temperature can cause another timeframe in which people are able to flee before getting hypothermic. Also other aspects, like an outbreak of life threatening diseases, should be considered for flood scenarios abroad. Additionally, in order to use the relations from the flow chart, the flow velocity should be low enough to not influence the fleeing time.

7.4. Suggestions for future research

More research should be conducted into which areas in the Netherlands are not suitable to flee and whether the capacity of the NRV is sufficient to rescue all people in this area. The suggestions about fleeing and being rescued are described in this paragraph.

7.4.1. Fleeing

In order to gain more insight in how people will flee after a flood, the ideas described below can be used for further research. If one idea should be chosen to be carried out, the test street shall be of most value. The test street is expected to be the most valuable as this is a flood scenario on a small scale and shows insight into fleeing of people and the rescue by emergency services.

Test street

Simulate a flood with people in for example a street with houses. Let people make their own choices whether they prefer to stay, flee or need to be rescued. Use realistic fleeing distances and a time period of at least a week. For the fleeing distance, maybe nature reserves can be used as these areas have different water depths. Create a realistic ratio of emergency services to citizens in the test street. A diverse group that reflects society should be used and the resources should match the average possessions in a general house.

The following aspect should be considered during this test:

- Available resources of people who are vertically evacuated and the inventiveness of people.
- The behaviour of each participant separately as well as group behaviour.
- How people leave the hiding location.
- The division between people who need to be rescued or who can flee.
- Probability of failing to flee.
- Chance of disruptions during the flight.
- The influence of debris should be investigated further.
- Timescale when people become hypothermic.
- Influence of clothes.
- The influence of weather conditions should be taken into account.
- Employability of lifeboats of the NRV: damage to the lifeboat, sufficient fuel, employability rescue crew.
- The searching time for finding people, the time needed for people to get off the lifeboat in a safe area and the time needed to check material before a new rescue attempt.

Long straight track

To gain more insight into the relationship between the water depth and the fleeing speed, a long track can be taken. Let people walk over this straight part and differ in water depths. The following aspects should be considered:

- Water depth at which people start swimming instead of walking.
- More insight into whether and how people can move at different flow rates and how this relates to simulations at a breach (category IV).
- The influence of fatigue of people can be determined.
- Timescale when people become hypothermic.
- Influence of clothes.
- The influence of weather conditions should be taken into account.

Flood of 2021 in Limburg, parts of Belgium and parts of Germany
There should be research into the flood of 2021 in Limburg. This is the most recent flood and observations can be useful for gaining more insight of the evacuation of people. Also, in Belgium and Germany there were floods. It will be interesting to investigate how the results in this report compare to the situation in Germany and Belgium where people walked through water and needed to be rescued. Also, these flood situations can provide more insight in why and how buildings collapse. More insight in this last part is necessary in order to make a decision whether it is better to flee or stay vertically evacuated.

Flow riders
The influence of flow velocities on people can be tested safely with flow riders. To give an idea what a flow rider is, figures 8.2 and 8.3 are added. These special tracks ensure that people cannot get hurt by falling. However, the disadvantage of these courses is that only a small water depth can be used.

Figure 8.2: Flow rider 180 degrees (FlowRider, n.d.).
Figure 8.3: Flow rider (Archi Expo, 2021).

Tracking telephones during a flood
Floods are more common abroad. During a flood, telephones could be traced in order to observe the fleeing behaviour of people.

Virtual reality
Make a virtual reality surrounding and let people try to survive during a fictitious flood. The choices of people can be observed.

7.4.2. Rescue equipment NRV

In order to gain more insight in how people are rescued during a flood, more research is necessary. The following aspects need more attention:

- **Navigation velocity:** More insight into the amount and type of debris ensures that the navigation speed can be determined more precisely. In addition, it would be interesting to conduct an experiment to see how likely it is that a lifeboat will be damaged and whether the boat (or another type of boat and engine) can be improved in order to prevent damage.

- **Number of people per rescue attempt:** Research into the stability of lifeboats could provide insight into how a lifeboat can be improved to be able to transport more people. If more people can be taken per rescue attempt, the area is evacuated faster.

- **Boarding time:** The time it takes to rescue people from a house can be further examined by testing this in practice. Make a distinction between different groups of people.

The above aspects can be combined to investigate if there is room for improvement and maybe another type of boat. In Scotland is a lot of experience with lifeboats, which can provide new insights.

7.5. Setup of a model

The total evacuation process during a flood can be combined into a model. The evacuation will be different for each flood scenario and corresponding flooded area. For each flood scenario the amount of vertically evacuated people who can flee and need rescue can be distinguished. The relations of the experiment can be processed for the part where people flee and for the part where people need rescue, the formula that calculates the time needed for each rescue attempt can be used.

With the relations from the experiment, there can be determined how much time it takes for people to flee to a safe area. The model should take into account aspects such as deviating water depths, distances, daylight versus darkness and the influence of debris. Hypothermia, injuries and tiredness determine the available time a person has to reach a safe location. This forms the upper boundary in the model. People with a fleeing time that exceeds this boundary shall die during fleeing and this can be included in the model as amount of people who lose their life.

With the results from this report the needed time per rescue attempt can be determined. If this is scaled up to a complete flooded area, this can be processed into a model in which the rescue capacity will be determined for specific flood scenarios. This rescue capacity can be compared to the amount of people who cannot flee out of a flooded area and thus needs to be rescued. This will show if the rescue capacity is sufficient to save all people who need to be rescued during a flood.

Based on the results from the model, the evacuation strategy can be adapted. If the fleeing time exceeds the available time, the advice to the people will be to stay vertically evacuated. Further, if the rescue capacity is larger than the amount of people who need to be rescued, the advice can be that it is safer for people to wait for rescue and not to flee by themselves.

8. Conclusion

8.1. Conclusion

This report seeks to answer the research question: **'How much time does it take to flee to a safe region during a flood, and what are the core factors that determine the success of a rescue operation by a lifeboat in the Netherlands?'**. To answer the question, an experiment took place that determines the time needed to move through different water depths and other deviating circumstances. In addition, a questionnaire was distributed among experts to estimate core factors of a rescue attempt.

There is no direct singular answer to this research question, because it depends on the area where the flood takes place and the extent of the flood. However, relations are found to answer the research question per area and flood scenario. Below, a separation is made of the research question into two parts:

- Fleeing: 'How much time does it take for one person to flee to a safe region?'
- Being rescued: 'What are the core factors that determine the success of a rescue operation by a lifeboat?'

8.1.1. Fleeing

The required (minimum) fleeing time is calculated with the flow chart for the water depths of 0.2, 0.4 and 0.6 meter, see figure 8.1. The flow chart is based on the results of the experiment.

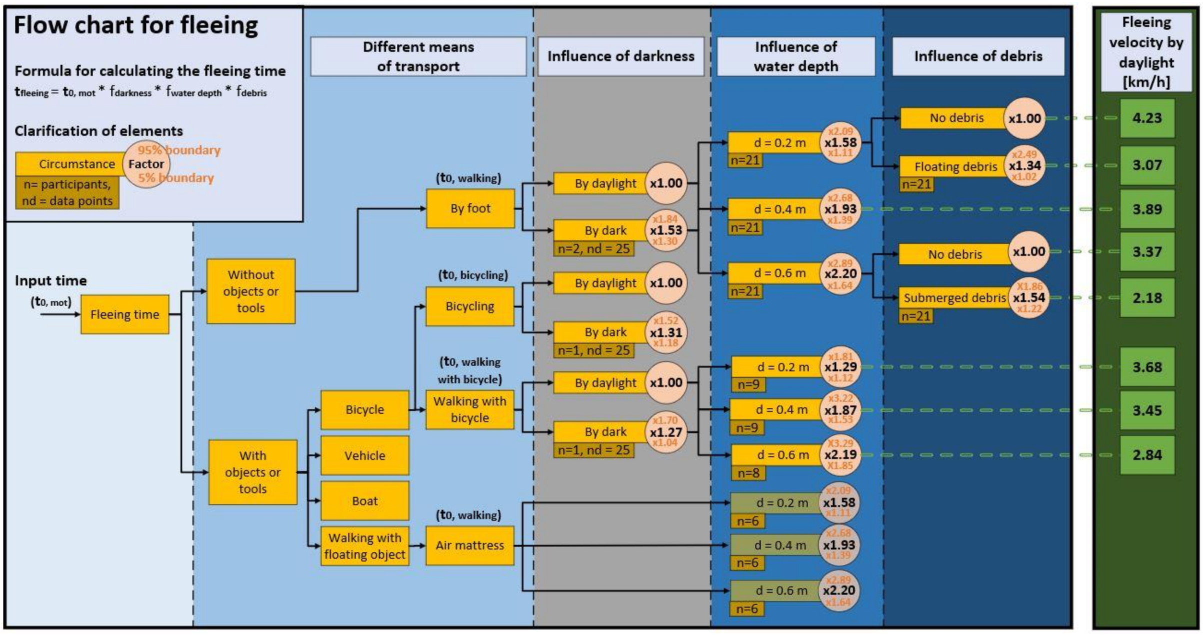


Figure 8.1: Flow chart.

As concluded from this figure fleeing during darkness and through debris increase the fleeing time. Also, larger water depths increase the fleeing time. The following section describes the most important conclusions from the flow chart in figure 8.1.

- **Different means of transport:** Fleeing by (walking with a) bicycle is (slightly) slower than walking. An advantage of bringing a bicycle is to transport luggage. This can also be done by bringing an air mattress.

- **Influence of darkness:** The increase in time due to darkness is respectively 53%, 31% and 27% walking, bicycling and walking with a bicycle for all water depths in respect to the mean times during daylight.

- **Influence of water depth:**
    - The increase of walking time is respectively 58%, 93% and 120% for the water depths 0.2, 0.4 and 0.6 meter in respect to the mean times without water.
    - The increase of walking time with a bicycle is respectively 29%, 87% and 119% for the water depths 0.2, 0.4 and 0.6 meter in respect to the mean times without water.

- **Influence of debris:** The increase in time for walking due to debris is respectively 34% for a water depth of 0.2 meter with floating debris and 54% for a water depth of 0.6 meter with submerged debris in respect to the mean times without debris.

- **Walking with a dog, bag or air mattress:** Walking with a dog, bag or air mattress does not influence the fleeing time. However, if the dog does not want to go into the water or walk easily with a person, the fleeing time will increase compared to walking without a dog. Also, people can earlier get tired by walking with a bag.

8.1.2. Being rescued

For the part of rescuing, the following formula calculates the time needed during a rescue attempt by a lifeboat of the NRV in order to rescue one person: $t_{\text{rescue attempt}} = t_{\text{alarm}} + t_{\text{loading}} + t_{\text{navigation}} + t_{\text{searching}} + t_{\text{boarding}} + t_{\text{unloading}} + t_{\text{material check}}$. Each time variable in this formula is a core value. The core factors depend on the water depth, type of lifeboat, location of the person who needs rescue and any damage caused by debris to the lifeboat. The navigation speed and boarding time is estimated by experts:

- **Navigation speed:** The navigation speed deviates for different water depths and types of lifeboats, see table 8.1. For a low water depth, the navigation speed deviates between 1.8 till 2.5 knots. For a water depth above 1 meter, the navigation speed deviates from 6.3 knots for a Vlet till 10.5 knots for the Rescue 3.

Vlet		Water depth [m]	0.0 – 0.5	0.5 – 1.0	+ 1.0
		Navigation speed [knots]	2.5 (4.6 km/h)	4.7 (8.7 km/h)	6.3 (11.7 km/h)
Tinn Silver		Water depth [m]	0.0 – 0.5	0.5 – 1.0	+ 1.0
		Navigation speed [knots]	2.2 (4.1 km/h)	4.6 (8.5 km/h)	9.5 (17.6 km/h)
Rescue 3		Water depth [m]	0.0 – 0.5	0.5 – 1.0	+ 1.0
		Navigation speed [knots]	1.8 (3.3 km/h)	4.2 (7.8 km/h)	10.5 (19.4 km/h)

Table 8.1: navigation speed per water depth (Reddingsbrigade Egmond aan Zee, n.d.), (Schepenkring Yachtbrokers, n.d.). [1 knot = 1.852 km/h].

- **Boarding time (transferring people into a lifeboat):** It is estimated that it takes 7½ minutes from the contact with a person located at a higher floor or attic until having this person into a lifeboat. For a collapsed building this takes 30 minutes and out of the water 1 minute.

8.2. Advice for a safer evacuation

The following advice should be considered for policy purposes. Before adjusting the strategy, it is important to note that there is a large uncertainty in the fleeing process of people as it depends on a lot of parameters.

Acute evacuation
Acute evacuation is very risky as people can get surprised by the flood and not able to find a safe hiding location in time with enough facilities to survive. For an urban area the opportunity to find a shelter is present to still vertically evacuate, however at a rural area this is not the case.

Fleeing
Make a consideration whether it is really necessary to flee and if this is possible. During the rise of water it will not be smart to flee, but at the end of the flood for category I it is possible. If a person decides to flee the following recommendations should be taken into account:

- Bring a bicycle to walk with or an air mattress to transport luggage. The luggage consists of valuable possessions, dry clothes in a bag to keep it dry, domestic animals and foods and drinks.
    - Bicycle: support and fast means of transport if a person travels out of the flooded area
    - Air mattress: floating object which can be used to hang on to prevent drowning if a person cannot flee further.
- Use materials, like a stick to check where the road is located, to notice changes in the bottom profile and to prevent stepping into holes.
- Avoid areas with debris as this will increase the fleeing time.
- The visibility during fleeing in the dark is limited and it takes more time to flee out of the flooded area. Therefore, it is not recommended to flee during darkness, except if this is inevitable to survive.
- Wear as much as possible warm and especially rainproof clothes. This will increase the time before a person becomes hypothermic.

Rescue
If a person decides to stay and wait for rescue, this can be done at a hiding place. In order to help emergency services with finding people, the amount of people and the location can be written on the roof by the people who need rescue. Especially for category III areas, fleeing is not an option and it is recommended to stay at a dry hiding place. Research is needed if houses are strong enough to withstand a flood and if the NRV has enough capacity. If this is the case, it is recommended to look for a campaign for citizens in which the citizens will be informed to stay at the hiding place. People need to make sure that it is clear for rescue workers where and how many people need to be rescued per hiding place by writing this on the wall or roof, and wait to be rescued. Additionally, people can be informed with a list of material which is necessary to survive, like water, food, medications, warm clothes, blankets and tools to cut the roof if necessary.

For the rescue crew, number one priority is safety. Try to avoid navigating through areas with a lot of debris as this may damage the lifeboat. Search the area systematically and make notes of where people are located. This should be included in trainings of the NRV. The advice for the NRV is to train on a flood scenarios which will match the reality and to train this scenario continuously for more than one day in a row to prepare as much as possible for a flood.

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Appendices

A. Impression of floods

This appendix provides an impression of the flooded area of New Orleans in 2005 and the flood of Mesa in 2014.

A.1. Flood at New Orleans after Hurricane Katrina in 2005

View of a flooded area

Figure A.1: Top view (Harris, 2017).

Figure A.2: Street view (Harris, 2017).

Emergency sleeping place for evacuated people

Figure A.3: Camp beds at for evacuated people (Harris, 2017).

Evacuation messages on roofs

Figure A.4: (Harris, 2017).

Figure A.5: (Tuffghosts, 2008).

Gathered people waiting for rescue

Figure A.6: (Tuffghosts, 2008)

Flee

Figure A.7: Fleeing with the use of floating objects (Tuffghosts, 2008).
Figure A.8: Fleeing with the use of a private boat (Tuffghosts, 2008).

Figure A.9: Man carries a child while fleeing (Tuffghosts, 2008)

Figure A.10: People walking through a flooded area (Teichner, 2015)

A.2. Flood at Mesa in 2014

Police vehicle crosses a threshold

Figure A.11: (StormChasingVideo, 2014).

Moving throug water with cars

Figure A.12: (StormChasingVideo, 2014).

Figure A.13: (StormChasingVideo, 2014).

Walking though water with objects

Figure A.14: (StormChasingVideo, 2014).

Figure A.15: (StormChasingVideo, 2014).

B. Flood characteristics

B.1. Types of floods

Table B.1 describes all types of floods. Also, a description is given with the definition of each type of flood.

Type of flood	Description
Coastal flood (or surge flood)	The high wind speeds from a storm causes the seawater to be pushed up to higher water levels than normal. If this occurs at the same time as high tide, this will result in extra high-water levels in the coastal areas. These high-water levels in combination with the wave loads can cause the coastal protection to break down and flood the area behind. An example of this type of flood in the Netherlands is the 1953 flood disaster.
River flood	If a river is supplied with more water than it can process due to for example extreme rainfall, the water level will rise which can result in a breached dike leading to a flood. Further, for rivers without a dike, an insufficient discharge capacity of the river causes overflow of the river bank resulting in a flood. Examples of river floods in the Netherlands are the floods of 1993, 1995 and 2021.
Pluvial flood (or surface water flood)	A pluvial flood is the result of precipitation with a high intensity. The surface area or water system cannot process the amount of precipitation. This type of flood is independent of an overflowing water body, but often occurs in combination with a coastal and river flood (Maddox, 2014).
Flash flood	Flash floods are the result of precipitation with a high intensity. The water flows to a lower part causing high flow velocities. Often a relatively small area is affected with many victims. Flash floods do not occur in the Netherlands. However, at locations where a dike breaks, the same flow situation could occur close to the breach (Klijn, Baan, De Bruijn, Kwadijk, & Van Buren, 2020).
Tsunami flood	Small waves with a longer wave period and longer length are created by a large displacement of water in a short time. The displacement can be caused by an earthquake that takes place in the earth's crust under water, the fall of a big ice block, or debris from space. The Netherlands is not sensitive to tsunamis, because it is not located in an earthquake-prone area. In addition, it is partly protected by the present of Great Britain against tsunamis from outside.
Breach of a dam or reservoir	A breach of a dam or reservoir with a lot of water behind it leads to a tidal wave. This is not applicable to the Netherlands.

Table B.1: Types of floods.

B.2. Background LIWO maps

In the project Veiligheid in Kaart (VNK2), flood risks in the Netherlands are analyzed by Rijkswaterstaat in collaboration with other parties. The Ministry of Infrastructure and Environment, the Union of Water Boards and the Interprovincial Consultation came with the initiative. In this project, dike rings were analyzed with the aim to make the investments in water safety more effective and economical efficient. Results from this research are SOBEK models which form the basis for LIWO maps.

SOBEK
SOBEK is a program in which models are set up to simulate floods in 1D and 2D. In the used models for the LIWO maps, a grid size of 25x25 meter is used. A smaller grid size results in a more accurate solution, however this also gives a longer simulation time.

Probability of exceedance
Every flood scenario area has several simulations in which the outside water levels have several probabilities of exceedance which are listed below. Note that in this report the scenario with the toetspeil (tp) is used as this seems the most likely scenario to occur in case of a flood.

• 1/200 per year	Toetspeil minus one decimation height	(tp -1)
• 1/2000 per year	Toetspeil	(tp)
• 1/20 000 per year	Toetspeil plus one decimation height	(tp +1)
• 1/200 000 per year	Toetspeil plus two decimation heights	(tp +2)

Types of LIWO maps
There are several LIWO maps, namely:

- the maximum water depth
- single and combined flood scenarios
- probability of a flood in 2019 and 2050
- evacuation possibilities like the availability of dry floors and the warning time before a flood.

HIS scenario viewer
Further, from the SOBEK models it is possible to make animations which can be viewed with the program HIS Scenario Viewer in order to see the change in flood characteristics at each time period.

B.3. Water temperature

The water temperature partly influences how quickly people become hypothermic if a person wants to move through flooded areas. In order to be able to determine the approximate temperature of the water during a flood in the Netherlands, it is first necessary to determine when the largest probability of a flood throughout a year is.

Coastal area

Table B.2 provides an overview of severe storms in the Netherlands since 1910 until 2020. These are storms in which wind force 10 or more was measured. Below this, the data is presented per month in figure B.1.

Jaar	Datum	Jaar	Datum	Jaar	Datum
1911	30 Sep/1 Oct	1953	31 Jan/1 Feb	1990	25 Jan
1912	27 Aug	1953	30 Mar	1990	26 Feb
1913	26/27 Dec	1954	21 Dec	1993	13 Jan
1914	12 Aug	1960	20 Jan	1993	8/9 Dec
1914	11 Nov	1962	12 Feb	1994	1 Apr
1914	28/29 Dec	1967	17 Oct	1995	3 Mar
1916	13 Jan	1971	21 Nov	1998	4 Jan
1916	23 Jan	1972	13 Nov	1999	3 Dec
1920	11 Jan	1973	2 Apr	2000	28 May
1921	6 Nov	1973	13 Dec	2000	29 Oct
1922	8 Mar	1974	16/17 Jan	2002	26 Feb
1925	9/10 Feb	1976	2/3 Jan	2002	9 Mar
1928	16/17 Nov	1977	12 Nov	2002	27 Oct
1928	23 Nov	1977	14 Nov	2007	18 Jan
1928	25 Nov	1977	24 Dec	2013	28 Oct
1938	3/4 Oct	1978	3 Jan	2013	5 Dec
1940	13/14 Nov	1978	16 Mar	2015	25 Jul
1943	7 Apr	1983	1 Feb	2016	20 Nov
1943	19 Dec	1983	27 Nov	2017	13 Sep
1944	23 Jan	1984	13/14 Jan	2018	3 Jan
1944	7 Sep	1986	19 Dec	2018	18 Jan
1949	1 Mar	1987	16 Oct	2020	9 Feb

Table B.2: Severe storms in the Netherlands since 1910. The dates in te table are the days on which one of the KNMI stations in the Neterhlands measured a mean wind speed during one hour of 24.5 m/s or more (KNMI, n.d.).

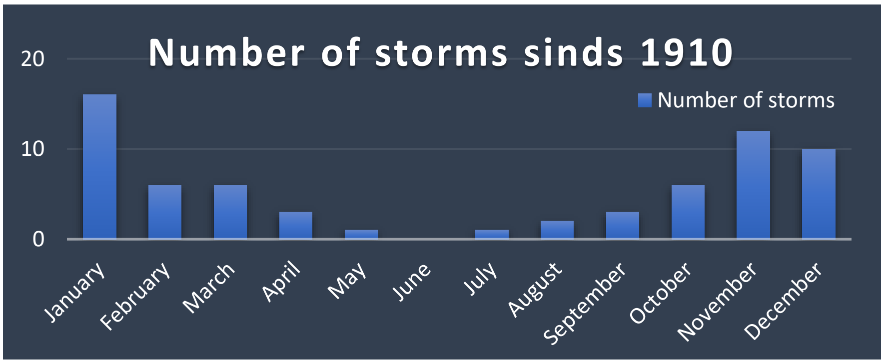


Figure B.1: Number of storms since 1910 from table B.1 collected into an overview of stroms since 1910 per month (KNMI, n.d.).

The chance of a flood in the coastal area is larger in the period from October to April than in the summer months. From figure B.2 it can be seen that the water temperature of seawater is between 5 and 17 degrees Celsius, with a rapid decrease in temperature in November and October.

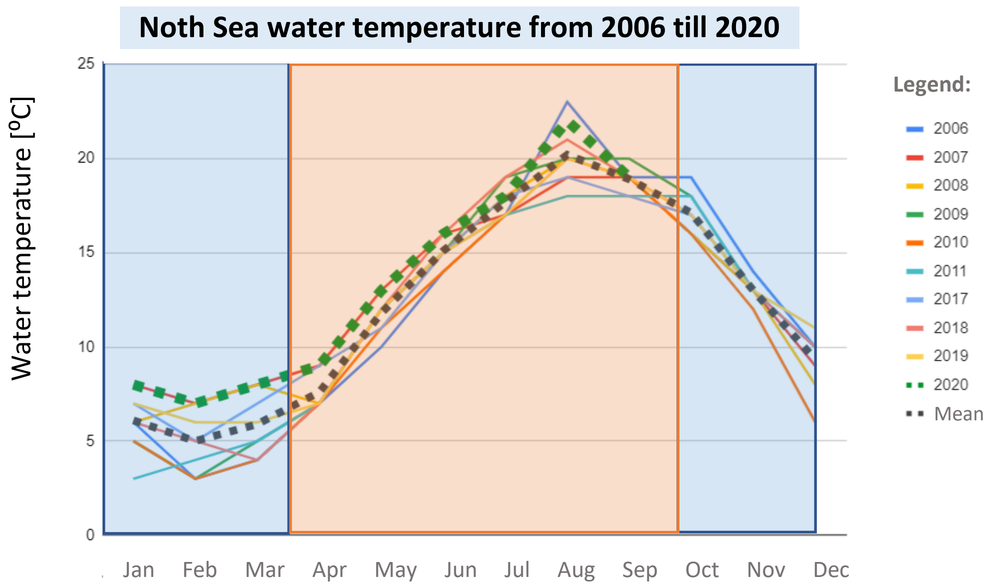


Figure B.2: Seawater temperature (Boardshortz, n.d.).

River area
The greatest risk of high water in the rivers is in the winter months and the beginning of the spring. In the summer months more water evaporates, the soil absorbs more water, and more water is absorbed by vegetation. As a result, less water runs off (Ministry of Infrastructure and Water Management, n.d.). The river water will be between 5 and 12 degrees Celsius during a flood, see figure B.3.

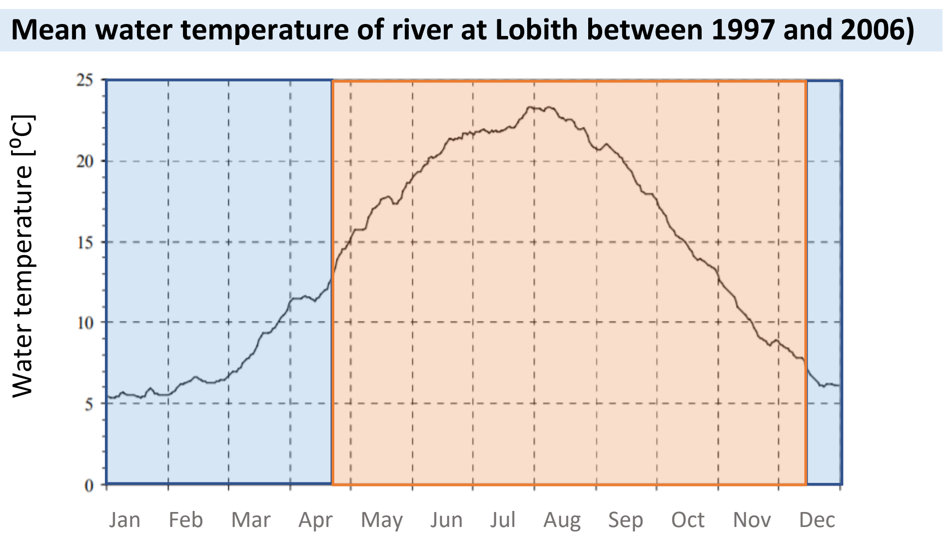


Figure B.3: Mean water temperature of the Rhine river at location Lobith (Van der Grinten, Van Herpen, Van Wijnen, Evers, Wuijts, & Verweij, 2008).

B.4. Debris

Debris can be categorized with the use of estimated dimensions, estimated weight and the buoyancy of an object.

- Estimated dimensions:

Larger objects can cause blockages for people in a flooded area. Also, a lot of small objects together can cause a blockage. Further, people can harm themselves at objects during a flood.

There is a wide variation in the dimensions of objects. To be able to classify the objects, the outer dimensions are looked at to estimate a volume. Objects are classified as a cube $(V_0 = LWH)$ or as a cylinder $(V_0 = \frac{1}{4}\pi d^2 H)$. This volume is therefore not the actual volume of an object.

Outer dimensions as volume (V_{out}) cubus or cylinder $[m^3]$	
XS	$V_{out} \leq 0.1$
S	$0.1 < V_{out} \leq 2$
M	$2 < V_{out} \leq 5$
L	$5 < V_{out} \leq 25$
XL	$V_{out} > 25$

Table B.3: Categorized estimated dimensions.

- Estimated weight:

Light objects will be easier transported.

Estimated weight (W) [kg]	
XS	$W \leq 50$
S	$50 < W \leq 100$
M	$100 < W \leq 250$
L	$250 < W \leq 500$
XL	$500 < W \leq 5000$
XXL	$W > 5000$

Table B.4: Categorized estimated dimensions.

- Buoyancy:

Objects can be classified by floating objects (F) and submerged objects (S). An object can float or sink. A floating object can be transported by wind and flow velocity, where a sunk object can be transported by flow velocities of the water. In case of cloudy water, a sunk object cannot be seen and can form an unexpected obstacle for people.

		Estimated dimension				Estimated weight [kg]
		L [m]	W [m]	H, t or d [m]	V [m^3]	
Wood	Tree	5 – 30	-	d = 0.3 – 1	0.5 – 25	300 – 5000
	Branch	0 – 10	-	d = 0 – 0.3	0 – 0.7	5 – 400
	Timber	0 – 5	0 – 0.3	0 – 0.1	0 – 0.2	25 – 100
	Plate	0 – 5	0 – 5	0 – 0.1	0 – 2	100 – 500
Vehicle	Car	3 – 5	1.5 – 2	1.5 – 2	5 – 20	800 – 1500
	Motor	1.5 – 2.5	0.2 – 0.5	0.5 – 2	0.2 – 2.5	100 – 250
	Trailer	2.5 – 5	1.5 – 2	1 – 2	4 - 20	500 – 1800
	Bicycle	1.5 – 2	0.2 – 0.5	0.5 – 1	0.2 – 1	10 – 25
	Moped	1.5 – 2	0.2 – 0.5	0.5 – 1	0.2 – 1	50 – 100
	Tractor	4 – 8	2.5 – 3	3 – 4	30 - 96	5000 – 9000
	Truck	12 – 20	2.5	4	120 – 200	15000 – 50000
Garden items	Chair	0.5 - 1	0.5 – 1	1 – 1.5	0.25 – 1.5	5 – 10
	Table	1 – 2	1 – 2	0.5 – 1.0	0.5 – 4	5 – 10
	Barbeque	1 – 2	1 – 2	0.5 – 1 d = 0.5	0.1 – 4	10 – 100
	Garden garbage can	0.2 – 0.5	0.2 – 0.5	0.5 – 1	0 – 0.3	5 – 20
	Flower pot or planter	0.1 – 1	0.1 – 1	0.2 – 0.5	0 – 0.5	10 – 100
	Wheelbarrow	1 – 1.5	0.5 – 1	0.5 – 1	0.25 – 1.5	10 – 15
	Rain barrel	-	-	1 – 1.5 d = 0.5 – 1	0.2 – 1.5	50 – 250
	Trampoline	-	-	0.1 d = 3 – 5	0.7 – 2	20 – 100
Building material	Construction fence	2.5 – 3	0.1	2 – 2.5	0.5 – 0.75	10 – 30
	Scaffolding	4 – 6	-	d = 0.1	0.1	3 – 10
	Deposition sign	1 – 1.5	0.5	0.5 – 1	0.25 – 0.75	10 – 50
Material from damaged buildings	Roof tile	0.3 – 0.4	0.3 – 0.5	-	0.1	2 – 4
	Brick	0.2	0.1	0.05	0.1	1 – 3
	Isolation material	0.5	1 – 1.5	0.1 – 0.3	0.1 – 0.2	10 – 20
	Solar panel	1 – 1.5	0.5 – 1	0.1 – 0.3	0.1 – 0.5	10 – 30
Shopping area	Shopping cart	1 – 1.5	0.5 – 1	0.5 – 1	0.25 – 1.5	20 – 30
	Folding billboard	1 – 1.5	0.5	1 – 1.5	0.5 – 1.1	10 – 20
	Rack	1 – 2	0.5	1.5 – 2	0.75 – 2.5	30 – 50
Other	Container	2 – 12	2 – 2.5	2 – 2.5	8 – 75	2000 – 4000
	Traffic bollards	5 – 10		d = 0.1	0.1	100 – 150
	Fixed playground equipment	2 – 4	1 – 3	1 – 2	2 – 24	250 – 500
	Bus shelter	1.5 – 2	0.5 – 1	0.5 – 1	0.4 – 2	50 – 100
	Bin	3 – 3.5	1 – 1.5	2 – 2.5	6 – 13	2000 – 3000
	Container	1 – 1.5	0.5 – 1	1 – 1.5	0.5 – 2.25	50

Table B.5: Categorization 1.

		Estimated dimension					Estimated weight						Buoyancy	
		XS	S	M	L	XL	XS	S	M	L	XL	XXL	F	S
Wood	Tree													
	Branch													
	Timber													
	Plate													
Vehicle	Car													
	Motor													
	Trailer													
	Bicycle													
	Moped													
	Tractor													
	Truck													
Garden items	Chair													
	Table													
	Barbeque													
	Garden garbage can													
	Flower pot or planter													
	Wheelbarrow													
	Rain barrel													
	Trampoline													
Building material	Construction fence													
	Scaffolding													
	Deposition sign													
Material from damaged buildings	Roof tile													
	Brick													
	Isolation material													
	Solar panel													
Shopping area	Shopping cart													
	Folding billboard													
	Rack													
Other	Container													
	Traffic bollards													
	Fixed playground equipment													
	Bus shelter													
	Bin													

Table B.6: Categorization 2.

Plate and timber include:
- Fence
- Garden shed
- Firewood
- Damaged building
- City sofa

Traffic bollards:
- Lamppost
- traffic bollard
- Traffic light
- Barrier

B.5. Maximum water depth for different flood scenarios

The maximum water depths for different flood scenarios are given in table B.7.

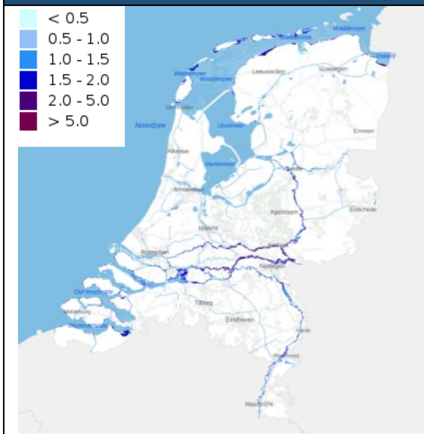
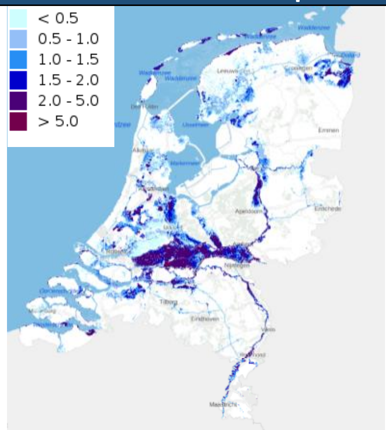
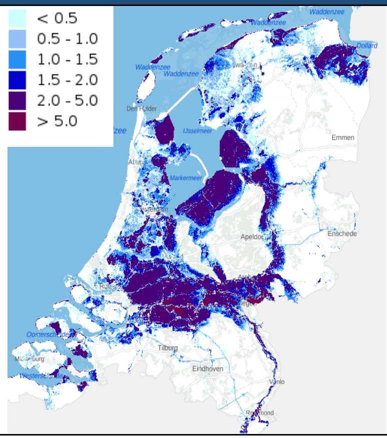
Maximum water depth		
		
Probability of flooding larger than 1/30 per year	Probability of flooding between 1/30 and 1/300 per year	Probability of flooding between 1/300 and 1/3000 per year

Table B.7: Maximum water depth in the Netherlands for three flood scenarios. Map received on the 26th of October 2020 (LIWO, n.d.).

B.6. Terschelling

Terschelling is named dike ring 3 which has the following breach locations in the model: Kinnem West, Kinnem East, North Sea 1 and North Sea 2.

Figure B.4: Breach locations in the model for Terschelling.

Probability of failure (2019)

The failure probability is small for the side of Kinnum and extreme small for the side of the North Sea. Due to the higher change of a flood at the side of Kinnum, the flood scenarios of this side will be used.

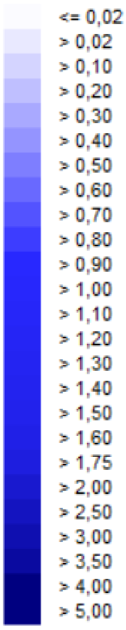
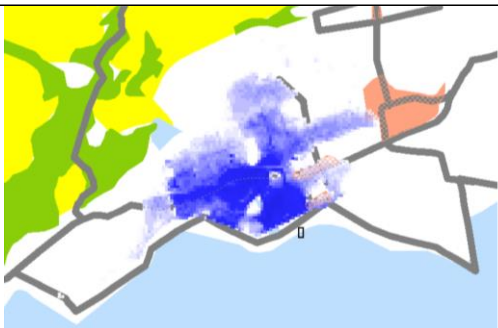
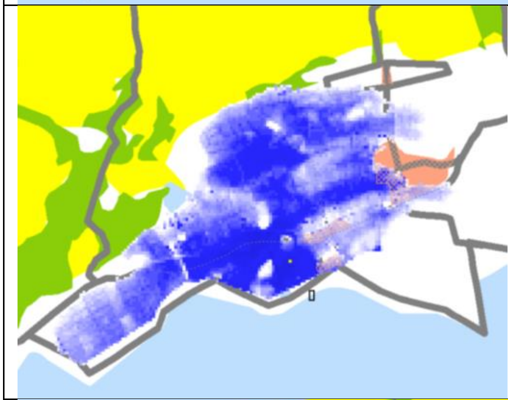
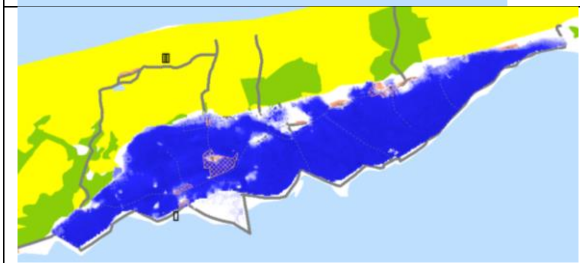
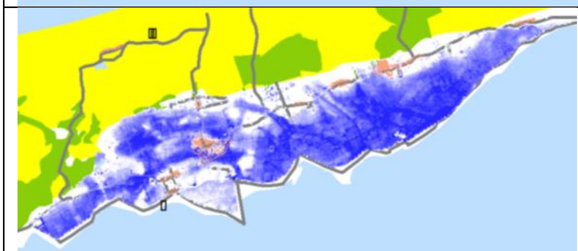
Legend: probability of failure [per year]	
	No significant flood probability
	Extreme small chance: < 1/30000 per year
	Very small chance: 1/3000 till 1/30000 per year
	Small chance: 1/300 till 1/3000 per year
	Medium chance: 1/30 till 1/300 per year
	Large chance: > 1/30 per year

Figure B.5: Probability of failure for dike ring 3 in 2019.

Water depth

1. Kinnum West

- Toetspijl (TP) is used, this is with a probability of failure of 1/2000 per year
- Start of the flood at Model hour 24.

Legend:  		Model hour: 25 Max. 1.8 meter Overall: +/- 1.0 meter ➔ 1 hour after breach
		Model hour: 26 Max. 1.8 meter Overall: +/- 1.2 meter ➔ 2 hours after breach
		Model hour: 39 Max. 2.0 meter Overall: +/- 1.6 meter ➔ 15 hours after breach ➔ Max. water dephts
		Model hour: 72 Max. 1.3 meter Overall: +/- 0.7 meter ➔ 2 days after breach
		Model hour: 96 Max. 1.1 meter Overall: +/- 0.5 meter ➔ 3 days after breach

(Table proceeds on the next page).

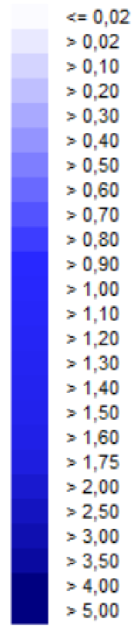
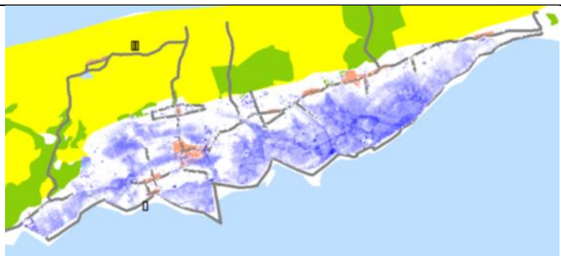
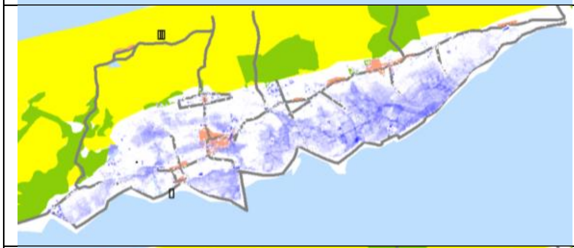
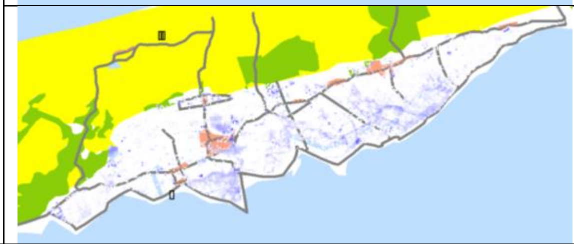
Legend:		
		Model hour: 120 Max. 1.1 meter Overall: +/- 0.4 meter ➔ 4 days after breach
		Model hour: 142 Max. 1.0 meter Overall: +/- 0.3 meter ➔ 5 days after breach
		Model hour: 190 Max. 0.9 meter Overall: +/- 0.2 meter ➔ 7 days after breach

Table B.8: Water depths at Kinnum West.

Maximum water depth (LIWO map):

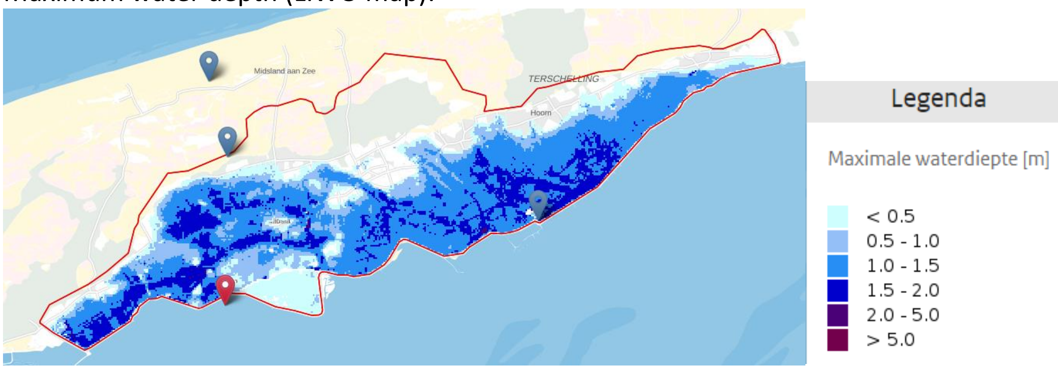


Figure B.6: Kinnum West with TP-1, this is with a probability of failure of 1/200 per year. Map received on the 26th of October 2020 (LIWO, n.d.).

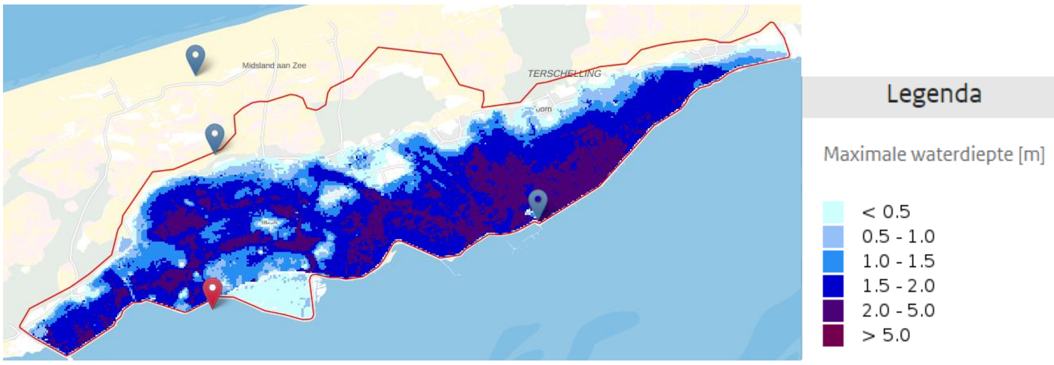
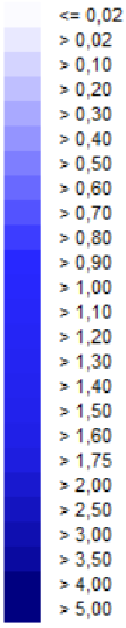
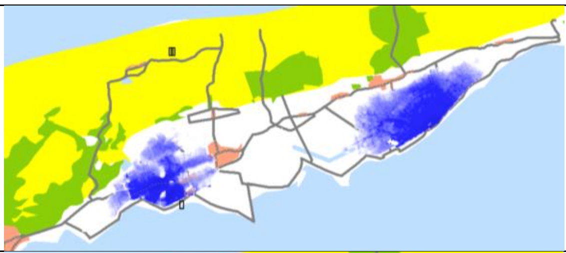
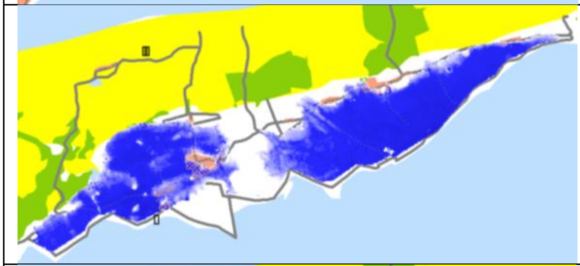
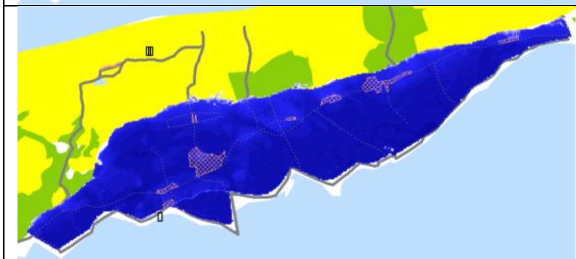
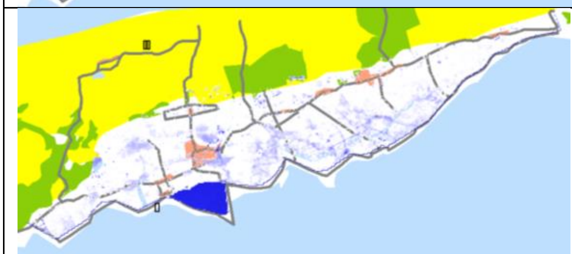


Figure B.7: Kinnum West with TP, this is with a probability of failure of 1/2000 per year. Map received on the 26th of October 2020 (LIWO, n.d.).

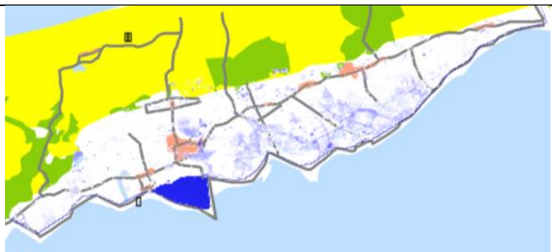
2. Kinnum West & Kinnum East

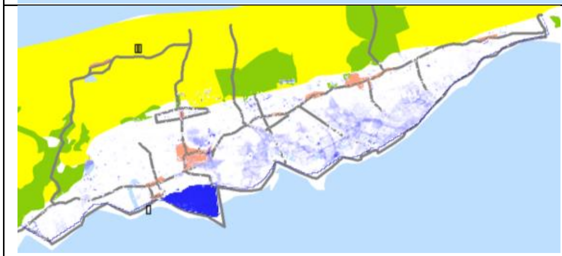
- Toetspijl (TP) is used, this is with a probability of failure of 1/2000 per year
- Start of the flood at Model hour 24,00

Legend: 		Model hour: 25 Max. 1.8 meter Overall: +/- 1.00 meter ➔ 1 hour after breach
		Model hour: 26 Max. 1.8 meter Overall: +/- 1.20 meter ➔ 2 hours after breach
		Model hour: 35 Max. 4.0 meter Overall: +/- 3.00 meter ➔ 11 hours after breach ➔ Max. water depths
		Model hour: 72 Max. 2.0 meter Overall: +/- 0.50 meter ➔ 2 days after breach
		Model hour: 96 Max. 1.8 meter Overall: +/- 0.30 meter ➔ 3 days after breach
		Model hour: 120 Max. 1.8 meter Overall: +/- 0.20 meter ➔ 4 days after breach

(Table proceeds on the next page).

<table>
<tr>
<td rowspan="2">Legend:

</td>
<td></td>
<td>Model hour: 142
Max. 1.8 meter
Overall: +/- 0.10 meter

➔ 5 days after breach</td>
</tr>
<tr>
<td></td>
<td>Model hour: 190
Max. 1.3 meter
Overall: +/- 0.4 meter
(Note that the East side breach gives a tidal influence)

➔ 7 days after breach</td>
</tr>
</table>

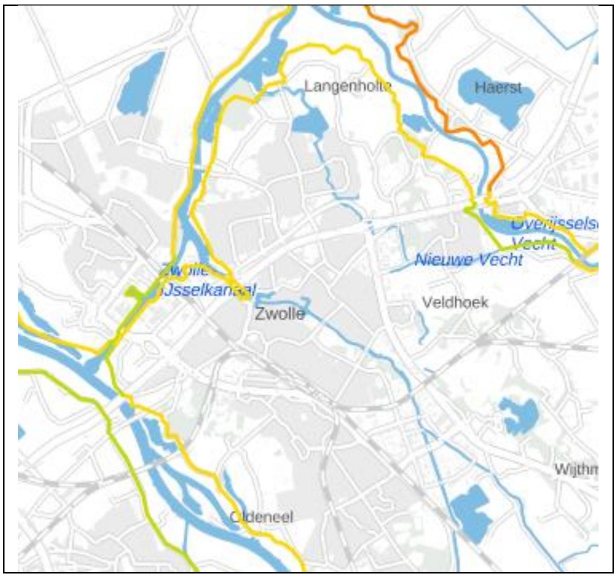
Table B.9: Water depths at Kinnum West and Kinnum East.

B.7. Zwolle

Figure B.8: Breach locations in the model for Zwolle.

Probability of failure (2019)

Most of this part has a small probability of failure. Only at Berkum and Noordwest the probability of failure is very small. A breach at location IJsselkanaal results in a small flooded area. Further, Holterbroek en Langenholte are both at the north side of Almelose kanaal. A breach at Langenholte gives a larger flooded area than a breach at Holterbroek. Therefore the locations Langenholte and Zuidwest are considered below.



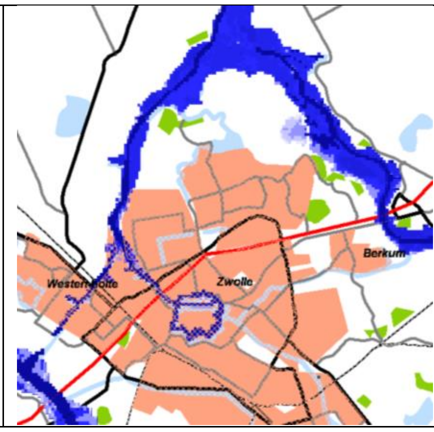
Legend: probability of failure [per year]	
	No significant flood probability
	Extreme small chance: < 1/30000 per year
	Very small chance: 1/3000 till 1/30000 per year
	Small chance: 1/300 till 1/3000 per year
	Medium chance: 1/30 till 1/300 per year
	Large chance: > 1/30 per year

Table B.10: Probability of failure for dike ring 53 in 2019.

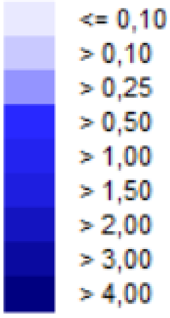
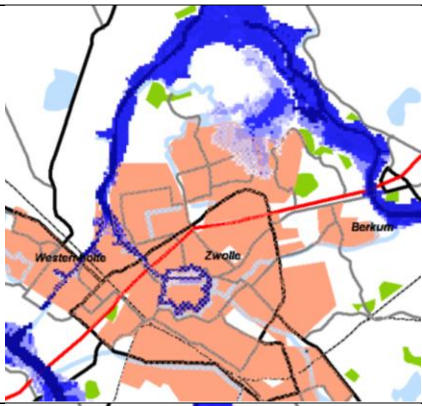
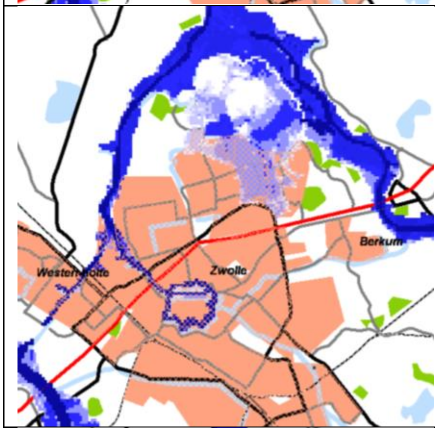
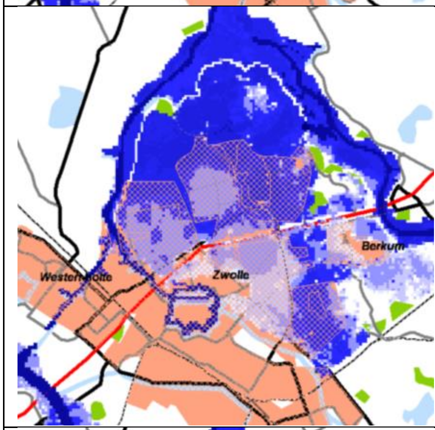
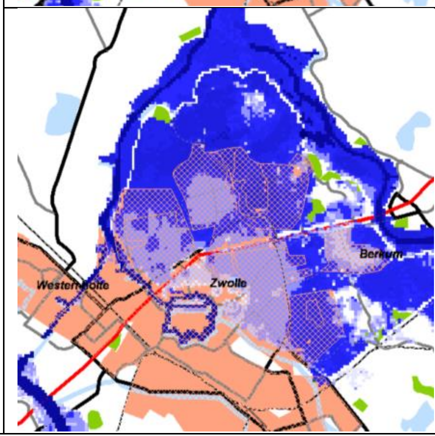
Water depth

1. Langenholte

Note that only the built area (indicated in orange) is considered in the determination of the maximum and the overall water depth.

Legend:		Model hour: 267
<= 0,10 > 0,10 > 0,25 > 0,50 > 1,00 > 1,50 > 2,00 > 3,00 > 4,00		➔ Breach

(Table proceeds on the next page).

Legend: 		Model hour: 268 ➔ 1 hours after breach
		Model hour: 269 Max. 1.0 meter Overall: +/- 0.5 meter for the flooded area ➔ 2 hours after breach
		Model hour: 291 Max. 2.0 meter Overall: +/- 0.5 meter ➔ 1 day after breach
		Model hour: 315 Max. 2.0 meter Overall: +/- 0.8 meter ➔ 2 days after breach

(Table proceeds on the next page).

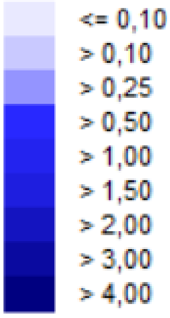
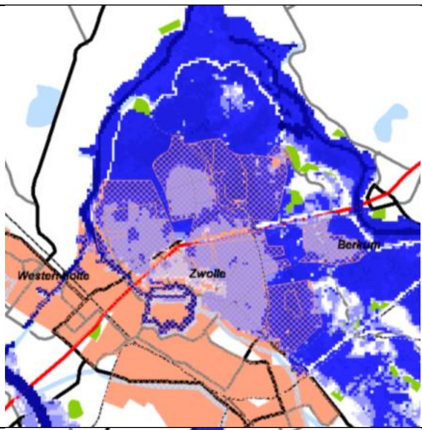
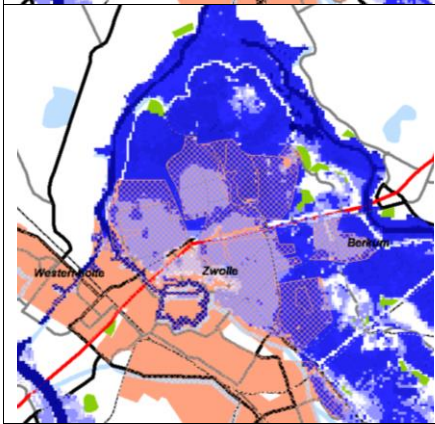
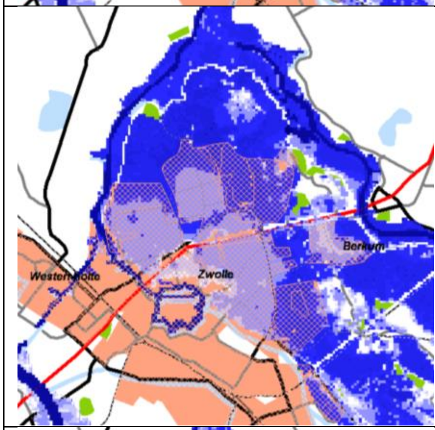
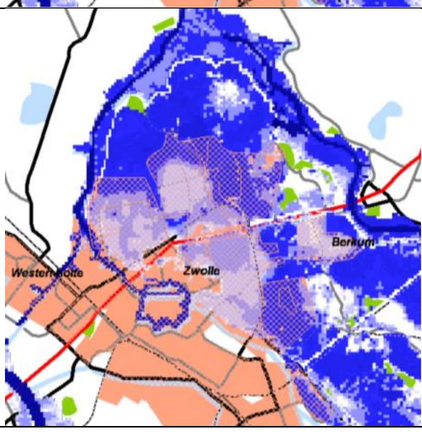
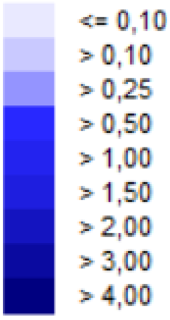
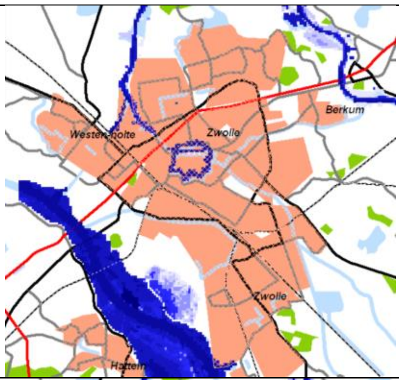
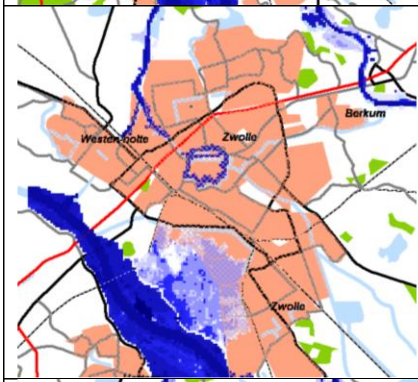
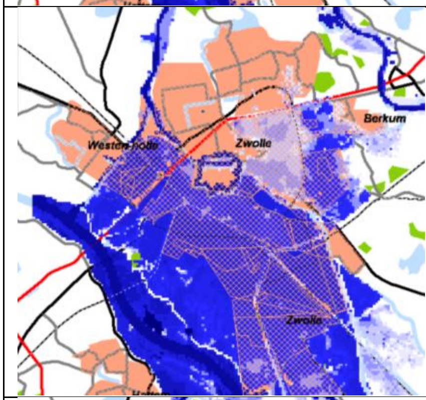
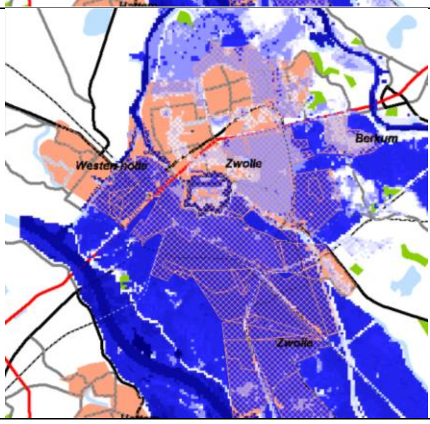
Legend:		
		Model hour: 339 Max. 2.0 meter Overall: +/- 1.0 meter ➔ 3 days after breach
		Model hour: 363 Max. 2.0 meter Overall: +/- 1.0 meter ➔ 4 days after breach
		Model hour: 387 Max. 2.0 meter Overall: +/- 1.0 meter ➔ 5 days after breach
		Model hour: 435 Max. 1.5 meter Overall: +/- 0.5 meter ➔ 7 days after breach

Table B.11: Water depths Langenholte.

2. Zuidwest

Note that only the built area (indicated in orange) is considered in the determination of the maximum and the overall water depth.

Legend: 		Model hour: 59 ➔ Breach at model hour 58
		Model hour: 60 ➔ 2 hours after breach
		Model hour: 82 Max. 2.0 meter Overall: +/- 0.5 and 1.5 meter ➔ 1 day after breach
		Model hour: 106 Max. 2.0 meter Overall: +/- 0.5 and 1.5 meter ➔ 2 days after breach

(Table proceeds on the next page).

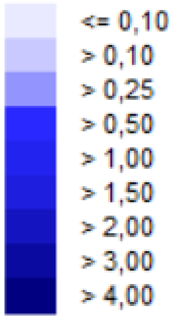
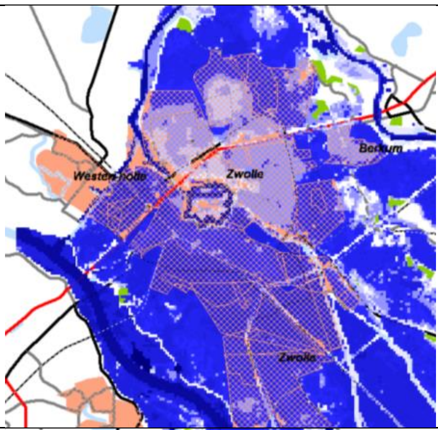
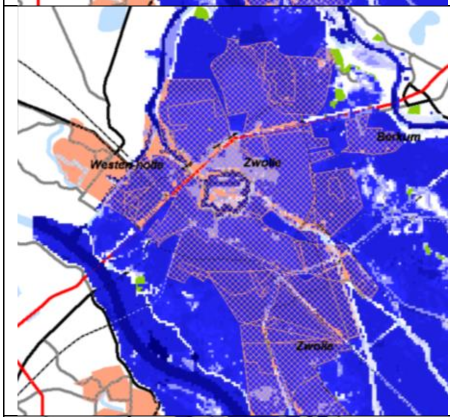
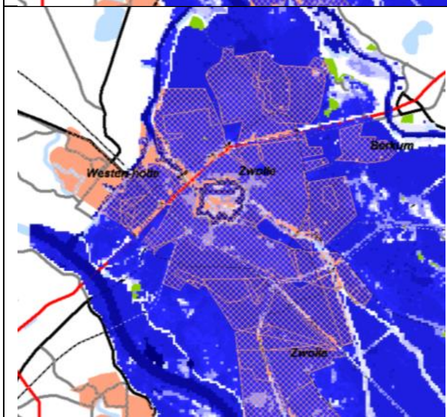
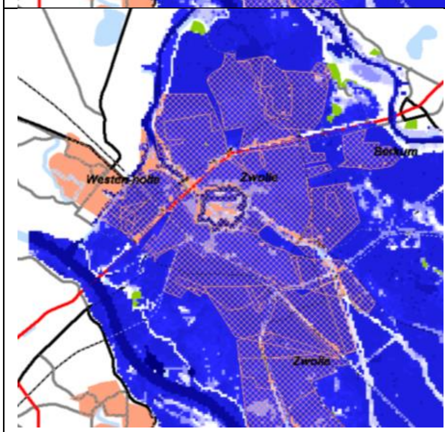
Legend: 		Model hour: 130 Max. 2.0 meter Overall: +/- 1.0 meter ➔ 3 days after breach
		Model hour: 154 Max. 3.0 meter Overall: +/- 1.2 meter ➔ 4 days after breach
		Model hour: 178 Max. 3.0 meter Overall: +/- 1.5 meter ➔ 5 days after breach
		Model hour: 226 Max. 3.0 meter Overall: +/- 1.7 meter ➔ 7 days after breach

Table B.12: Water depths Zuidwest.

B.8. Dordrecht

Dordrecht is named dike ring 22 which has the following breach locations: Dordtsche Kil, Hollandsch diep, Nieuwe Merwede 1, 2, 3 and 4, Wantij 1, 2, 3, 4 and 5, and Oude Maas.

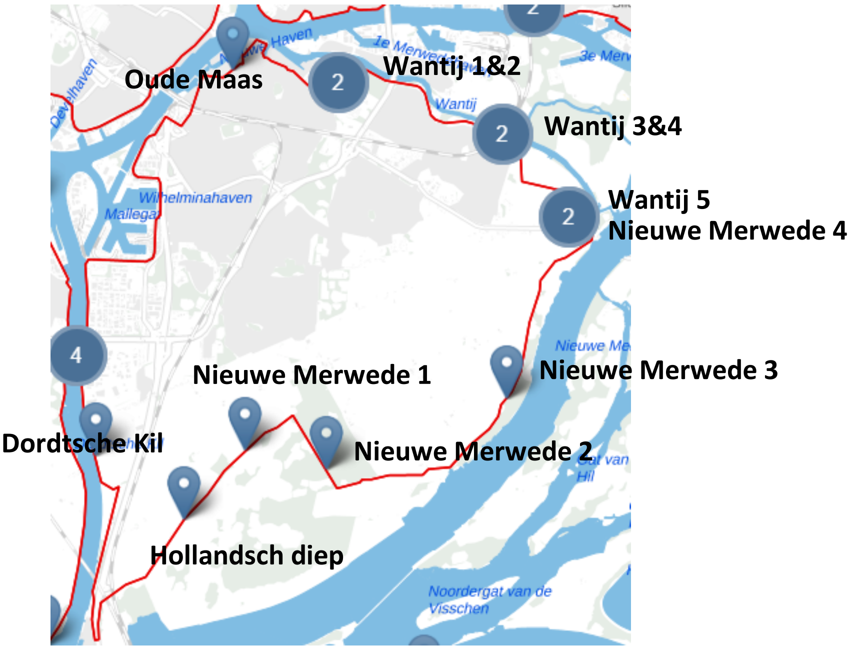
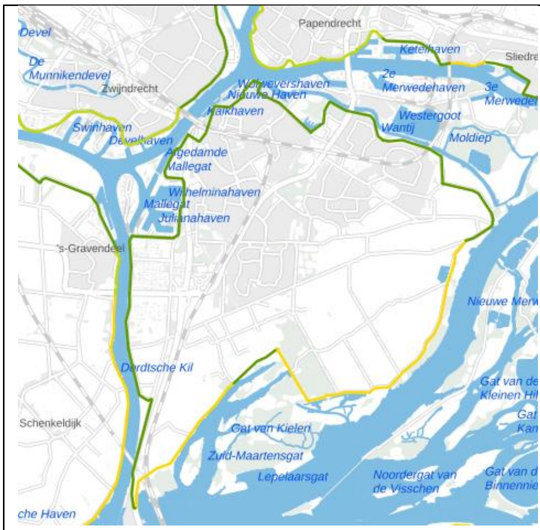


Figure B.9: Breach locations in the model for Dordrecht.

Probability of failure (2019)

The failure probability is extreme small for the north side of Dordrecht and small for the south-east side of Dordrecht. At the south-east side there are mostly forests, meadows and fields. In the north side there are mostly houses.



Legend: probability of failure [per year]	
	No significant flood probability
	Extreme small chance: < 1/30000 per year
	Very small chance: 1/3000 till 1/30000 per year
	Small chance: 1/300 till 1/3000 per year
	Medium chance: 1/30 till 1/300 per year
	Large chance: > 1/30 per year

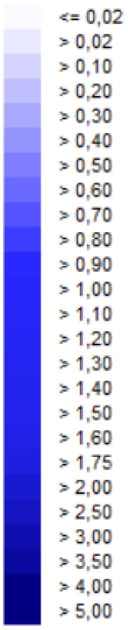
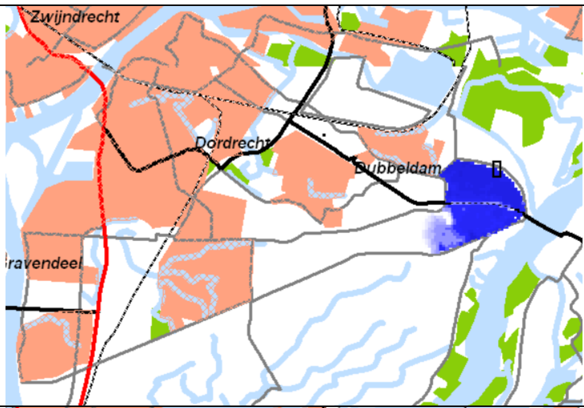
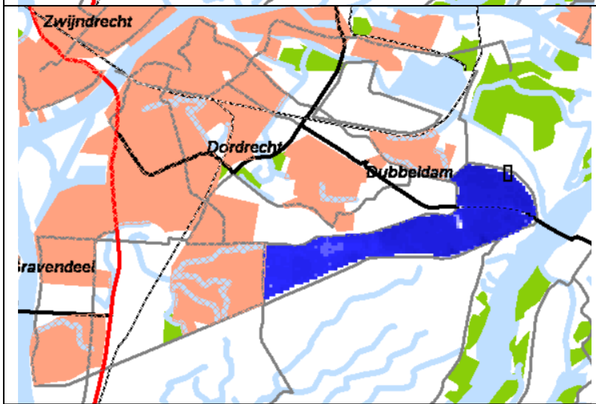
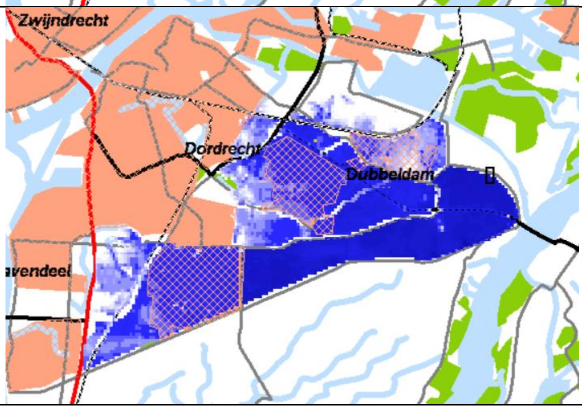
Table B.13: Probability of failure for dike ring 22.

A breach in section Wantij 5 gives the largest flooded area in which most buildings are located compared to the other breach sections.

Water depth

Wantij 5

- Toetspijl (TP) is used, this is with a probability of failure of 1/2000 per year
- Start of the flood at Model hour 24,00

Legend:		
		Model hour: 61 Max. 1.8 meter Overall: +/- 1.5 meter ➔ 1 hour after breach
		Model hour: 63 Max. 3.0 meter Overall: +/- 1.8 meter ➔ 3 hours after breach
		Model hour: 69 Max. 3.5 meter Overall: +/- 2.8 meter for the part nearby the breach and 1.00 meter for the other parts ➔ 9 hours after breach

(Table proceeds on the next page).

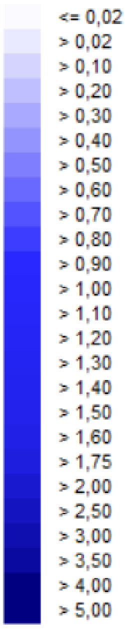
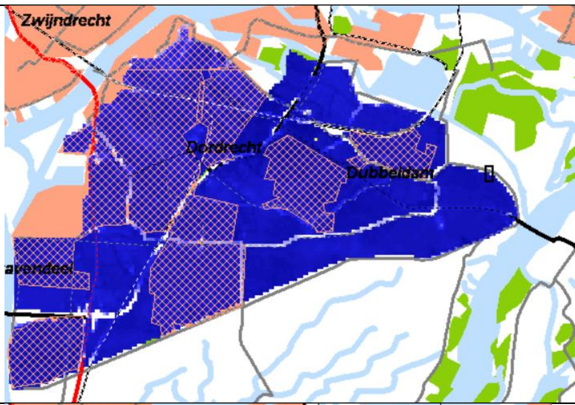
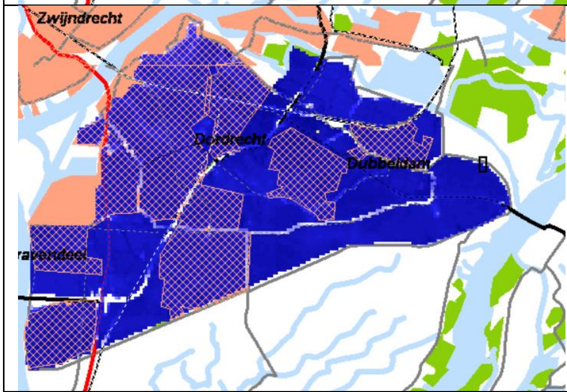
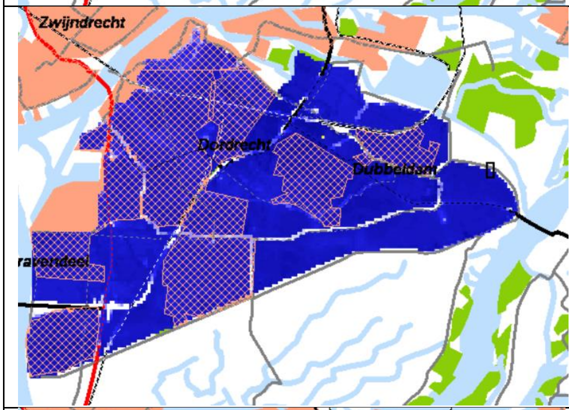
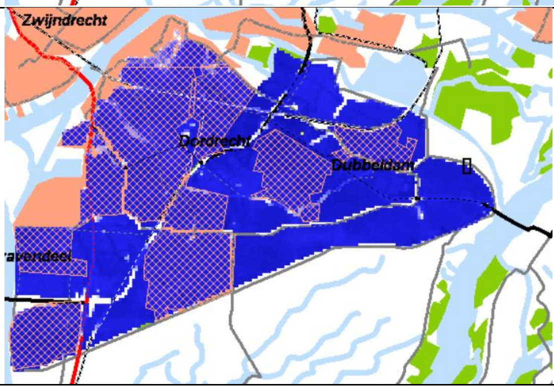
Legend:		
		Model hour: 98 Max. 4.3 meter Overall: +/- 3.0 meter ➔ 38 hours after breach ➔ Whole area under water
		Model hour: 108 Max. 4.3 meter Overall: +/- 3.0 meter ➔ 2 days after breach
		Model hour: 132 Max. 4.0 meter Overall: +/- 2.8 meter ➔ 3 days after breach
		Model hour: 228 Max. 3.5 meter Overall: +/- 2.0 meter ➔ 7 days after breach

Table B.14: Water depths Wantij 5.

C. Experiment: set-up

To answer the questions about fleeing, an experiment is executed about how people navigate on foot, on bicycle and with floating objects over flooded ground. For this a parcourse should be formed and variations are added, like different water levels and with or without the presence of debris.

C.1. Test location: Flood Proof Holland

The experiment is carried out at test facility Flood Proof Holland in Delft and consists of six basins with in the middle a reservoir. At each basin, the water inlet is located at the side of the reservoir and is controllable with a valve to reach water levels up to 0.60 meters. At the other end of the basins there is a water outlet which can be blocked to obtain stagnant water levels in the basins. For the experiment the first three basins are used to form a parcourse, see figure C.1.

Figure C.1: Overview Flood Proof Holland (Google, n.d.-a).

C.2. Parcourse and measurement

Impression of the parcourse

Figure C.2 gives an impression of the parcourse. The parcourse consists of a slope which leads participants into basin 1. During the displacement from basin 1 into basin 2 there is a slope and on the downwards side a stairs. After completing basin 2, there is an upward slope and at basin 3 participants move over a bend toward the finish.

Figure C.2: Impression parcourse.

Measurement

A schematic side view of the parcourse is shown in figure C.3 from which can be seen that the parcourse is divided into five parts. The boundaries of each part consist of piles at the parcourse. When a participant completes the parcourse, a time measurement is done with a stopwatch for each part. Furthermore, two cameras are placed at part 2 and 4 to verify if the time measurements are accurate and to correct missing or incorrect data.

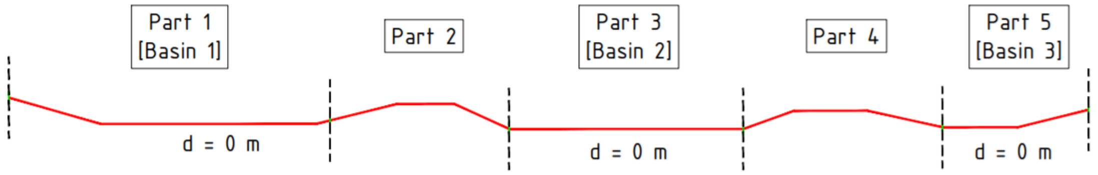


Figure C.3: Side view parcourse.

Dimensions

- Length: The lengths and the slopes of each part of the parcourse are given in table C.1.

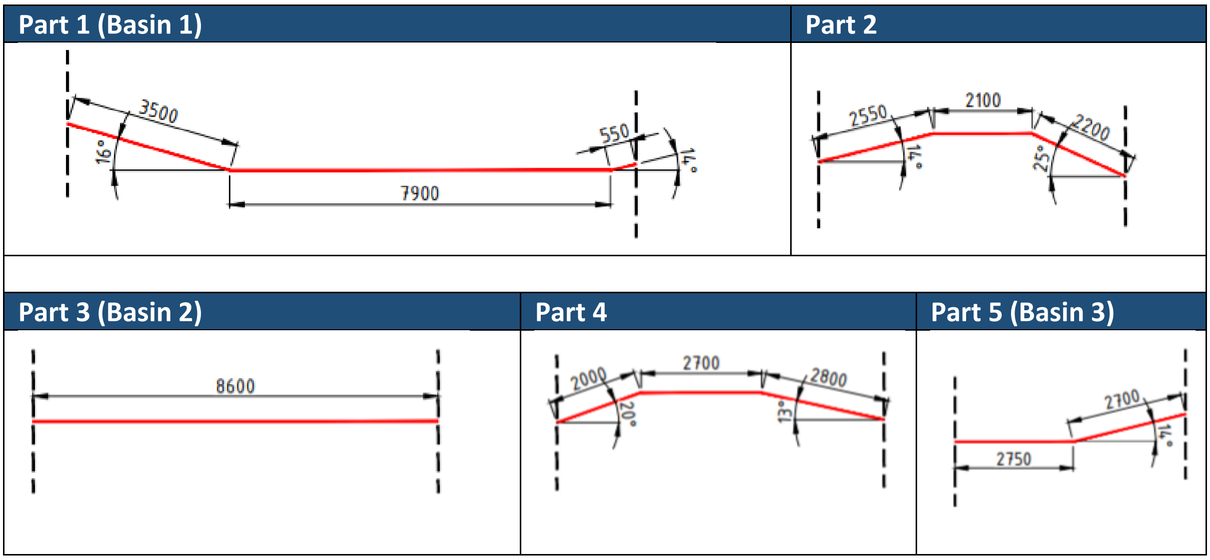
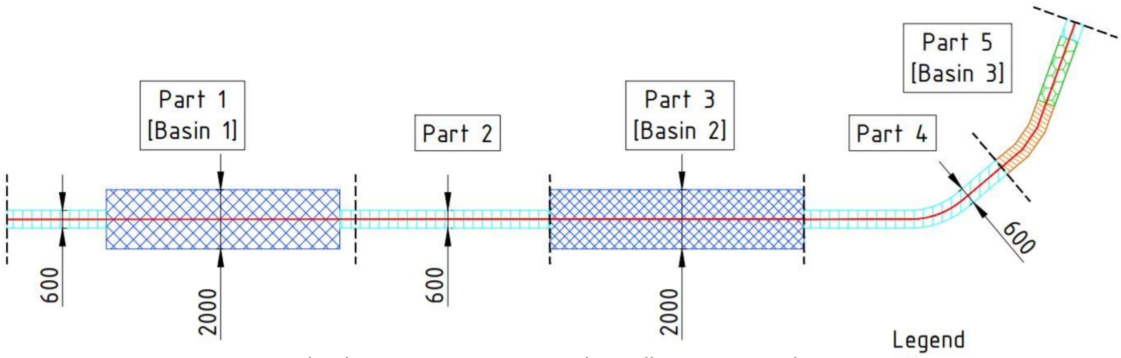


Table C.1: Length of the parcourse divided into parts. The dimensions are expressed in millimeter. Note that this is a standard way of expressing measurements but should not be interpreted as an accuracy.

- **Width:** Parts of the parcourse consist of a width of 600 mm and the other parts of 2000 mm, the widths are indicated in figure C.4.



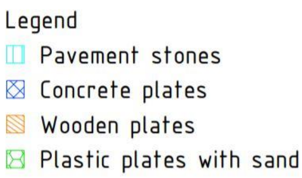


Figure C.4: Top view parcourse. The dimensions are expressed in millimeter. Note that this is a standard way of expressing measurements, but should not be interpreted as an accuracy.

Bottom profile

In figure C.4 a top view of the parcourse is shown with an indication of which part consists of which bottom material. Overall, the bottom profile consists of:

- Pavement stones: 600x300 mm and 300x300 mm
- Concrete plates: 2000x2000 mm

Further, basin 3 consist of a bend and other materials than only pavement stones and concrete plates, see figures C.5 and C.6 with the following bottom profile:

- Three wooden plates with sand- and gravel bags at the sides
- Two plastic mats with sand on it
- Pavement stones: 600x300 and 300x300 mm

Figure C.5: Impression of part 5 (Basin 3)

Figure C.6: Impression of part 5 (Basin 3).

C.3. Rounds

The experiment consists of five main rounds and an additional round 0. At each round the means of transport is walking or riding a bicycle, see figure C.7 for the type of bicycle. Except of round 4 by which participants completed the round only by foot. Below, a description of each round is given.

Figure C.7: Bicycle.

Round 0

Round 0 has the same circumstances as round 1, see figure C.8, however the participants did wear normal shoes instead of a wader. Only a few participants have completed this round. This round is intended to see whether there is an influence of wearing a wader instead of normal clothes.

Round 1

For this round, participants complete the parcourse without water in the basins, see figure C.8.

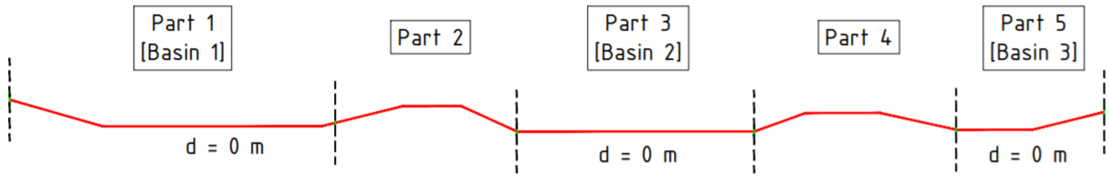


Figure C.8: Parcourse water depths round 1, d = water depth.

Round 2
For this round, participants complete the parcourse with the water depths indicated in figure C.9.

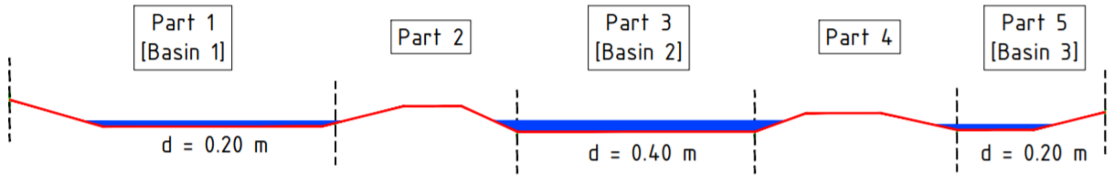


Figure C.9: Parcourse water depths round 2, d = water depth.

Round 3
For this round, participants complete the parcourse with the water depths indicated in figure C.10.

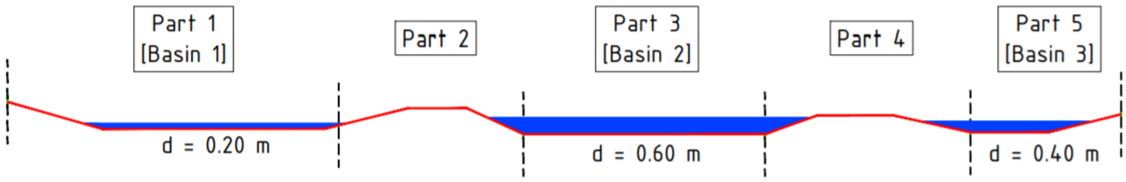


Figure C.10: Parcourse water depths round 3, 4 and 5, d = water depth.

Round 4
This round consists of walking with an air mattress, a bag, or a dog. See table C.2 for an overview. The water depth is the same as described in round 3.

Air mattress: LxWxH = 1.91x0.76x0.22 m	**Bag:** 10 kg	**Bag:** 20 kg	**Dog:** Labrador, 35 kg
			

Table C.2: Deviations in round 4.

- Air mattress: There are a lot of floating objects that can be used during fleeing out of a flooded area, like an air mattress, surfboard, inflatable tube, inflatable boat, etcetera. Although it is not known how many people in the Netherlands are in possession of small floating objects, an air mattress is chosen because it is expected that this object is most present in households in the Netherlands. Further, an air mattress has in comparison to other floating objects a large floating surface area and can therefore be useful.
- Dog: The dog is a 35 kg Labrador, not afraid of water and used to walk on a leach.
- Bag: two types of bags are used: one of 10 kg and one of 20 kg.

Round 5

This round includes debris in the water and the water depth is the same as described in round 3. The objects which are used as debris are shown in figure C.11. Note that the watering can is missing on this figure. Further table C.3 shows which object is classified in which basin.

Figure C.11: Used objects as debris.

Basin 1: Floating debris	**Basin 2:** Submerged debris
• 5 branches: Ø +/- 20, L ≈ 1000 mm Ø +/- 80, L ≈ 1600 mm • Beam: 2000x100x60 mm • Plank: 1800x100x20 mm • 2 blocks aerated concrete: 600x200x150 mm 	• Wheelbarrow: 1450x600x600 mm • 2 PVC tubes: Ø 400, L ≈ 500 mm Ø 160, L ≈ 1800 mm • Bucket: 10 l, Ø 28, H = 240 mm • Watering can: 530x180x360 mm 

Table C.3: Debris in basin 1 and in basin 2.

Overall notes

From the rounds described above the following can be noticed:

- Round 2 has the same circumstances as round 3 for part 1 (Basin 1)
- Round 3 has the same circumstances as round 5 for part 5 (Basin 3)

C.4. Participants

The experiment is carried out 25 times. See table C.4 for an overview of information about the participants. The round order varies, to eliminate influences of completing a round after another round and the age of the participants variate from 13 till 64 years old. Further, the participants are almost equal divided into males and females. Below the table, some notes are included.

Date	Round order	Person number	Age	Height	Gender (M/F)
27th of December 2020	1-2-3-4-5	1	53	193	M
		2	52	163	F
		3	22	169	F
		4	23	180	M
		5	20	175	M
		6	20	163	F
		7	17	163	F
		8	13	163	F
28th of December 2020	1-4-5-2-3	9	53	167	F
		10	15	171	M
		11	25	181	M
29th of December 2020	1-3-4-5-2	12	47	183	M
		13	32	179	M
		14	28	180	M
		15	20	189	M
29th of December 2020, in darkness	1-2-3-4-5	16	60	183	M
		17	56	164	F
		18	26	174	F
		19	24	189	M
30th of December 2020	1-2-3-4-5	20	56	164	F
		21	26	174	F
		22	64	165	F
		23	49	162	F
		24	15	163	F
		25	13	165	M

Table C.4: Participants.

Notes:

- Person 16, 17, 18 and 19 did the experiment in the dark
- Person 17 = person 20
- Person 18 = person 21
- During the experiment all participants wore waders and a life vests.

D. Experiment: method for analysing the data

For each round a dataset which consist of time measurements is obtained. To analyse if there are relations two methods are used which are described in paragraphs D.1 and D.2. Lastly, the method to determine the relation is described in paragraph D.3.

D.1. Pearson product-moment correlation

The outcome of the experiment are time measurements of parts of the parcourse which can be compared to each other. From the data a scatter plot can be made in which the correlation is visualized. The correlation shows if there is a relationship between two variables and the strength of that relationship. Once the correlation between two variables is known, it can be used to predict other values.

There are several methods for estimating correlation between two variables and to fit a line through the data from the experiment. The line through the data is a matter of choice for modeling the relation and it seems like a linear line is the best fit through the continuous variables from the experiment. Because the data to be analyzed seems to tend towards a linear line, the Pearson product-moment correlation method is used which measures the strength of a linear relationship between normally distributed variables.

The Pearson product moment correlation measures only the linear correlation between two sets of data, so there must be paid attention to the possibility of nonlinear relationships as this will not be detected from filling in the Pearson product-moment formula. Further, with this method there cannot be derived a formula for a line through the data. Therefore, in paragraph D.3, methods are described to determine a line through the data which will represents the relationship between the variables.

Assumptions linear correlation
All assumptions mentioned in table D.1 should be met to be able to use the Pearson product-moment correlation method.

	Assumption	Description why this assumption is met for the results from the experiment
1.	Random samples	The participants are random selected, for example different age and height
2.	Variables are (approximately) normally distributed	This can be checked with the Kolmogorov-Smirnov test of normality
3.	Independence of observations	The observations of each round are individually measured. One observation does not influence the other observation
4.	Linear association exists	This can be seen from the scatter graphs
5.	Continuous variables	The data consists of time measurements in seconds
6.	Related pairs	Each participant has a pair of values
7.	Absence of outliers. An outlier is a value that is lower than $\mu - 3.29\sigma$ or higher than $\mu + 3.29\sigma$.	No outliers

Table D.1: Assumptions and description why all assumptions are met (Soumyadip Pal, 2017).

Variables
X = independent observations of data set X
Y = independent observations of data set Y

Null hypothesis
$H_0: r_{xy} = 0$, this means there is no correlation between X and Y.
$H_1: r_{xy} \neq 0$

Equation
Covariant of two variables, divided by the product of their standard deviations:
$r_{XY} = \frac{Cov(X,Y)}{\sigma_X \sigma_Y}$ with $Cov = Covaraince$
$\sigma_X =$ standard deviation of X
$\sigma_Y =$ standard deviation of Y

$$r_{XY} = \frac{\sum_{i=1}^{n}(X_i-\overline{X})(Y_i-\overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i-\overline{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i-\overline{Y})^2}}$$

$$r_{XY} = \frac{n(\sum XY)-(\sum X)(\sum Y)}{\sqrt{n(\sum X^2)-(\sum X)^2}\sqrt{n(\sum Y^2)-(\sum Y)^2}}$$

Range
The range of correlation coefficient is from:
$-1 \leq r_{XY} \leq 1$ with $r_{XY} = -1$; Indicates a perfect negative correlation
$r_{XY} = 0$; Indicates that there is no correlation
$r_{XY} = 1$; Indicates a perfect positive correlation

The value for the correlation coefficient denotes the strength of the correlation. The classification is given below.

- $0.00 < r_{XY} \leq 0.30$; Indicates a very weak correlation
- $0.30 < r_{XY} \leq 0.50$; Indicates a weak correlation
- $0.50 < r_{XY} \leq 0.70$; Indicates a moderate correlation
- $0.70 < r_{XY} \leq 0.90$; Indicates a strong correlation
- $0.90 < r_{XY} \leq 1.00$; Indicates a very strong correlation (Calkins, 2005)

Outcome of the Pearson product-moment correlation
1.) Correlation coefficient (r_{XY}):
- Direction of a linear relation
- Strength of correlation

2.) Coefficient of determination (${r_{XY}}^2$):
- The percentage of the variability in X is explained by the variability in Y, or the percentage of the variability in Y is explained by the variability in X
- $(1 - {r_{XY}}^2) * 100\%$ of variance is explained by unknown factors, like measurement errors

3.) Probability of the Null-hypothesis being true (p):
$p =$ probability of finding no correlation between variable X and Y ($r_{XY} = 0$). If there is no correlation, variable X does not increase when variable Y increases and vice versa.

In case of a small probability, there is a relation between variable X and Y. However, the linear relation does not indicate if variable X differs from variable Y or that the variables are equal. To see if there is a difference between the variables, another method must be used. This is the sample T-test and described in the next paragraph.

Statistical significance
The available data from the experiment is a small sample from a much larger group. This means that a non-zero correlation can be found, even if it is zero for the total group.

This can be explained from figure D.1 where a sample of 20 realizations is drawn (the orange dots). The drawn sample forms a linear line, indicating that there is a strong positive correlation (r = 0.98) between variable X and Y. However, if looked at the total group, there is a very low correlation (r = 0.07) between variable X and Y. So, the statement that there is a strong positive correlation is wrong in this case (van den Berg, n.d.).

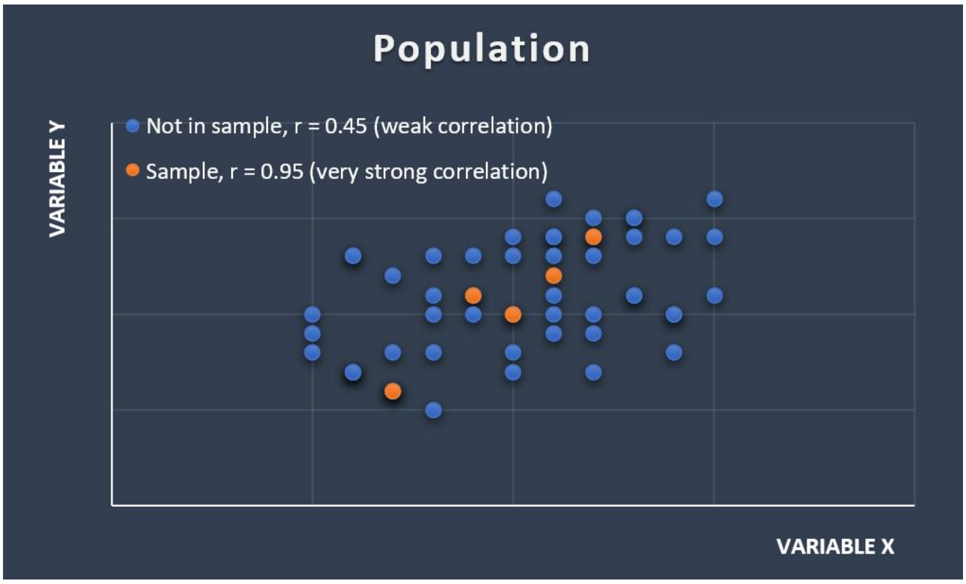


Figure D.1: Explanation of statistical significance.

To check what the probability is of finding correlated samples by change, the correlation coefficient (r_{XY}) must be compared to the values in the table of critical values.

Table of critical values
Degrees of freedom: $df = n - 2$

	α				α		
df	**0.1**	**0.05**	**0.01**	**df**	**0.1**	**0.05**	**0.01**
1	0.988	0.997	0.999	**14**	0.426	0.497	0.623
2	0.900	0.950	0.990	**15**	0.412	0.482	0.606
3	0.805	0.878	0.959	**16**	0.400	0.468	0.590
4	0.729	0.811	0.917	**17**	0.389	0.456	0.575
5	0.669	0.754	0.875	**18**	0.378	0.444	0.561
6	0.621	0.707	0.834	**19**	0.369	0.433	0.549
7	0.584	0.666	0.798	**20**	0.360	0.423	0.537
8	0549	0.632	0.735	**21**	0.352	0.413	0.526
9	0.521	0.602	0.735	**22**	0.344	0.404	0.515
10	0.497	0.576	0.708	**23**	0.337	0.396	0.505
11	0.476	0.553	0.684	**24**	0.330	0.388	0.496
12	0.458	0.532	0.661	**25**	0.323	0.381	0.487
13	0.441	0.514	0.641	**…**	…	…	…

Table D.2: Table of critical values for r_{XY} (Statistics Solutions Advancement Through Clarity, n.d.).

D.2. Paired sample t-test

The correlation coefficient described in the previous paragraph does not indicate whether there is a difference between variable X and variable Y. See for example the perfect linear relationship shown in figure D.2 where variable X is equal to variable Y (blue line) or the variables is differently related (green line). To indicate if there is a difference between the two variables, a sample T-test can be performed.

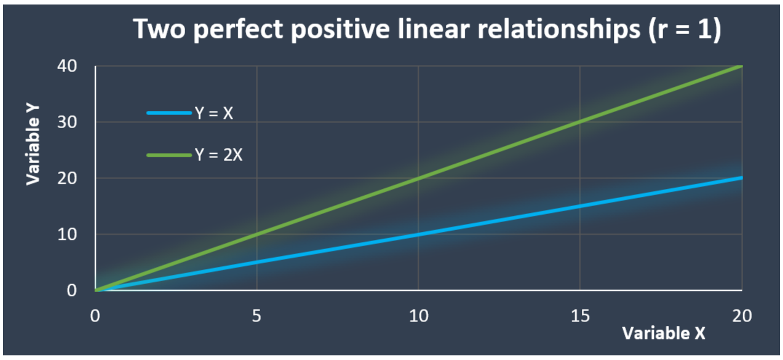


Figure D.2: Both relationships have a perfect positive linear correlation.

Types of sample t-tests

- One sample t-test: This test compares a single sample to a known population value.

- Two sample t-test (also known as independent sample t-test): The independent sample t-test compares two samples to each other from different groups to see if there is a difference between variable X and Y. To check whether there is or there is not a difference between variable X and Y, a null hypothesis is assumed and is evaluated by using the test statistic compared to critical values of the table.

- Paired sample t-test: This test is almost the same as the independent sample t-test, however the difference is that the variables are from the same group at the paired sample t-test and from different groups at the independent sample t-test. This means that the paired sample t-test should be chosen if two measurements are on the same item, person or thing. So, the paired sample t-test is chosen to use for analysing the time measurements from the experiment.

Assumptions of the paired sample t-test

- Independent observations.
- The correlation between all X variables themselves must be zero ($\rho = 0$).
- The correlation between all Y variables themselves must be zero ($\rho = 0$).
- Normality: the 2 variables involved are bivariate normally distributed in the population. However, this is not needed for a reasonable sample size (Van den Berg, n.d.).

Hypothesis

$H_0: \mu_z = 0$, this means there is no difference between X and Y.

$H_1: \mu_z \neq 0$

The null-hypothesis, in this case the expectation that there is no difference, will be tested against the first hypothesis. The first hypothesis of the t-test includes two tails of the distribution.

Variables

X_i = independent observations of data set X for person i = 1, 2, …
Y_i = independent observations of data set Y for person i = 1, 2, …
Z_i = the difference between the two variables, written as $Z_i = X_i - Y_i$ for person i = 1, 2, …

Equation – Test statistic

$T = \frac{\bar{Z}-\mu_z}{s}\sqrt{n}$ $\bar{Z}$ = mean value of Z
μ_z = described mean at hypothesis H0
n = number of samples
$s = \sigma_z$ = standard deviation of Z

Note that the null-hypothesis is rejected for large values of T. To determine when the value of T is large, the table below is used.

Table of critical values

Because of the H_1, there are two tails and the degrees of freedom become: df = n – 2. From table D.3 it can be seen what the probability is of rejecting the null-hypothesis.

df	α									
1-tail	25%	20%	15%	10%	5%	2.5%	1%	0.5%	0.1%	0.05%
2-tails	50%	40%	30%	20%	10%	5%	2%	1%	0.2%	0.1%
1	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.33	31.599
3	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.21	12.924
4	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707

Table D.3: Critical values for T (San Jose State University, 2007).

The values from table D.3 can be visualised with figure D.3. For α = 0.05, the probability of finding a range outside -T and T is 5%. If the T-value is outside the range of -T and T, it is unlikely and thus the null hypothesis will be rejected in this case.

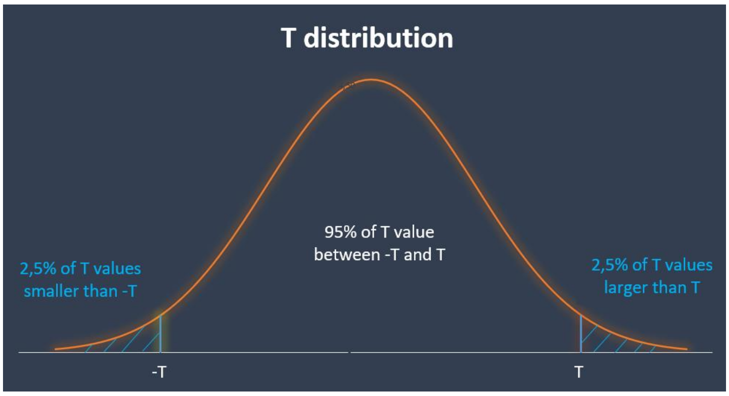


Figure D.3: T distribution for α = 0.05 (van den Berg, n.d.).

D.3. Linear regression

In this paragraph two methods of linear regression are described to find the best possible linear function through the data. Further, a line of the mean of the factor between variables X and Y is added as a comparison. All three lines will be plotted through the data from the experiments to see which gives a better relation.

Least squares linear regression

Linear relation: $Y = aX + b$

Slope or gradient: $a = \frac{n\sum XY - \sum X \sum Y}{n\sum(X)^2 - (\sum X)^2}$ with $n =$ the number of samples

Interception vertical axis: $b = \frac{\sum Y - a\sum X}{n}$

This method works by making the total of the squares of the difference between variables, named errors, as small as possible. The best line of fit is the one which minimizes the variance, in other words to minimize the sum of the squared errors. By doing this the variables which are located further away from the line count more heavily than the points which are closer to the line. This is further explained by using figure D.4 which shows a comparison between correlated data with six samples and the same correlated data with five samples. Point 6 is located further away and due to squaring the error, this point has a lot of influence on the correlation coefficient and the least squared linear regression line. The regression line becomes in this case even descending, see the blue line compared to the orange line in the figure.

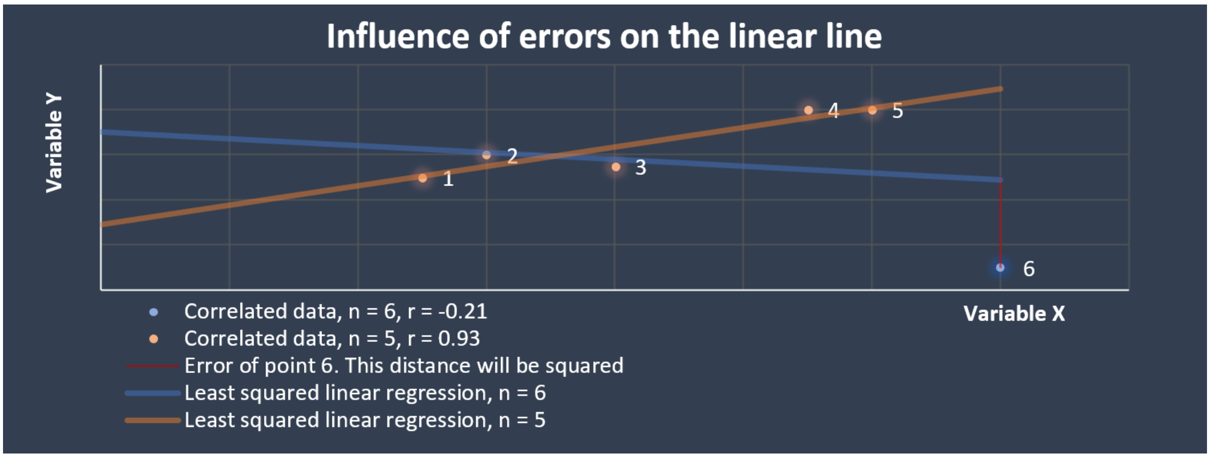


Figure D.4: Influence of errors on the linear regression.

Least squares intercept free linear regression
This model is also called the simple linear model.

Linear relation: $\mathrm{Y} = \mathrm{aX} + \mathrm{b}$

Slope or gradient: $\mathrm{a} = \frac{\sum \mathrm{XY}}{\sum \mathrm{X}^2}$

Interception vertical axis: $\mathrm{b} = 0$, as the line should go through the origin (0,0)

The linear relation can be rewritten to $\mathrm{Y} = \mathrm{aX}$, which implies a linear line which goes through the origin (0,0). This method is the same as the least squares linear regression model, only in this case the line goes through the origin.

Mean slope linear relation
This model is the same as the intercept free linear regression, only in this case the error is not squared. If there is one point far away from the points following the linear line, this point will cause the line of the intercept free linear regression method to deviate to that one point. To see if this happens, the mean slope linear relation line is used.

Linear relation: $\mathrm{Y} = \mathrm{aX} + \mathrm{b}$

Slope or gradient: $\mathrm{a} = \sum \mathrm{Y}/\mathrm{X}$

Interception vertical axis: $\mathrm{b} = 0$, as the line should go through the origin (0,0)

E. Questionnaire: experiences on boat rescues

In this questionnaire you will be asked to estimate some characteristics that influence rescue speed and capacity. To make sure every participant has more or less the same image for answering the questions, some background information is described below.

Boat type of NRV ('Nationale ReddingsVloot')

1.) Vlet 9.9 – 15 pk	2.) Tinn Silver[1] 50 – 60 pk	3.) Rescue 3[2] ~ 70 pk
		

Table E.1: Boat types of the NRV.

Notes on flood characteristics

- <u>Water depth :</u> I.) 0.0 - 0.5 meter
  II.) 0.5 - 1.0 meter
  III.) 1.0+ meter

  Assume that for a longer distance the water depth varies within the given range.

- <u>Flow velocity of water in the flooded area (due to the river or tide):</u> Assume that the flow velocity is below 0.5 m/s (1,8 km/h). If you think it is necessary, indicate a different flow velocity for the situation you describe.

- <u>Wind:</u> Assume that the wind speed is low during the rescuing of people during a flood.

Comment

If you think it is necessary to add more some information or characteristics about the flood/rescue situation when answering the questions, please do so. You are also asked to distinguish between different situations (for example coastal or river floods) if you think it affects the answer.

The questionnaire is given below and consists of six parts.

[1] https://reddingsbrigade.info/wp-content/uploads/2013/09/3470957_1_org.jpg.

[2] https://www.schepenkring.nl/aanbod-boten/89300/rescue-3/#gallery01-1

1. Introduction

How much years of experience do you have with boat rescues?	… [years]		
Do you have experience with navigating with a lifeboat on rivers, the North Sea and/or a lake?		Yes	No
	Rivers		
	North Sea		
	Lake		
		Yes	No
Are you a member of the Reddingsbrigade? If the answer is 'yes'; indicate the following: *Lifeguard station: ____ *Function/title: ____ *Experience: ______ years			
Are you a member of the KNRM? If the answer is 'yes'; indicate the following: *Lifeboat station: ____ *Function/title: ____ *Experience: ______ years			
Did you participate during the evacuation of people during the floods in 1954, 1993 and/or 1995? (If yes, please indicate which years)			

Table E.2: Introduction.

2. Navigation speed

2a) What is your estimation about the navigation speed and what is the navigation speed in a flooded area for a lifeboat [knots]? Please fill in the table below.

		1.) Vlet	2.) Tinn Silver	3.) Rescue 3	(Optional) Other lifeboat type:
Estimation of navigation speed non flooded area [knots]					
	Water depth:				
Estimation of navigation speed in flooded area for different water depths [knots]	I.) 0.0 – 0.5 m				
	II.) 0.5 – 1.0 m				
	III.) 1.0+ m				

Table E.3: Navigation speed.

2b) What is the influence of debris on the navigation speed compared to the navigation speed in a normal waterway? If relevant, distinguish between different situations.

2c) Does the hinder that waves from lifeboats cause to the environment reduce the navigation speed during a flood? If relevant, distinguish between different situations.

3. Transferring people into a lifeboat

For question 3, make a distinction between the following groups if necessary:

- Children till the age of 6 year
- Injured people who are not able to walk
- Elderly (60+)
- Handicapped

3a) How can a person be saved from a higher floor above the water and be brought into a life boat?

3b) How can a person be saved from a collapsed building in a flooded area and brought into a lifeboat? If necessary, distinguish between different situations. Furthermore, indicate if you think it is not safe or possible to rescue this person.

3c) In which ways can a person be taken out of the water into a lifeboat?

3d) How much time do you estimate it takes to transfer one person from the hiding place into a lifeboat? This is the time between making contact with the person till the moment that a person is in the lifeboat. Please distinguish the scenarios of question 3a, 3b and 3c and mention the time unit (seconds, minutes, hours).

	3a) Higher floor / attic	3b) Collapsed building	3c) Water
Time estimation			

Table E.4: Boarding time.

3e) What equipment is needed during a flood, in addition to the regular equipment in a boat regarding transportation of people into a lifeboat?

4. Employability of rescue equipment and people

4a) In what way and by what can a boat be damaged during navigating in a flooded area? Arrange this from largest to lowest risk of occurrence and indicate if a lifeboat can proceed to rescue people during the flood.

4b) Is it likely that a lifeboat is damaged due to navigating in a flooded area and cannot proceed to rescue people during the flood?

4c) How many times can a boat be deployed during the total rescue operation of the flood, until it is unsafe to deploy and must be repaired? If necessary, indicate different situations and indicate if there is a difference for boat types.

4d) What material(s) or specifications are useful to prevent damage to a lifeboat?

4e) How many people do you think are necessary to have one boat operational for 24 hours during a flood? If necessary, differentiate between different scenarios.

5. Reaching people

5a) Can you think of a way to systematically search the flooded area for survivors?

5b) Do you think it is realistic to find every person that needs to be rescued after a flood? If necessary, describe different situations and make a distinction between the Vlet, Tinn Silver, Rescue 3 and other lifeboats.

6. Experience

6a) Can you describe your own experience with boat rescues?

F. Experiment: walking – General

First the weather conditions are given in paragraph F.1. After this, the influence of the wader on the time measurements is checked in paragraph F.2. Further at the end of paragraph C.3, the following is noticed which will be elaborated in paragraphs F.3 and F.4:

- Round 2 has the same circumstances as round 3 for part 1 (Basin 1)
- Round 3 has the same circumstances as round 5 for part 5 (Basin 3)

F.1. Weather conditions

As the experiment took place at an outside location, the weather conditions are also measured and given in table F.1. This table shows that there were no extreme weather conditions during the experiments.

	27th of December 2020	28th of December 2020	29th of December 2020		30th of December 2020
Participants	1, 2, 3, 4, 5, 6, 7, 8	9, 10, 11	12, 13, 14, 15	16, 17, 18, 19	20, 21, 22, 23, 24, 25
Wind direction	South-West	South-East	West	West	West
Wind force [Bft]	6	2	2	2	3
Precipitation [mm]	5.1	0	0	Rain only at round 5	0
View	Good / Gray / Clouded	Good / Clouded	Good / Clouded	Dark, limited view	Good / Clouded
Temperature environment	7	4	6	2	6

Table F.1: Weather conditions during the experiment.

F.2. Influence of walking with a wader

In this part the influence of walking with a wader is considered. It is expected that a wader does not influence the time measurements. Only five persons participated at round 0.

I) Data

Time measurements of walking with and without a wader												
	Part 1 (Basin 1)		Part 2		Part 3 (Basin 2)		Part 4		Part 5 (Basin 3)		Total parcourse	
Round **Person:**	0	1	0	1	0	1	0	1	0	1	0	1
20	7.45	7.72	6.69	6.43	5.03	5.22	5.70	6.02	5.68	5.78	30.55	31.16
22	8.96	9.17	4.32	3.83	4.48	4.31	5.03	4.85	5.25	5.23	28.04	27.38
23	8.93	8.56	7.39	7.35	4.38	4.48	5.90	6.16	5.25	5.04	31.85	31.58
24	6.46	6.82	5.93	6.11	4.28	4.25	6.43	6.20	4.83	4.73	27.93	28.09
25	8.06	8.11	7.51	7.69	4.51	4.65	5.51	5.70	4.67	4.94	30.26	31.09

Table F.2: Time measurements in seconds of round 0 (without wader) and round 1 (with wader).

II) Variables

Variables of walking with and without a wader	
X	Time round 0, d = 0.0 m, no wader [sec.]
Y	Time round 1, d = 0.0 m [sec.]

Table F.3: Variables X and Y.

III) Correlation

Hypothesis: $H_0: r_{XY} = 0$
$H_1: r_{XY} \neq 0$

Formula: $$r_{XY} = \frac{n(\sum XY)-(\sum X)(\sum Y)}{\sqrt{n(\sum X^2)-(\sum X)^2}\sqrt{n(\sum Y^2)-(\sum Y)^2}}$$
$$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1-r_{XY}^2}} \text{ with } df = n-2$$

Correlation of walking with and without a wader										
Part	$\sum X$	$\sum X^2$	$\sum XY$	$\sum Y$	$\sum Y^2$	**n**		r_{XY}	**T**	**p**
1 (Basin 1)	39.86	322.22	325.21	40.38	329.18	5		0.971	7.07	0.00583
2	31.84	209.60	207.74	31.39	206.27	5		0.990	11.92	0.00127
3 (Basin 2)	22.68	103.21	104.33	22.91	105.54	5		0.949	5.24	0.01353
4	28.57	164.31	166.18	28.91	168.35	5		0.888	3.34	0.04423
5 (Basin 3)	25.68	132.53	132.61	25.71	132.84	5		0.890	3.38	0.04307
Total parcourse	148.63	149.29	4429.7	4472.6	4450.4	5		0.954	5.51	0.01175

Table F.4: Correlation per part and for the total parcourse. r_{XY} = correlation coefficient, T = Test statistic, p = probability. The null hypothesis is rejected for large values of T, thus low values of p.

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
3	0.805	0.878	0.959

Table F.5: Table of critical values for the correlation coefficient with n = 5.

See table F.5, for $df = 3$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.878 \leq r_{XY} \leq 0.878$ and 5% probability of finding a correlation outside this range.

Conclusion

- Individual parts:
  - Part 1: $r_{XY;\,part\,1} = 0.97 > 0.878$
  - Part 2: $r_{XY;\,part\,2} = 0.99 > 0.878$
  - Part 3: $r_{XY;\,part\,3} = 0.95 > 0.878$
  - Part 4: $r_{XY;\,part\,4} = 0.89 > 0.878$
  - Part 5: $r_{XY;\,part\,5} = 0.89 > 0.878$

  This means that for all parts the null hypothesis of $r_{XY} = 0$ is rejected and there is a strong or very strong positive linear relationship that is significant.

- Total parcourse:
  - $r_{XY;\,\text{total parcourse}} = 0.95 > 0.878$

This means that the null hypothesis of $r_{XY} = 0$ is rejected and there is a very strong positive linear relationship that is significant.

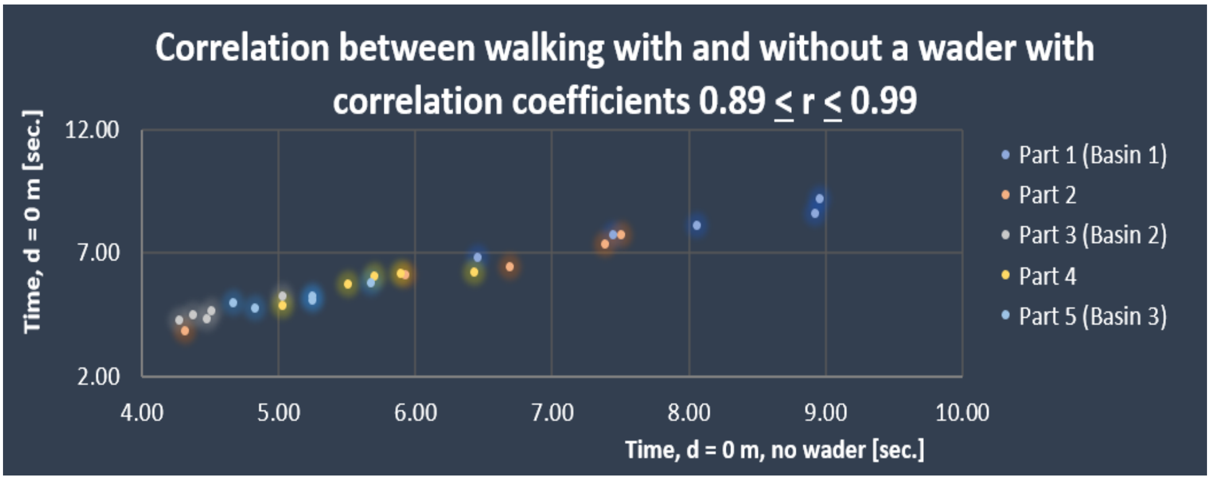


Figure F.1: Correlation between round 0 (without wader) and round 1 (with wader) for part 1 till part 5.

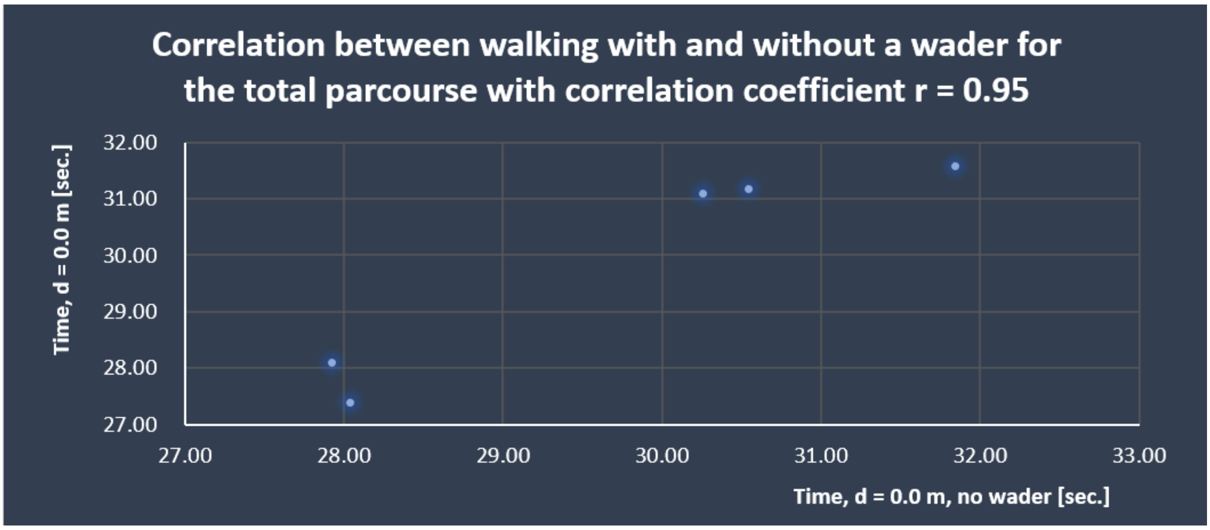


Figure F.2: Correlation between round 0 (without wader) and round 1 (with wader) for the total parcourse.

IV) Difference

Hypothesis: $H_0: \mu_z = 0$

$H_1: \mu_z \neq 0$

Formula: $T = \frac{\bar{Z} - \mu_z}{S}\sqrt{n}$

Difference between walking with and without a wader						
Part	T	$\overline{Z}$	μ_z	n	$s = \sigma_z$	p
1 (Basin 1)	-0.80	-0.10	0	5	0.29	0.467
2	0.69	0.09	0	5	0.29	0.528
3 (Basin 2)	-0.69	-0.05	0	5	0.15	0.530
4	-0.58	-0.07	0	5	0.26	0.592
5 (Basin 3)	-0.07	-0.01	0	5	0.19	0.658
Total parcourse	-0.48	-0.13	0	5	0.61	0.658

Table F.6: Test statistic and probability for the difference between round 0 (without wader) and round 1 (with wader).

Table of critical values for test statistic T										
df	**α**									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
3	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.21	12.924

Table F.7 Table of critical values for test statistic T with n = 5.

See table F.7, for $df = 3$ with critical value $\alpha = 0.05$, the null hypothesis ($\mu_z = 0$) is rejected with a certainty of more than 95% if the p-value from the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

<u>Conclusion</u>

- Individual parts:
  - Part 1: $p_{part\ 1} = 0.467 > \alpha = 0.05$
  - Part 2: $p_{part\ 2} = 0.528 > \alpha = 0.05$
  - Part 3: $p_{part\ 3} = 0.530 > \alpha = 0.05$
  - Part 4: $p_{part\ 4} = 0.592 > \alpha = 0.05$
  - Part 5: $p_{part\ 5} = 0.658 > \alpha = 0.05$

  This means that for all parts the null hypothesis of $\mu_z = 0$ is not rejected. This can also be seen from figure F.3.

- Total parcourse:
  - $p = 0.658 > \alpha = 0.05.$

  This means that the null hypothesis of $\mu_z = 0$ is not rejected.

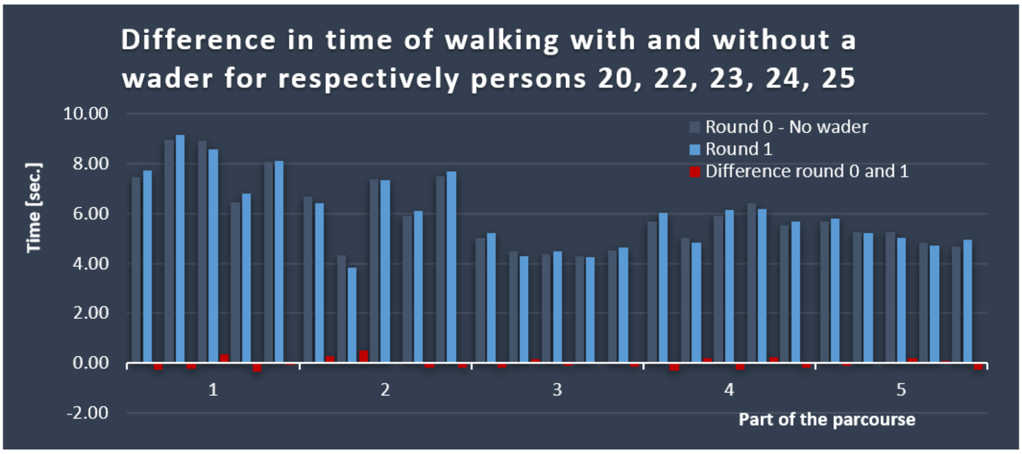


Figure F.3: Difference between round 0 (without wader) and round 1 (with wader) for parcourse part 1 till 5.

V) Conclusion

There is a very strong positive linear relationship that is significant between walking with and without a wader. The difference between walking with and without a wader is approximately zero and thus it can be concluded that walking with a wader does not reduce the walking speed of a person.

F.3. Comparison of round 2 and round 3 at basin 1

As mentioned at the beginning of this appendix, round 2 has the same circumstances as round 3 at basin 1. The time measurements of each round are compared to each other to see if it is a good approximation to use the mean of both rounds for each person in further calculations.

I) Data

Time measurements of walking through the same water depth of d = 0.2 meter at basin 1				
Person	**Round 2**	**Round 3**		**Mean round 2 and 3**
1	13.61	11.64		12.63
2	11.93	12.52		12.22
3	9.23	10.68		9.95
4	6.39	6.20		6.30
5	5.95	5.80		5.87
6	11.51	11.43		11.47
7	6.52	5.22		5.87
8	8.52	8.42		8.47
9	18.02	17.85		17.93
10	8.77	9.26		9.01
11	9.03	9.66		9.35
12	8.16	8.28		8.22
13	8.57	8.75		8.66
14	7.31	8.49		7.90
15	7.11	8.75		7.93
20	10.63	10.25		10.44
21	6.10	6.14		6.12
22	17.51	16.18		16.84
23	14.82	14.93		14.87
24	12.57	12.11		12.34
25	12.59	11.36		11.98

Table F.8: Time measurements in seconds of round 2 and round 3 at basin 1. Persons 16 – 19 are not considered as this experiment took place in the dark.

II) Variables

Variables of walking through the same water depth of d = 0.2 meter at basin 1	
X	Time round 2, d = 0.2 m [sec.]
Y	Time round 3, d = 0.2 m [sec.]

Table F.9: Variables X and Y.

III) Correlation

Hypothesis: $H_0: r_{XY} = 0$

$H_1: r_{XY} \neq 0$

Formula: $$r_{XY} = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{n(\sum X^2) - (\sum X)^2}\sqrt{n(\sum Y^2) - (\sum Y)^2}}$$

$$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1 - r_{XY}^2}} \text{ with } df = n - 2$$

Correlation between walking through the same water depth of d = 0.2 meter at different rounds at basin 1								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
0.97	214.81	2455.76	213.87	2400.57	2419.88	21	16.92	$6.53 * 10^{-13}$

Table F.10: Correlation between time measurements from round 2 and round 3. r_{XY} = correlation coefficient, T = Test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
19	0.369	0.433	0.549

Table F.11: Table of critical values for the correlation coefficient with n = 21.

See table F.11, for $df = 19$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.433 \leq r_{XY} \leq 0.433$ and 5% probability of finding a correlation outside this range.

Conclusion

From table F.10 the $r_{XY} \approx 0.97 > 0.433$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a very strong positive relation that is significant between walking through the same water depth of 0.2 meter at basin 1.

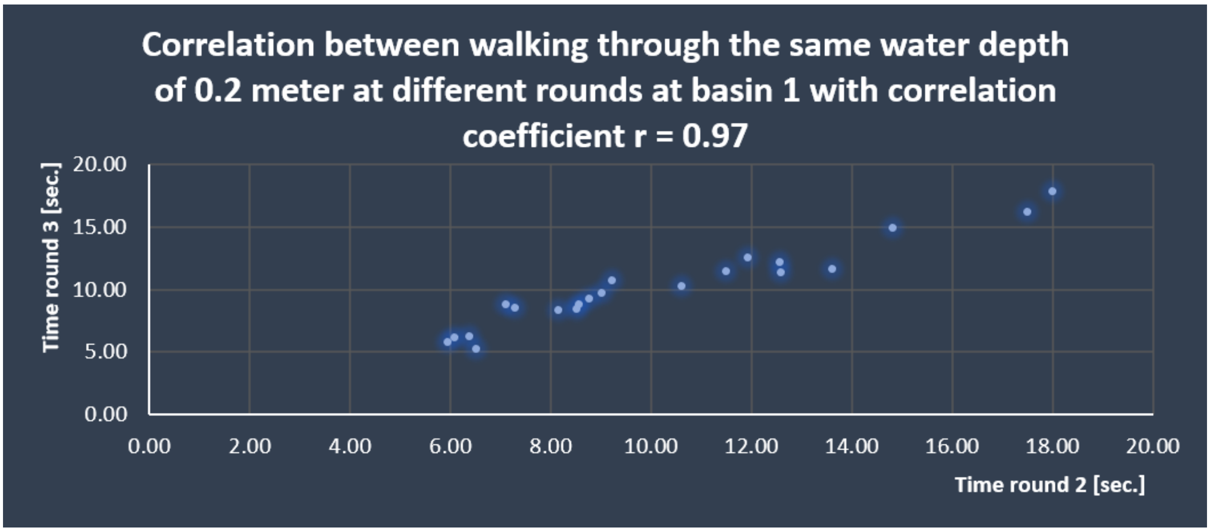


Figure F.4: Correlation between round 2 and round 3 at basin 1.

IV) Difference

Hypothesis: $H_0: \mu_z = 0$
$H_1: \mu_z \neq 0$

Formula: $T = \frac{\bar{Z} - \mu_z}{s}\sqrt{n}$

Difference between walking through the same water depth at different rounds at basin 1					
T	$\bar{Z}$	μ_z	n	$s = \sigma_z$	p
0.23	0.04	0	21	0.909	0.823

Table F.12: Test statistic and probability for the difference between round 2 and round 3 at basin 1.

Table of critical values for test statistic T										
df	**α**									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
19	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883

Table F.13: Table of critical values for test statistic T with n = 21.

See table F.13, for $df = 19$ with critical value $\alpha = 0.05$, the null hypothesis of $\mu_z = 0$ is rejected with a certainty of more than 95% if the p-value from the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

Conclusion

The p-value ($p = 0.823$), see table F.12, is higher than the critical value ($\alpha = 0.05$). This means that the null hypothesis of $\mu_z = 0$ is not rejected with a certainty of more than 95%. The difference between round 2 and 3 at basin 1 is approximately zero.

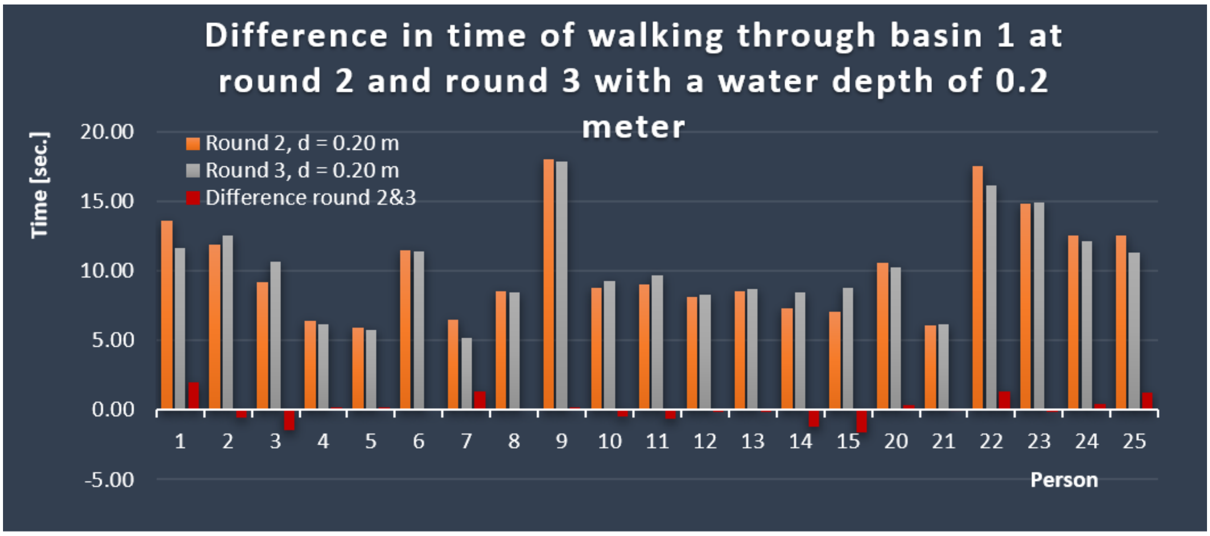


Figure F.5: Difference between round 2 and round 3 at basin 1.

V) Conclusion

There is a very strong positive linear relationship that is significant between round 2 and round 3 at basin 1. The difference between the time measurements of round 2 and round 3 is approximately zero which implies the time measurements from round 2 and round 3 are almost equal. Because of the equality, the mean of round 2 and round 3 of each person is used for basin 1 in further calculations.

F.4. Comparison of round 3 and round 5 at basin 3

As mentioned at the beginning of this appendix, round 3 has the same circumstances as round 5 at basin 2. The time measurements of each round are compared to each other to see if it is a good approximation to use the mean of both rounds for each person in further calculations.

I) Data

Time measurements of walking through the same water depth of d = 0.4 meter at basin 3				
Person	**Round 3**	**Round 5**		**Mean round 3 and 5**
9	12,64	13,11		12,87
10	7,71	7,73		7,72
11	7,10	7,80		7,45
12	9,84	7,61		8,73
13	8,24	7,59		7,91
14	6,44	7,75		7,09
15	6,48	6,06		6,27
20	11,11	10,19		10,65
21	7,20	8,86		8,03
22	11,82	13,06		12,44
23	11,57	13,19		12,38
24	9,37	9,93		9,65
25	7,35	7,47		7,41

Table F.14: Time measurements in seconds of round 3 and round 5 at basin 3.

Note:
- Persons 16 – 19 are not considered as this experiment took place in the dark.
- Persons 1 – 8 did not fully complete round 5. To limit the amount of time that day, basin 3 was left out of consideration at round 5.

II) Variables

Variables of walking through the same water depth of d = 0.4 meter at basin 3	
X	Time round 3, d = 0.4 m [sec.]
Y	Time round 5, d = 0.4 m [sec.]

Table F.15: Variables X and Y.

III) Correlation

Hypothesis: $H_0: r_{XY} = 0$
$H_1: r_{XY} \neq 0$

Formula: $$r_{XY} = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{n(\sum X^2) - (\sum X)^2}\sqrt{n(\sum Y^2) - (\sum Y)^2}}$$

$$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1 - r_{XY}^2}} \text{ with } df = n - 2$$

Correlation between walking through the same water depth of d = 0.4 meter at different rounds at basin 3								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
0.89	116.84	1107.86	120.33	1185.69	1138.73	13	6.42	$4.95 * 10^{-5}$

Table F.16: Correlation between time measurements from round 3 and round 5. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
13	0.441	0.514	0.641

Table F.17: Table of critical values for the correlation coefficient with n = 15.

See table F.17, for $\mathrm{df} = 13$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.514 \leq r_{XY} \leq 0.514$ and 5% probability of finding a correlation outside this range.

Conclusion

From table F.16 the $r_{XY} \approx 0.89 > 0.514$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a strong positive relation that is significant between round 3 and round 5 at basin 3.

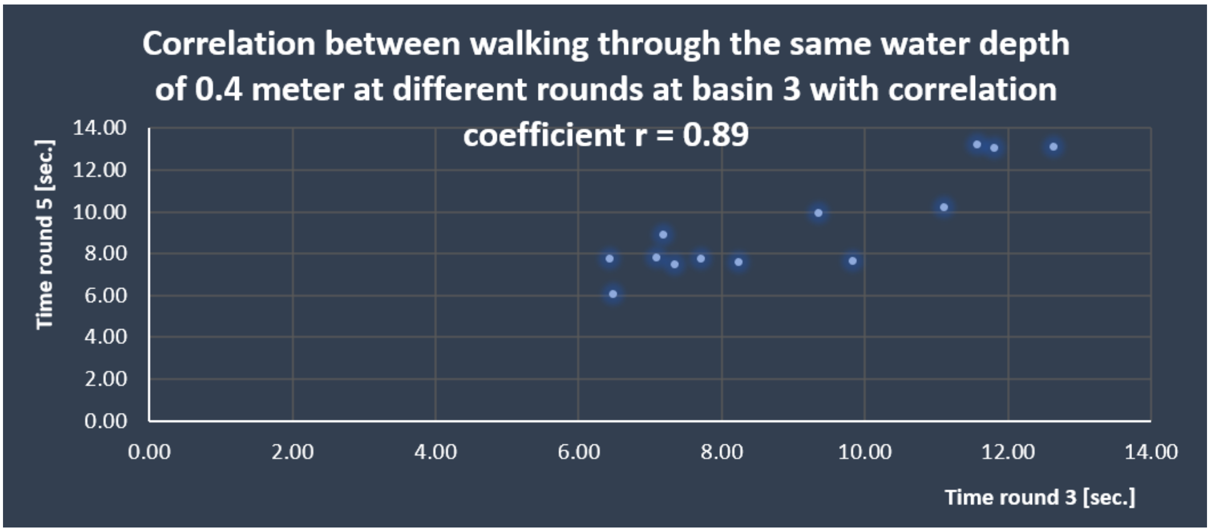


Figure F.6: Correlation between round 3 and round 5 at basin 3.

IV) Difference

Hypothesis: $H_0: \mu_z = 0$
$H_1: \mu_z \neq 0$

Formula: $T = \frac{\overline{Z} - \mu_z}{s}\sqrt{n}$

Test statistic and probability of the comparison of walking through the same water depth at different rounds at basin 3					
T	$\overline{Z}$	μ_z	n	$s = \sigma_z$	p
0.86	0.27	0	13	1.124	0.405

Table F.18 Test statistic and probability for the difference between round 3 and round 5 at basin 3.

Table of critical values for test statistic T										
df	**α**									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
13	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221

Table F.19: Table of critical values for test statistic T with n = 15.

See table F.19, for $df = 13$ with critical value $\alpha = 0.05$, the null hypothesis of $\mu_z = 0$ is rejected with a certainty of more than 95% if the p-value from the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

Conclusion

The p-value ($p = 0.405$), see table F.18, is higher than the critical value ($\alpha = 0.05$). This means that the null hypothesis of $\mu_z = 0$ is not rejected with a certainty of more than 95%. The difference between round 3 and 5 at basin 3 is approximately zero.

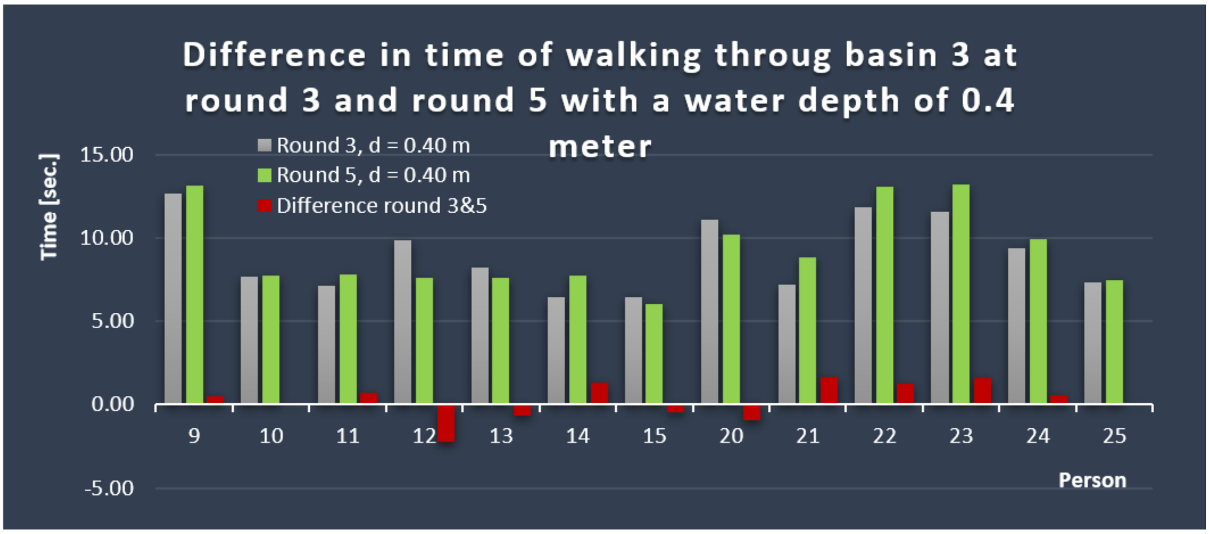


Figure F.7: Difference between round 3 and round 5 at basin 3.

V) Conclusion

There is a strong positive linear relationship that is significant between round 3 and round 5 at basin 3. The difference between the time measurements of round 3 and round 5 is approximately zero which implies the time measurements from round 3 and round 5 are almost equal. Because of the equality, the mean of round 3 and round 5 of each person is used for basin 3 in further calculations.

G. Experiment: walking – Influence water depth

- **What is the influence of water depth on the fleeing speed?**

Overview

Table G.1 gives an overview of which rounds with corresponding water depths will be compared to each other. Each basin has its own paragraph with the following structure: Data (I), Variables (II), Correlation (III), Difference (IV), Relation (V), and Graphs (VI).

		Round	Water depth
1.A)	**Basin 1**	1 and mean of 2&3	0.0 m and 0.2 m
2.A)	**Basin 2**	1 and 2	0.0 m and 0.4 m
2.B)		1 and 3	0.0 m and 0.6 m
2.C)		2 and 3	0.4 m and 0.6 m
3.A)	**Basin 3 – Bend**	1 and 2	0.0 m and 0.2 m
3.B)		1 and mean of 3&5	0.0 m and 0.4 m
3.C)		2 and mean of 3&5	0.2 m and 0.4 m

Table G.1: Overview.

Number of samples: n = 21
Degrees of freedom (2-tailed): df = 19

Correlation

Hypothesis: $H_0: r_{XY} = 0$
$H_1: r_{XY} \neq 0$

Formula:
$$r_{XY} = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{n(\sum X^2) - (\sum X)^2}\sqrt{n(\sum Y^2) - (\sum Y)^2}}$$
$$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1 - r_{XY}^2}} \text{ with } df = n - 2$$

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
19	0.369	0.433	0.549

Table G.2: Table of critical values for the correlation coefficient with n = 21.

See table G.2, for $df = 19$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.433 \leq r_{XY} \leq 0.433$ and 5% probability of finding a correlation outside this range.

Difference

Hypothesis: $H_0: \mu_z = 0$

$H_1: \mu_z \neq 0$

Formula: $T = \frac{\bar{Z} - \mu_z}{s}\sqrt{n}$

Table of critical values for test statistic T										
df	**α**									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
19	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883

Table G.3: Table of critical values for test statistic T with n = 21.

See table G.3, for $df = 19$ with critical value $\alpha = 0.05$, the null hypothesis of $\mu_z = 0$ is rejected with a certainty of more than 95% if the p-value from the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

G.1. Basin 1: Walking through water depths of 0.0 and 0.2 meter

I) Data

Time measurements of walking through water depths of 0.0 and 0.2 meter at basin 1		
Person	**Time round 1 [sec.]**	**Time mean round 2&3 [sec.]**
1	6.92	12.63
2	5.17	12.22
3	4.76	9.95
4	5.68	6.30
5	4.70	5.87
6	5.74	11.47
7	4.44	5.87
8	4.14	8.47
9	11.10	17.93
10	7.00	9.01
11	8.39	9.35
12	6.08	8.22
13	6.93	8.66
14	5.34	7.90
15	4.27	7.93
20	7.72	10.44
21	3.27	6.12
22	9.17	16.84
23	8.56	14.87
24	6.82	12.34
25	8.11	11.98

Table G.4: Time measurements in seconds of round 1 and the mean of round 2&3 at basin 1. Persons 16 – 19 are not considered as this experiment took place in the dark.

II) Variables

Variables of walking through water at basin 1	
X	Time round 1, d = 0.0 m [sec.]
Y	Time mean round 2 and round 3, d = 0.2 m [sec.]

Table G.5: Variables X and Y.

III) Correlation

Correlation between walking through water depths of d = 0.0 and d = 0.2 meter at basin 1								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
0.80	134.28	935.25	214.34	2424.02	1477.92	21	5.77	$1.46 * 10^{-5}$

Table G.6: Correlation between time measurements from round 1 and the mean of round 2&3 at basin 1. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

From table G.6 the $r_{XY} \approx 0.80 > 0.433$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a strong positive relationship that is significant between walking through water depths of 0.0 ad 0.2 meter at basin 1.

IV) Difference

Test statistic and probability of the comparison of walking through water depths of 0.0 and 0.2 meter at basin 1					
T	$\overline{Z}$	μ_Z	n	$s = \sigma_Z$	p
7.88	3.81	0	21	2.216	$1.46 * 10^{-7}$

Table G.7: Test statistic and probability.

The p-value ($p = 1.46 * 10^{-7}$), see table G.7, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking through water depths of 0.0 and 0.2 meter at basin 1.

V) Relation

Reduction in speed:

$$\text{Reduction in speed} = \frac{\sum \frac{|\text{round 1} - \text{mean round 2\&3}|}{\text{mean round 2\&3}}}{n} * 100\% = 35\%$$

The reduction in speed in case of d = 0.20 m, compared to 0 m, is approximately 35%.

Least squares linear regression: $\text{Time}_{d=0.2\text{ m}} \approx 1.40\ \text{Time}_{d=0.0\text{ m}} + 1.25$
Least squares intercept free linear regression: $\text{Time}_{d=0.2\text{ m}} \approx 1.58\ \text{Time}_{d=0.0\text{ m}}$
Mean slope linear relation: $\text{Time}_{d=0.2\text{ m}} \approx 1.62\ \text{Time}_{d=0.0\text{ m}}$

VI) Graphs

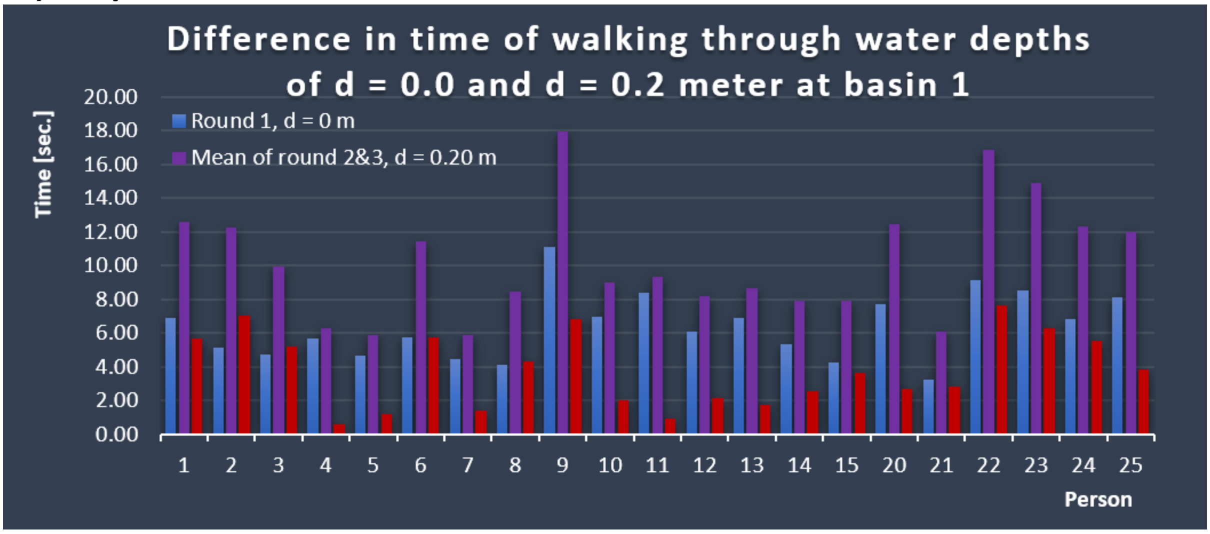


Figure G.1: Difference between round 1 and the mean of round 2&3 at basin 1.

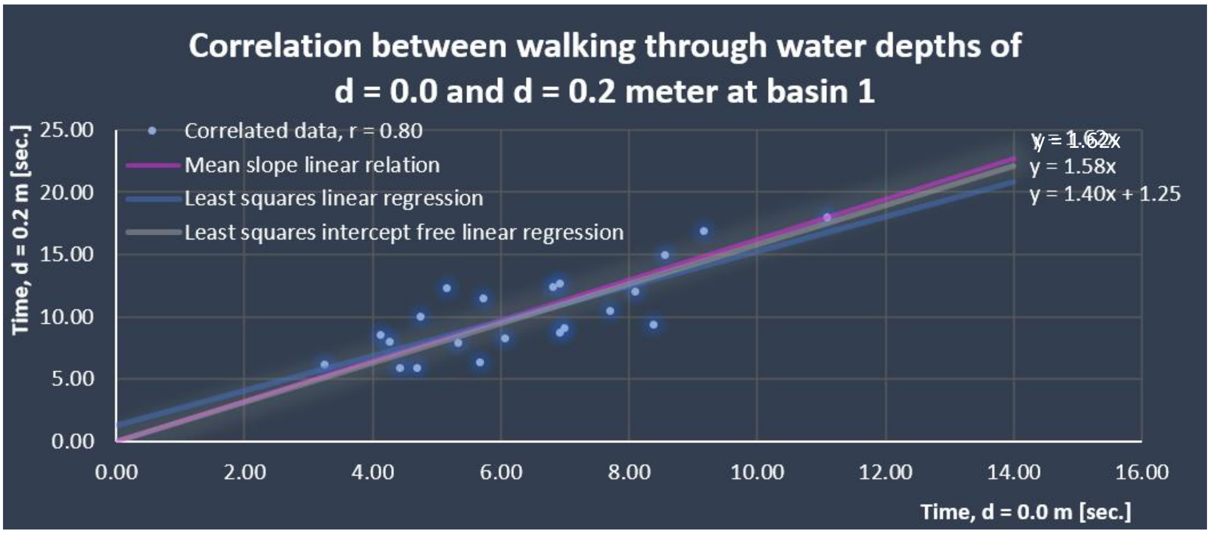


Figure G.2: Correlation between round 1 and the mean of round 2&3 at basin 1.

G.2. Basin 2: Walking through water depths of 0.0, 0.4 and 0.6 meter

I) Data

Time measurements of walking through water depths of 0.0, 0.4 and 0.6 meter at basin 2			
Person	**Time round 1 [sec.]**	**Time round 2 [sec.]**	**Time round 3 [sec.]**
1	4.64	11.23	10.61
2	3.38	10.10	11.43
3	3.27	7.90	8.71
4	4.23	5.89	6.89
5	3.19	5.26	6.45
6	3.92	8.83	9.94
7	3.35	5.21	9.46
8	3.12	7.31	7.99
9	5.19	10.97	11.02
10	4.95	8.19	8.62
11	5.27	6.98	8.66
12	4.12	6.55	8.74
13	4.30	7.61	9.17
14	3.90	6.19	7.32
15	2.51	5.64	7.25
20	5.22	8.64	10.42
21	3.48	6.67	7.81
22	4.31	11.54	11.14
23	4.48	6.37	10.82
24	4.25	10.65	10.81
25	4.65	9.53	9.51

Table G.8: Time measurements in seconds of round 1, round 2 and round 3 at basin 2. Persons 16 – 19 are not considered as this experiment took place in the dark.

II) Variables

Variables of walking through water at basin 2			
	2.A	**2.B**	**2.C**
X	Time round 1, d = 0.0 m [sec.]	Time round 1, d = 0.0 m [sec.]	Time round 2, d = 0.4 m [sec.]
Y	Time round 2, d = 0.4 m [sec.]	Time round 3, d = 0.6 m [sec.]	Time round 3, d = 0.6 m [sec.]

Table G.9: Variables X and Y.

III) Correlation

Correlation between walking through water depths of d = 0.0, d = 0.4 and d = 0.6 meter at basin 2			
	2.A	**2.B**	**2.C**
	X: d = 0.0 m Y: d = 0.4 m	X: d = 0.0 m Y: d = 0.6 m	X: d = 0.4 m Y: d = 0.6 m
r_{XY}	0.45 $\sum X = 85.70$ $\sum X^2 = 361.69$ $\sum Y = 167.21$ $\sum Y^2 = 1414.71$ $\sum XY = 696.63$ $n = 21$	0.45 $\sum X = 85.70$ $\sum X^2 = 361.69$ $\sum Y = 192.70$ $\sum Y^2 = 1814.43$ $\sum XY = 797.03$ $n = 21$	0.78 $\sum X = 167.21$ $\sum X^2 = 1414.71$ $\sum Y = 192.70$ $\sum Y^2 = 1814.43$ $\sum XY = 1582.81$ $n = 21$
T	2.21	2.21	5.46
p	0.03969	0.03946	$2.85 * 10^{-5}$

Table G.10: Correlation between time measurements from round 1, round 2 and round 3 at basin 2. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

- 2.A) From table G.10 the $r_{XY} \approx 0.45 > 0.433$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a weak positive relationship which is significant between walking through water depths of 0.0 and 0.4 meter at basin 2.

- 2.B) From table G.10 the $r_{XY} \approx 0.45 > 0.433$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a weak positive relationship which is significant between walking through water depths of 0.0 and 0.6 meter at basin 2.

- 2.C) From table G.10 the $r_{XY} \approx 0.78 > 0.433$. The null hypothesis $r_{XY} = 0$ is rejected and the conclusion is that there is a strong positive relationship which is significant between walking through water depths of 0.4 and 0.6 meter at basin 2.

IV) Difference

Test statistic and probability of the comparison of walking through water depths of d = 0.0, d = 0.4 and d = 0.6 meter at basin 2			
	2.A	**2.B**	**2.C**
	X: d = 0.0 m Y: d = 0.4 m	X: d = 0.0 m Y: d = 0.6 m	X: d = 0.4 m Y: d = 0.6 m
T	9.73 $\overline{Z} = 3.88$ $\mu_z = 0$ $n = 21$ $s = \sigma_z = 2.828$	17.20 $\overline{Z} = 5.10$ $\mu_z = 0$ $n = 21$ $s = \sigma_z = 1.358$	4.36 $\overline{Z} = 1.21$ $\mu_z = 0$ $n = 21$ $s = \sigma_z = 1.276$
p	$4.99 * 10^{-9}$	$1.89 * 10^{-13}$	$3.03 * 10^{-4}$

Table G.11: Test statistic and probability.

- 2.A) The p-value ($p = 1.46 * 10^{-9}$), see table G.11, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking through water depths of 0.0 and 0.4 meter at basin 2.

- 2.B) The p-value ($p = 1.89 * 10^{-13}$), see table G.11, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking through water depths of 0.0 and 0.6 meter at basin 2.

- 2.C) The p-value ($p = 3.03 * 10^{-4}$), see table G.11, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking through water depths of 0.4 and 0.6 meter at basin 2.

V) Relation

Relation between walking through water depths of d = 0.0, d = 0.4 and d = 0.6 meter at basin 2			
	2.A	**2.B**	**2.C**
Reduction	47% $\frac{\sum \frac{\lvert \text{round 1} - \text{round 2} \rvert}{\text{round 2}}}{n} * 100\%$	55% $\frac{\sum \frac{\lvert \text{round 1} - \text{round 3} \rvert}{\text{round 3}}}{n} * 100\%$	14% $\frac{\sum \frac{\lvert \text{round 2} - \text{round 3} \rvert}{\text{round 3}}}{n} * 100\%$
Factor	$\frac{\sum \frac{\text{round 2}}{\text{round 1}}}{n} = 1.98$	$\frac{\sum \frac{\text{round 3}}{\text{round 1}}}{n} = 2.30$	$\frac{\sum \frac{\text{round 3}}{\text{round 2}}}{n} = 1.19$

Table G.12: Relation between rounds and factor.

- 2.A) The reduction in speed in case of d = 0.4 m, compared to 0.0 m, is approximately 35%.
  - Least squares linear regression: $\text{Time}_{d=0.4\text{ m}} \approx 1.19\ \text{Time}_{d=0.0\text{ m}} + 3.09$
  - Least squares intercept free linear regression: $\text{Time}_{d=0.4\text{ m}} \approx 1.93\ \text{Time}_{d=0.0\text{ m}}$
  - Mean slope linear relation: $\text{Time}_{d=0.4\text{ m}} \approx 1.98\ \text{Time}_{d=0.0\text{ m}}$

- 2.B) The reduction in speed in case of d = 0.6 m, compared to 0.0 m, is approximately 55%.
  - Least squares linear regression: $\text{Time}_{d=0.6\text{ m}} \approx 0.89\ \text{Time}_{d=0.0\text{ m}} + 5.55$
  - Least squares intercept free linear regression: $\text{Time}_{d=0.6\text{ m}} \approx 2.20\ \text{Time}_{d=0.0\text{ m}}$
  - Mean slope linear relation: $\text{Time}_{d=0.6\text{ m}} \approx 2.30\ \text{Time}_{d=0.0\text{ m}}$

- 2.C) The reduction in speed in case of d = 0.6 m, compared to 0.4 m, is approximately 14%.
  - Least squares linear regression: $\text{Time}_{d=0.6\text{ m}} \approx 0.58\ \text{Time}_{d=0.4\text{ m}} + 4.54$
  - Least squares intercept free linear regression: $\text{Time}_{d=0.6\text{ m}} \approx 1.12\ \text{Time}_{d=0.4\text{ m}}$
  - Mean slope linear relation: $\text{Time}_{d=0.6\text{ m}} \approx 1.19\ \text{Time}_{d=0.4\text{ m}}$

VI) Graphs

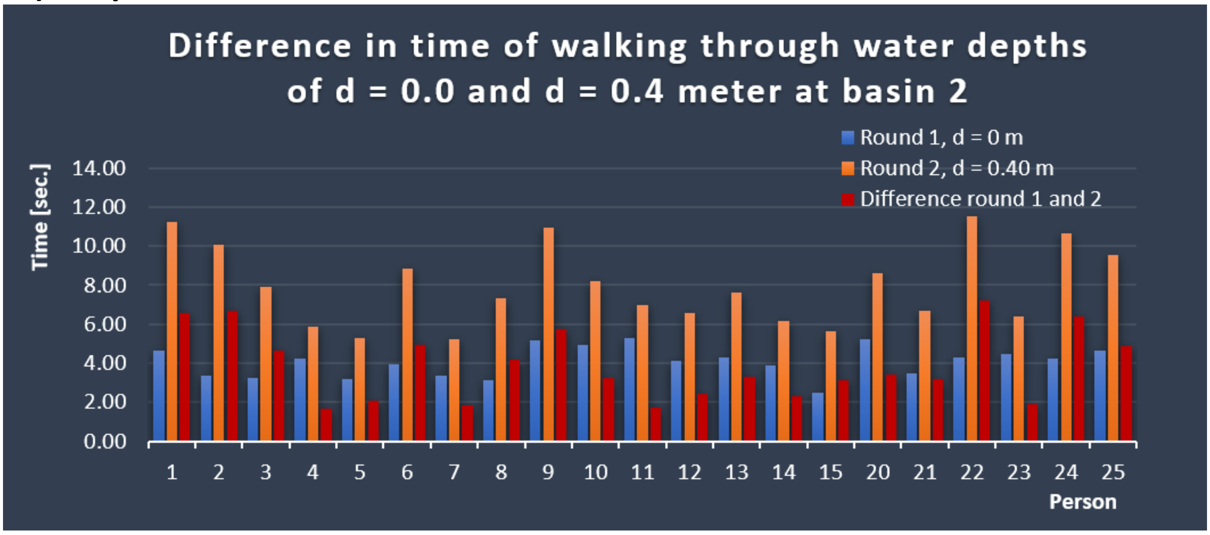


Figure G.3: Difference between round 1 and round 2 at basin 2.

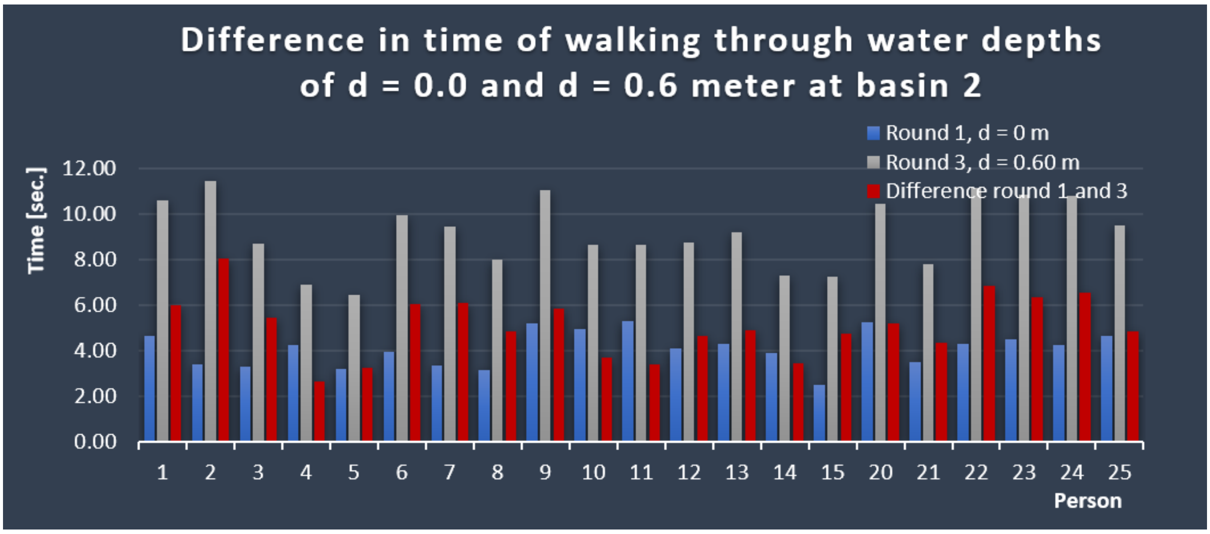


Figure G.4: Difference between round 1 and round 3 at basin 2.

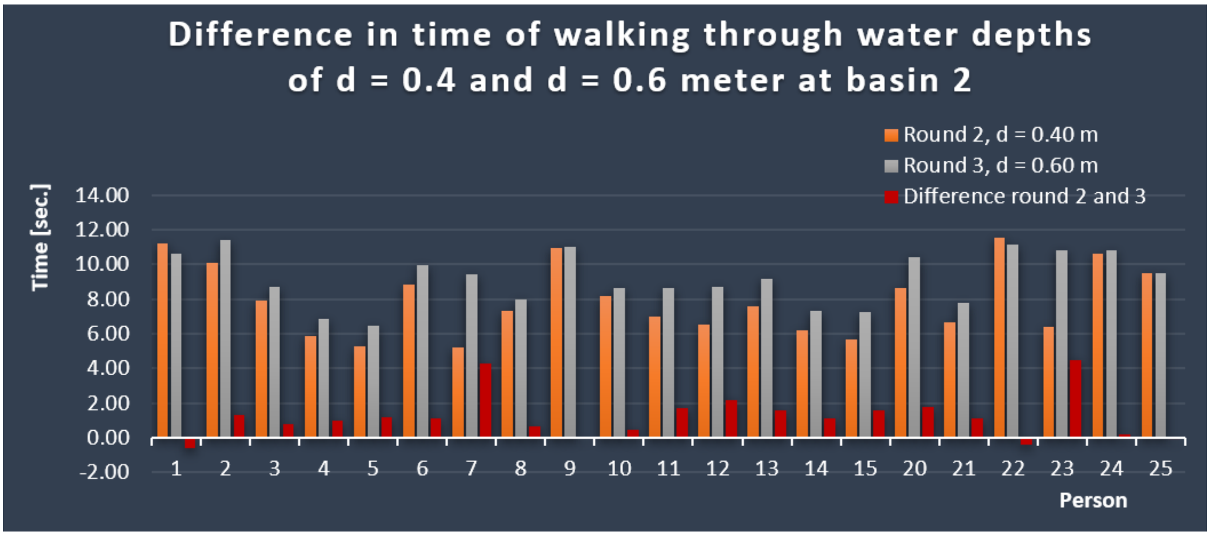


Figure G.5: Difference between round 2 and round 3 at basin 2.

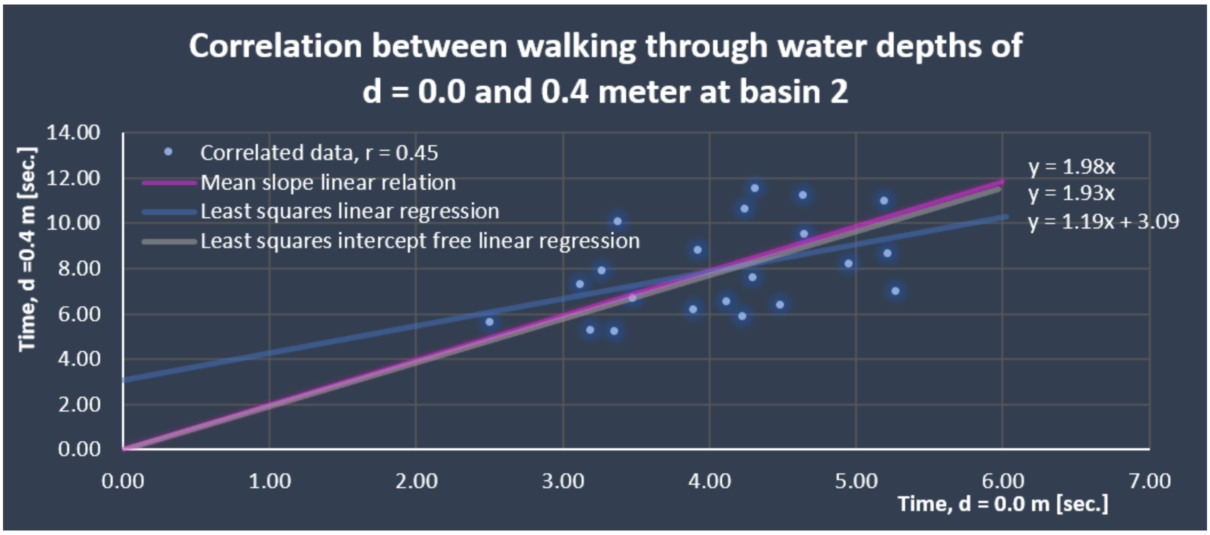


Figure G.6: Correlation between round 1 and round 2 at basin 2.

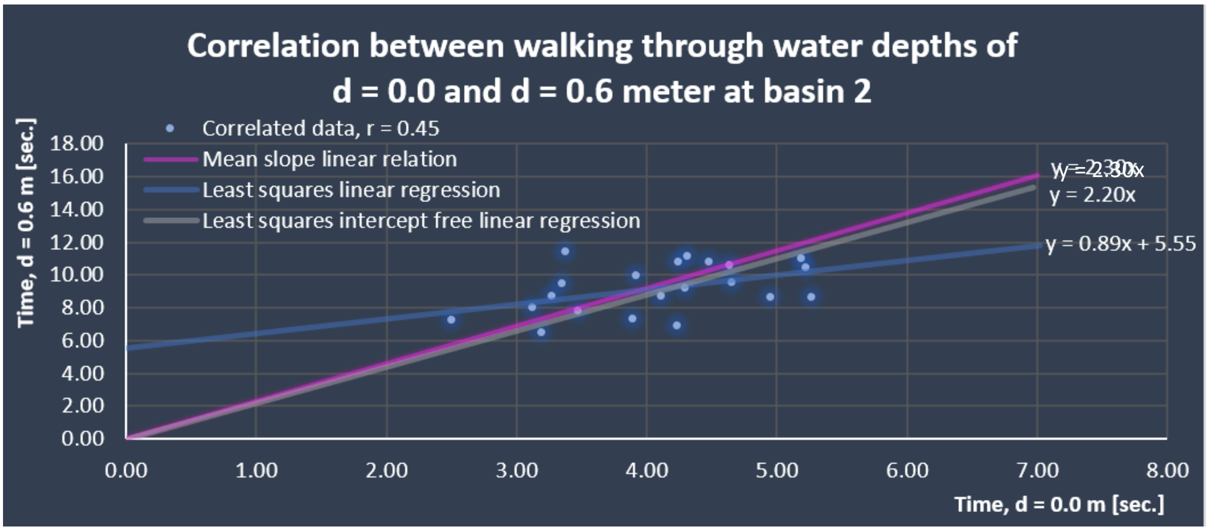


Figure G.7: Correlation between round 1 and round 3 at basin 2.

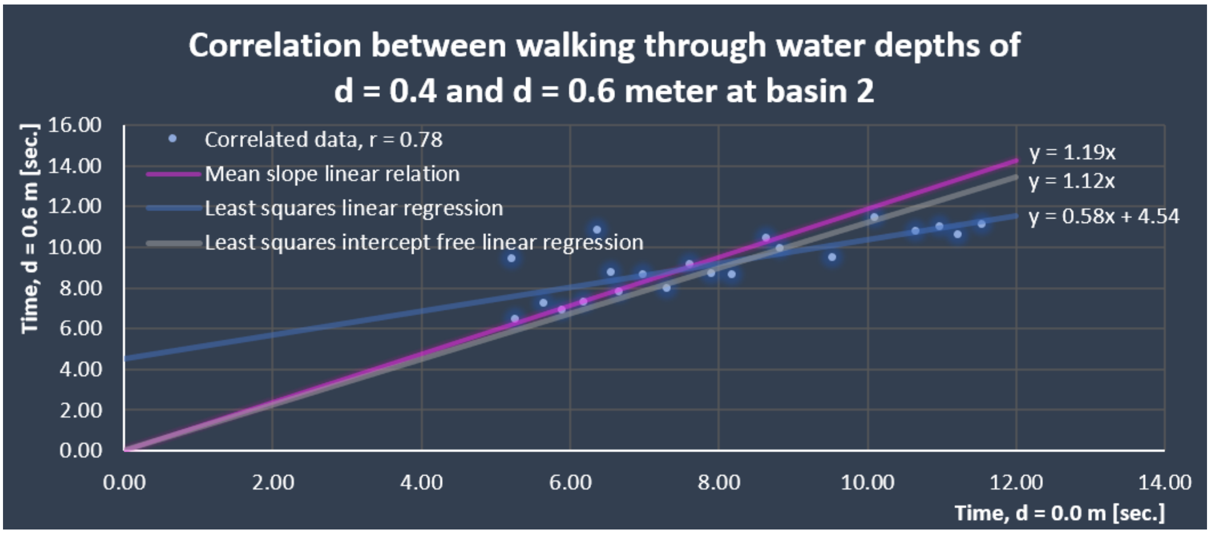


Figure G.8: Correlation between round 2 and round 3 at basin 2.

G.3. Basin 3: Walking through water depths of 0.0, 0.2 and 0.4 meter

I) Data

Time measurements of walking through basin 3			
Person	**Time round 1 [sec.]**	**Time round 2 [sec.]**	**Time mean round 3&5 [sec.]**
1	5.03	8.93	9.17
2	3.60	5.99	9.96
3	3.35	5.73	8.15
4	3.69	4.24	5.74
5	3.66	4.94	5.51
6	3.14	5.83	9.70
7	3.33	4.53	6.16
8	2.65	4.81	7.30
9	7.18	9.32	12.87
10	4.59	6.03	7.72
11	5.40	6.02	7.45
12	4.12	4.65	8.73
13	4.65	5.92	7.91
14	3.42	5.28	7.09
15	2.73	4.53	6.27
20	5.78	9.27	10.65
21	3.13	3.71	8.03
22	5.23	11.50	12.44
23	5.04	10.90	12.38
24	4.73	9.58	9.65
25	4.94	6.73	7.41

Table G.13: Time measurements in seconds of round 1, round 2 and the mean of round 3&5. Persons 16 – 19 are not considered as this experiment took place in the dark.

II) Variables

Variables of walking through basin 3			
	3.A	**3.B**	**3.C**
X	Time round 1, d = 0.0 m [sec.]	Time round 1, d = 0.0 m [sec.]	Time round 2, d = 0.2 m [sec.]
Y	Time round 2, d = 0.2 m [sec.]	Time mean round 3&5, d = 0.4 m [sec.]	Time mean round 3&5, d = 0.4 m [sec.]

Table G.14: Variables X and Y.

III) Correlation

Correlation between walking through different water depths at basin 3			
	3.A)	**3.B)**	**3.C)**
	X: d = 0.0 m Y: d = 0.2 m	X: d = 0.0 m Y: d = 0.4 m	X: d = 0.2 m Y: d = 0.4 m
r_{XY}	0.74 $\sum X = 89.34$ $\sum X^2 = 406.28$ $\sum Y = 138.40$ $\sum Y^2 = 1020.33$ $\sum XY = 628.06$ $n = 21$	0.65 $\sum X = 89.34$ $\sum X^2 = 406.28$ $\sum Y = 180.25$ $\sum Y^2 = 1640.74$ $\sum XY = 798.93$ $n = 21$	0.84 $\sum X = 138.40$ $\sum X^2 = 1020.33$ $\sum Y = 180.25$ $\sum Y^2 = 1640.74$ $\sum XY = 1272.21$ $n = 21$
T	4.76	3.71	6.68
p	$1.36 * 10^{-4}$	0.00149	$2.18 * 10^{-6}$

Table G.15: Correlation between time measurements from round 1, round 2 and round 3 at basin 3. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

- 3.A) From table G.15 the $r_{XY} \approx 0.74 > 0.433$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a strong positive linear relationship that is significant between walking through water depths of 0.0 and 0.20 meter at basin 3.

- 3.B) From table G.15 the $r_{XY} \approx 0.65 > 0.433$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a strong positive linear relationship that is significant between walking through water depths of 0.0 and 0.4 meter at basin 3.

- 3.C) From table G.15 the $r_{XY} \approx 0.84 > 0.433$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a strong positive linear relationship that is significant between walking through water depths of 0.2 and 0.4 meter at basin 3.

IV) Difference

Comparison of walking through different water depths at basin 3			
	3.A)	**3.B)**	**3.C)**
	X: d = 0.0 m Y: d = 0.2 m	X: d = 0.0 m Y: d = 0.4 m	X: d = 0.2 m Y: d = 0.4 m
T	6.41 $\bar{Z} = 2.34$ $\mu_z = 0$ $n = 21$ $s = \sigma_z = 1.671$	11.90 $\bar{Z} = 4.33$ $\mu_z = 0$ $n = 21$ $s = \sigma_z = 1.667$	7.09 $\bar{Z} = 1.99$ $\mu_z = 0$ $n = 21$ $s = \sigma_z = 1.289$
p	$3.00 * 10^{-6}$	$1.58 * 10^{-10}$	$7.21 * 10^{-7}$

Table G.16: Test statistic and probability.

- 3.A) The p-value ($p = 3.00 * 10^{-6}$), see table G.16, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a relationship between walking through water depths of 0.0 and 0.2 meter at basin 3.

- 3.B) The p-value ($p = 1.58 * 10^{-10}$), see table G.16, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a relationship between walking through water depths of 0.0 and 0.4 meter at basin 3.

- 3.C) The p-value ($p = 7.21 * 10^{-7}$), see table G.16, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a relationship between walking through water depths of 0.2 and 0.4 meter at basin 3.

V) Relation

Relation between walking through water depths of d = 0.0, d = 0.2 and d = 0.4 meter at basin 3			
	3.A	**3.B**	**3.C**
Reduction	33% $\frac{\sum \frac{\lvert\text{Round 1} - \text{Round 2}\rvert}{\text{Round 2}}}{n} * 100\%$	49% $\frac{\sum \frac{\lvert\text{Round 1} - \text{Mean round 3\&5}\rvert}{\text{Mean round 3\&5}}}{n} * 100\%$	24% $\frac{\sum \frac{\lvert\text{Round 2} - \text{Mean round 3\&5}\rvert}{\text{Mean round 3\&5}}}{n} * 100\%$
Factor	$\frac{\sum \frac{\text{Round 2}}{\text{Round 1}}}{n} = 1.55$	$\frac{\sum \frac{\text{Mean round 3\&5}}{\text{Round 1}}}{n} = 2.08$	$\frac{\sum \frac{\text{Mean round 3\&5}}{\text{Round 2}}}{n} = 1.36$

Table G.17: Relation between rounds and factor.

- 3.A) The reduction in speed in case of d = 0.2 m, compared to 0.0 m, is approximately 33%.
  - Least squares linear regression: $\text{Time}_{d=0.2\text{ m}} \approx 1.50\ \text{Time}_{d=0.0\text{ m}} + 0.21$
  - Least squares intercept free linear regression: $\text{Time}_{d=0.2\text{ m}} \approx 1.55\ \text{Time}_{d=0.0\text{ m}}$
  - Mean slope linear relation: $\text{Time}_{d=0.2\text{ m}} \approx 1.55\ \text{Time}_{d=0.0\text{ m}}$

- 3.B) The reduction in speed in case of d = 0.4 m, compared to 0.0 m, is approximately 49%.
  - Least squares linear regression: $\text{Time}_{d=0.4\text{ m}} \approx 1.22\ \text{Time}_{d=0.0\text{ m}} + 3.37$
  - Least squares intercept free linear regression: $\text{Time}_{d=0.4\text{ m}} \approx 1.97\ \text{Time}_{d=0.0\text{ m}}$
  - Mean slope linear relation: $\text{Time}_{d=0.4\text{ m}} \approx 2.08\ \text{Time}_{d=0.0\text{ m}}$

- 3.C) The reduction in speed in case of d = 0.4 m, compared to 0.2 m, is approximately 24%.
  - Least squares linear regression: $\text{Time}_{d=0.4\text{ m}} \approx 0.78\ \text{Time}_{d=0.2\text{ m}} + 3.45$
  - Least squares intercept free linear regression: $\text{Time}_{d=0.4\text{ m}} \approx 1.25\ \text{Time}_{d=0.2\text{ m}}$
  - Mean slope linear relation: $\text{Time}_{d=0.4\text{ m}} \approx 1.36\ \text{Time}_{d=0.2\text{ m}}$

VI) Graphs

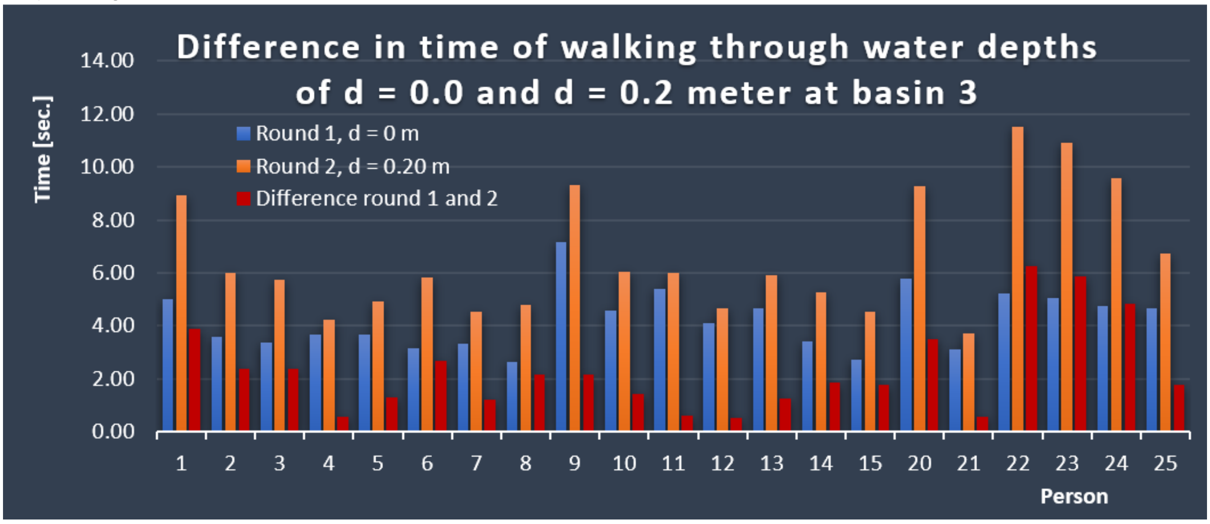


Figure G.9: Difference between round 1 and round 2 at basin 3.

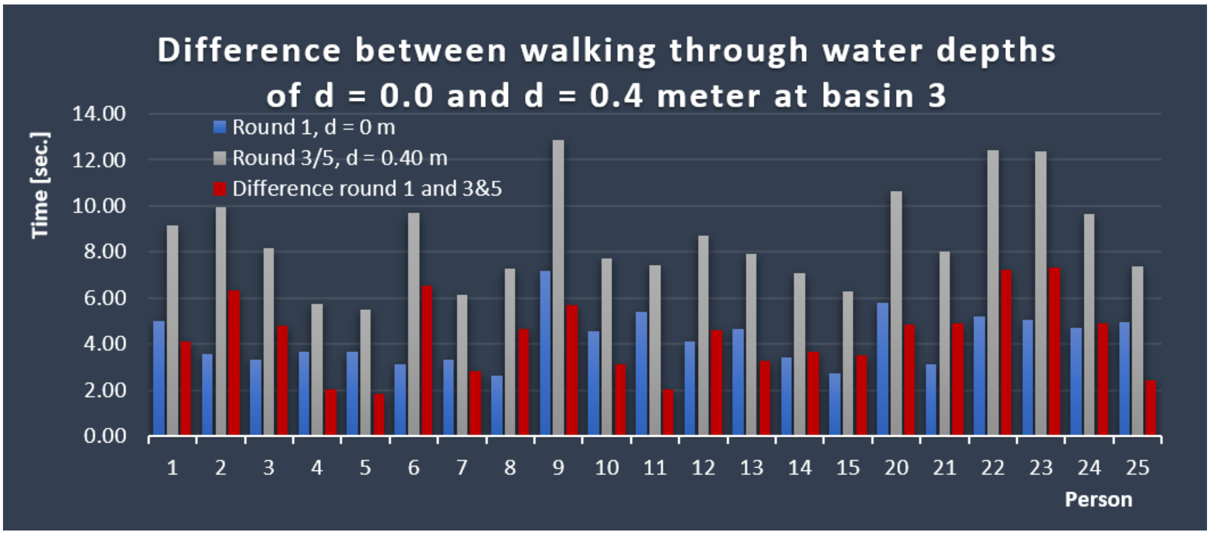


Figure G.10: Difference between round 1 and the mean of round 3&5 at basin 3.

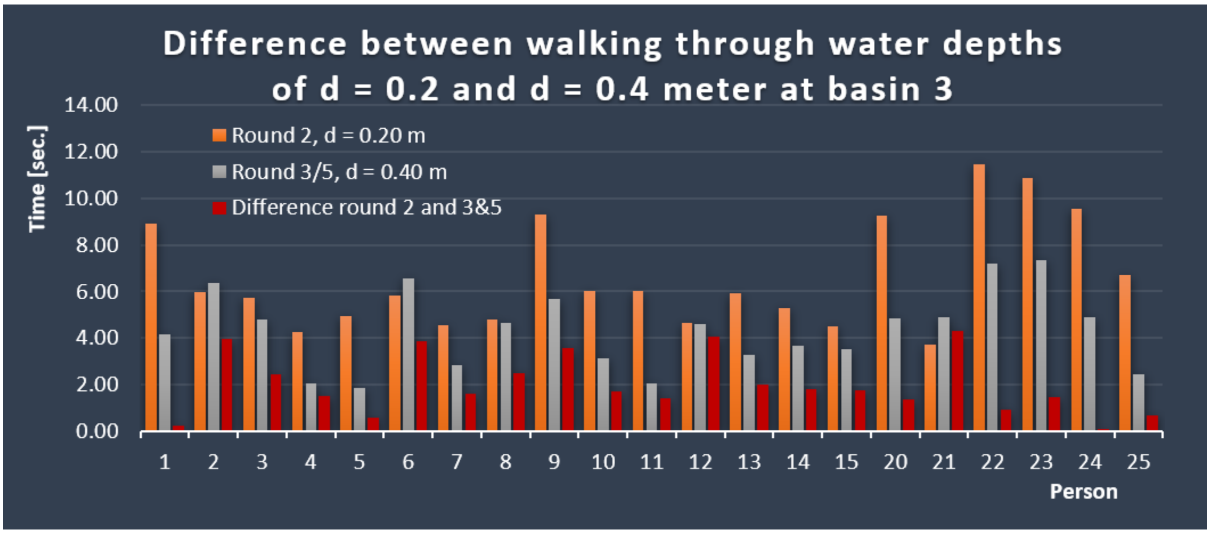


Figure G.11: Difference between round 2 and the mean of round 3&5 at basin 3.

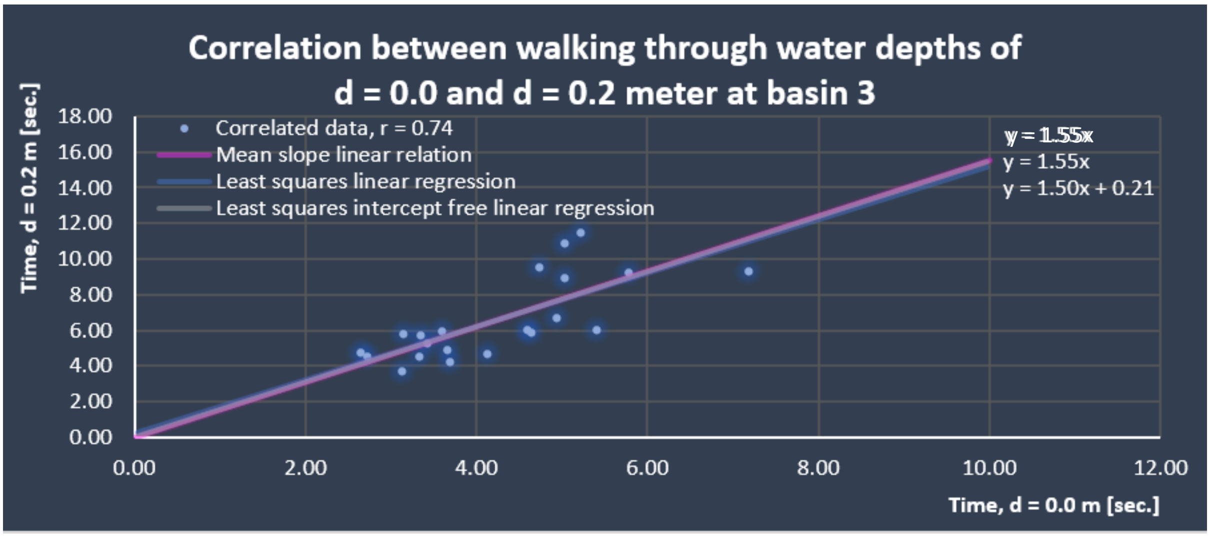


Figure G.12: Correlation between round 1 and round 2 at basin 3.

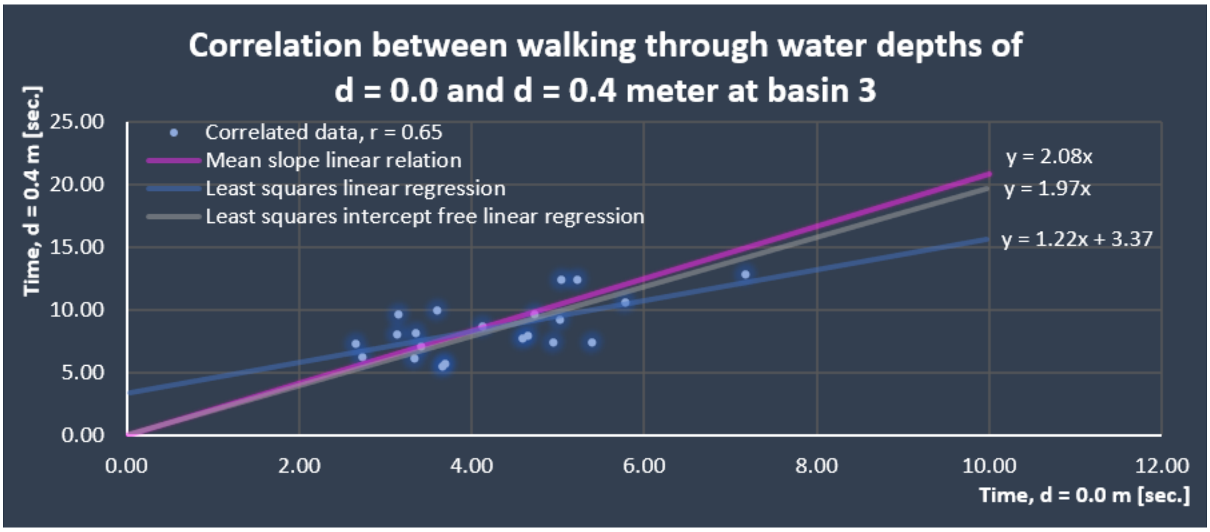


Figure G.13: Correlation between round 1 and round 3 at basin 3.

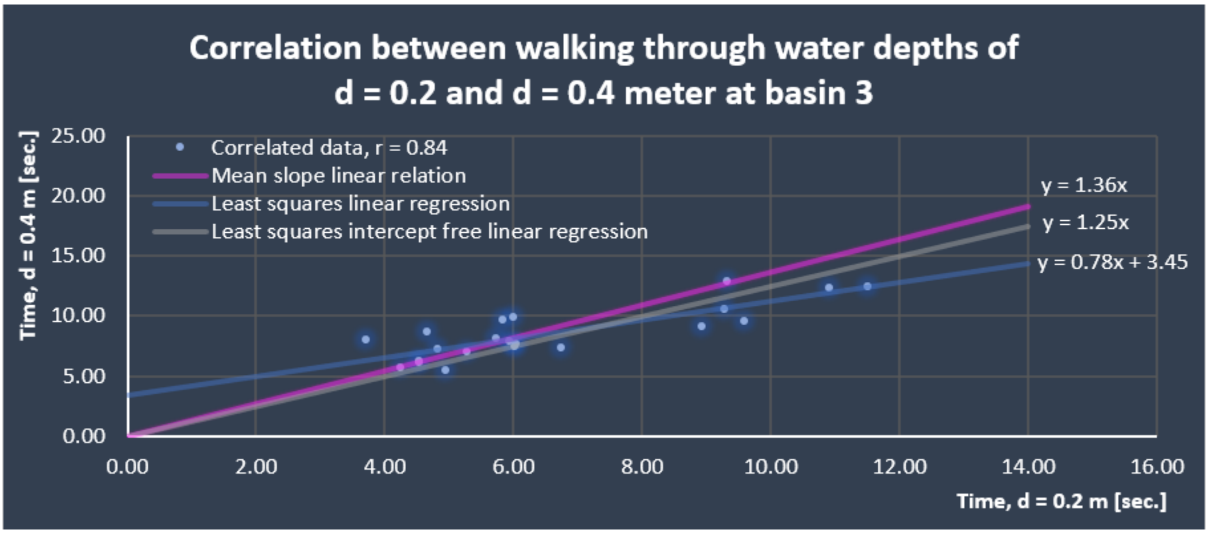


Figure G.14: Correlation between round 2 and round 3 at basin 3.

G.4. Overview of walking through different water depths

Basin		Round	Water depth	Correlation (Pearson T-test)			Difference (T-test)		Relation
				r_{XY}	T	p	T	p	
1)	A	1 and mean of 2&3	0.0 m 0.2 m	0.80	5.77	$1.46 * 10^{-5}$	7.88	$1.46 * 10^{-7}$	$t_{d=0.2\ m} \approx 1.58\ t_{d=0.0\ m}$
2)	A	1 and 2	0.0 m 0.4 m	0.45	2.21	0.03969	9.73	$4.99 * 10^{-9}$	$t_{d=0.4\ m} \approx 1.93\ t_{d=0.0\ m}$
	B	1 and 3	0.0 m 0.6 m	0.45	2.21	0.03946	17.20	$1.89 * 10^{-13}$	$t_{d=0.6\ m} \approx 2.20\ t_{d=0.0\ m}$
	C	2 and 3	0.4 m 0.6 m	0.78	5.46	$2.85 * 10^{-5}$	4.36	$3.03 * 10^{-4}$	$t_{d=0.6\ m} \approx 1.12\ t_{d=0.4\ m}$
3)	A	1 and 2	0.0 m 0.2 m	0.74	4.76	$1.36 * 10^{-4}$	6.41	$3.00 * 10^{-6}$	$t_{d=0.2\ m} \approx 1.55\ t_{d=0.0\ m}$
	B	1 and mean of 3&5	0.0 m 0.4 m	0.65	3.71	0.00149	11.90	$1.58 * 10^{-10}$	$t_{d=0.4\ m} \approx 1.97\ t_{d=0.0\ m}$
	C	2 and mean of 3&5	0.2 m 0.4 m	0.84	6.68	$2.18 * 10^{-6}$	7.09	$7.21 * 10^{-7}$	$t_{d=0.4\ m} \approx 1.25\ t_{d=0.2\ m}$

Table G.18: Overview results.

Correlation

- r_{XY} = correlation coefficient. A large value for r_{XY} gives a low probability p and a strong linear correlation.
- T = test statistic. A large value for T gives a low probability p.
- p = probability of finding no correlation between variable X and Y ($r_{XY} = 0$). If there is no correlation, variable X does not increase when variable Y increases and vice versa.

Difference

- T = test statistic. A large value for T gives a low probability p.
- p = probability of finding a zero-mean difference between variable X and Y ($\mu_z = 0$). If the mean difference is zero, variable X and Y are equal and there is no difference the time measurements.

Relation

The relation of the least squares intersect free linear regression method is displayed in this table as this seems to be the most accurate method.

H. Experiment: walking – Influence of debris

- **What is the influence of debris on the fleeing speed?**

Overview

Table H.1 gives an overview of which rounds with corresponding water depths will be compared to each other. Each basin has its own paragraph with the following structure: Data (I), Variables (II), Correlation (III), Difference (IV), Relation (V), and Graphs (VI).

		Round	Water depth
1.A)	**Basin 1 – Floating debris**	1 and 5	0.0 m and 0.2 m
1.B)		Mean of 2&3 and 5	0.2 m and 0.2 m
2.A)	**Basin 2 – Submerged debris**	1 and 5	0.0 m and 0.6 m
2.B)		3 and 5	0.6 m and 0.6 m

Table H.1: Overview.

Number of samples: $n = 21$
Degrees of freedom (2-tailed): $df = 19$

Correlation

Hypothesis: $H_0: r_{XY} = 0$
$H_1: r_{XY} \neq 0$

Formula: $$r_{XY} = \frac{n(\sum XY)-(\sum X)(\sum Y)}{\sqrt{n(\sum X^2)-(\sum X)^2}\sqrt{n(\sum Y^2)-(\sum Y)^2}}$$

$$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1-r_{XY}^2}} \text{ with } df = n - 2$$

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
19	0.369	0.433	0.549

Table H.2: Table of critical values for the correlation coefficient with n = 21.

See table H.2, for $df = 19$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.433 \leq r_{XY} \leq 0.433$ and 5% probability of finding a correlation outside this range.

Difference

Hypothesis: $H_0: \mu_z = 0$
$H_1: \mu_z \neq 0$

Formula: $$T = \frac{\overline{Z}-\mu_z}{S}\sqrt{n}$$

Table of critical values for test statistic T										
df	**α**									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
19	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883

Table H.3: Table of critical values for test statistic T with n = 21.

See table H.3, for $\mathrm{df} = 19$ with critical value $\alpha = 0.05$, the null hypothesis of $\mu_z = 0$ is rejected with a certainty of more than 95% if the p-value from the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

H.1. Basin 1: Walking through floating debris with water depth 0.0 and 0.2 meter

I) Data

Time measurements of walking through basin 1			
Person	**Time round 1 [sec.]**	**Time mean round 2&3 [sec.]**	**Time round 5 [sec.]**
1	6.92	12.63	15.22
2	5.17	12.22	15.48
3	4.76	9.95	10.55
4	5.68	6.30	9.51
5	4.70	5.87	14.63
6	5.74	11.47	20.28
7	4.44	5.87	19.46
8	4.14	8.47	13.97
9	11.10	17.93	27.62
10	7.00	9.01	12.43
11	8.39	9.35	13.16
12	6.08	8.22	8.59
13	6.93	8.66	10.02
14	5.34	7.90	9.96
15	4.27	7.93	8.07
20	7.72	10.44	13.11
21	3.27	6.12	9.47
22	9.17	16.84	17.41
23	8.56	14.87	19.52
24	6.82	12.34	12.47
25	8.11	11.98	14.92

Table H.4: Time measurements in seconds of round 1, the mean of round 2&3 and round 5 at basin 1. Persons 16 – 19 are not considered as this experiment took place in the dark.

II) Variables

Variables of walking through basin 1		
	1.A	**1.B**
X	Time round 1, d = 0.0 m [sec.]	Time mean round 2&3, d = 0.2 m [sec.]
Y	Time round 5, d = 0.2 m [sec.]	Time round 5, d = 0.2 m [sec.]

Table H.5: Variables X and Y.

III) Correlation

Correlation of walking through different water depths at basin 1		
	1.A	**1.B**
	X: d = 0.0 Y: d = 0.2, with floating debris	X: d = 0.2 Y: d = 0.2, with floating debris
r_{XY}	0.56 $\sum X = 134.28$ $\sum X^2 = 935.25$ $\sum Y = 295.81$ $\sum Y^2 = 4623.98$ $\sum XY = 1996.53$ $n = 21$	0.66 $\sum X = 214.34$ $\sum X^2 = 2424.02$ $\sum Y = 295.81$ $\sum Y^2 = 4623.98$ $\sum XY = 3237.78$ $n = 21$
T	2.96	3.88
p	0.00810	0.00101

Table H.6: Correlation between time measurements from round 1, the mean of round 2&3 and round 5 at basin 1. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

- 1.A) From table H.6 the $r_{XY} \approx 0.56 > 0.433$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a moderate positive correlation that is significant between walking through a water depth of 0.0 m without floating debris and 0.2 m with floating debris at basin 1.

- 1.B) From table H.6 the $r_{XY} \approx 0.66 > 0.433$. The null hypothesis $r_{XY} = 0$ is rejected and the conclusion is that there is a moderate positive correlation that is significant between walking through a water depth of 0.2 m without floating debris and 0.2 m with floating debris at basin 1.

IV) Difference

Test statistic and probability of the comparison of walking through water depths of d = 0.0 and d = 0.2 meter at basin 1		
	1.A	**1.B**
	X: d = 0.0 Y: d = 0.2, with floating debris	X: d = 0.2 Y: d = 0.2, with floating debris
T	8.76 $\bar{Z} = 7.69$ $\mu_z = 0$ $n = 21$ $s = \sigma_z = 4.023$	4.97 $\bar{Z} = 3.88$ $\mu_z = 0$ $n = 21$ $s = \sigma_z = 3.580$
p	$2.77 * 10^{-8}$	$7.43 * 10^{-5}$

Table H.7: Test statistic and probability.

- 1.A) The p-value ($p = 2.77 * 10^{-8}$), see table H.7, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking with a water depth of 0.0 m without floating debris and 0.2 m with floating debris at basin 1.

- 1.B) The p-value ($p = 7.43 * 10^{-5}$), see table H.7, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking with a water depth of 0.4 m without floating debris and 0.2 m with floating debris at basin 1.

V) Relation

Relation between walking through water depths of d = 0.0 and d = 0.2 meter with and without floating debris at basin 1		
	1.A	**1.B**
Reduction	52% $\frac{\sum \frac{\lvert \text{round 1} - \text{round 5} \rvert}{\text{round 5}}}{n} * 100\%$	25% $\frac{\sum \frac{\lvert \text{round 2\&3} - \text{round 5} \rvert}{\text{round 5}}}{n} * 100\%$
Factor	$\frac{\sum \frac{\text{round 5}}{\text{round 1}}}{n} = 2.30$	$\frac{\sum \frac{\text{round 5}}{\text{mean round 2\&3}}}{n} = 1.45$

Table H.8: Relation between rounds and factor.

- 1.A) The reduction in speed in case of d = 0.2 m with floating debris, compared to 0.0 m without debris, is approximately 52%.

Least squares linear regression: $\text{Time}_{d=0.2\ m;\text{floating debris}} \approx 1.37\ \text{Time}_{d=0.0\ m} + 5.32$
Least squares intercept free linear regression: $\text{Time}_{d=0.2\ m;\text{floating debris}} \approx 2.13\ \text{Time}_{d=0.0\ m}$
Mean slope linear relation: $\text{Time}_{d=0.2\ m;\text{floating debris}} \approx 2.30\ \text{Time}_{d=0.0\ m}$

- 1.B) The reduction in speed in case of d = 0.2 m with floating debris, compared to 0.2 m without debris, is approximately 25%.

Least squares linear regression: $\text{Time}_{d=0.2\ m;\text{floating debris}} \approx 0.92\ \text{Time}_{d=0.2\ m} + 4.65$
Least squares intercept free linear regression: $\text{Time}_{d=0.2\ m;\text{floating debris}} \approx 1.34\ \text{Time}_{d=0.2\ m}$
Mean slope linear relation: $\text{Time}_{d=0.2\ m;\text{floating debris}} \approx 1.45\ \text{Time}_{d=0.2\ m}$

VI) Graphs

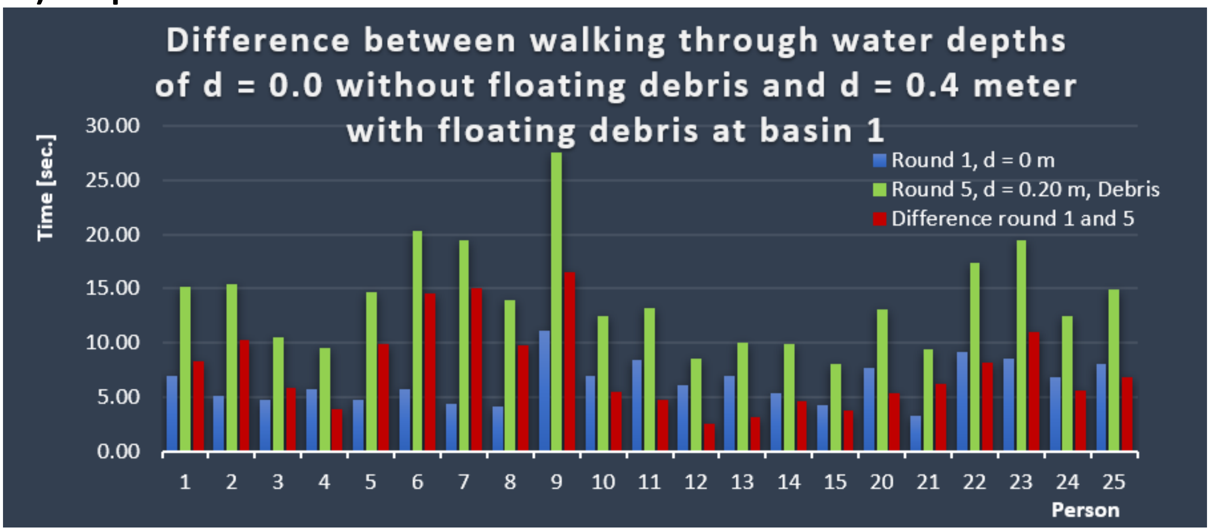


Figure H.1: Difference between round 1 and round 5 at basin 1.

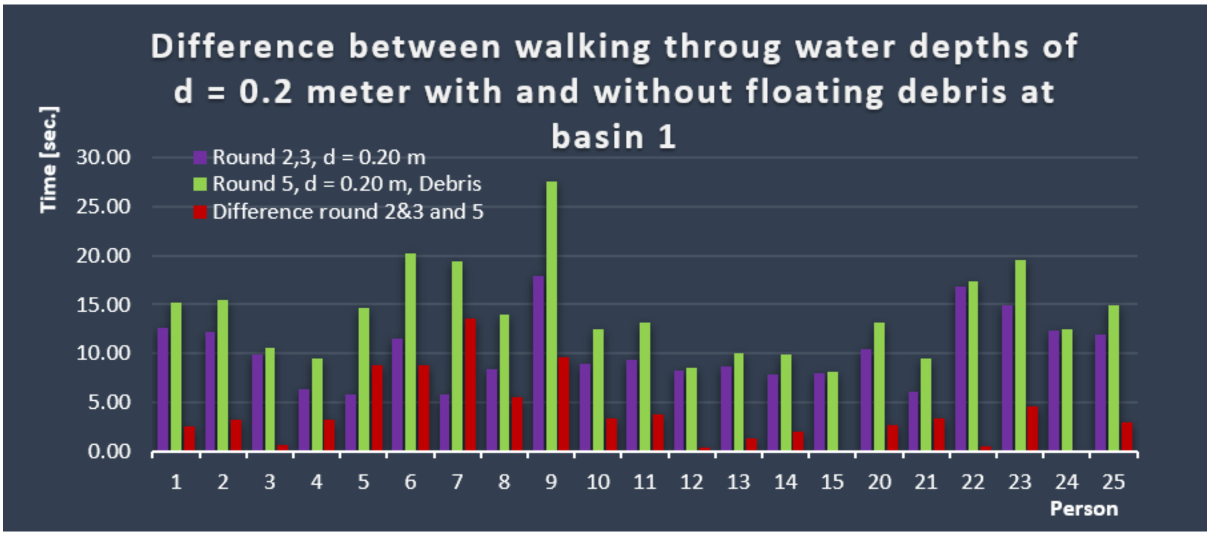


Figure H.2: Difference between the mean of round 2&3 and round 5 at basin 1.

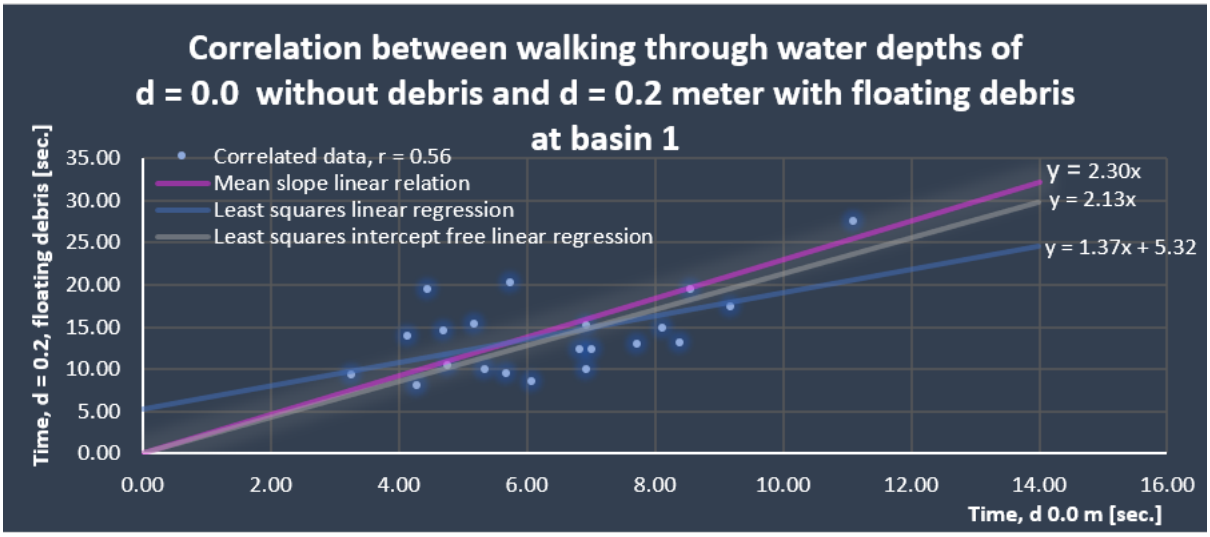


Figure H.3: Correlation between round 1 and round 5 at basin 1.

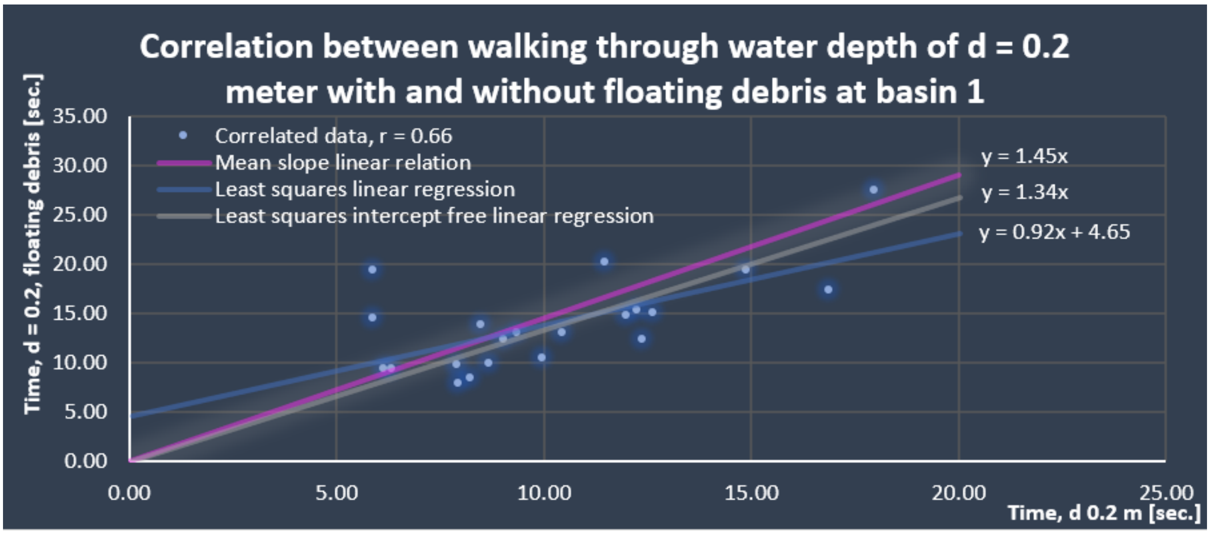


Figure H.4: Correlation between the mean of round 2&3 and round 5 at basin 1.

H.2. Basin 2: Walking through submerged debris with a water depth of 0.6 meter

I) Data

Time measurements of walking through basin 2			
Person	**Time round 1 [sec.]**	**Time round 3 [sec.]**	**Time round 5 [sec.]**
1	4.64	10.61	12.79
2	3.38	11.43	13.93
3	3.27	8.71	11.98
4	4.23	6.89	9.88
5	3.19	6.45	13.36
6	3.92	9.94	14.88
7	3.35	9.46	16.34
8	3.12	7.99	14.86
9	5.19	11.02	18.83
10	4.95	8.62	13.77
11	5.27	8.66	14.18
12	4.12	8.74	15.24
13	4.30	9.17	12.17
14	3.90	7.32	9.74
15	2.51	7.25	8.87
20	5.22	10.42	16.96
21	3.48	7.81	11.68
22	4.31	11.14	18.80
23	4.48	10.82	18.93
24	4.25	10.81	17.30
25	4.65	9.51	13.34

Table H.9: Time measurements in seconds of round 1, round 3 and round 5 at basin 2. Persons 16 – 19 are not considered as this experiment took place in the dark.

II) Variables

Variables of walking through basin 2		
	2.A	**2.B**
X	Time round 1, d = 0.0 m [sec.]	Time round 3, d = 0.6 m [sec.]
Y	Time round 5, d = 0.6 m [sec.]	Time round 5, d = 0.6 m [sec.]

Table H.10: Variables X and Y.

III) Correlation

Correlation between walking through different water depths with and without submerged debris at basin 2		
	2.A	**2.B**
	X: d = 0.0 Y: d = 0.6, with submerged debris	X: d = 0.6 Y: d = 0.6, with submerged debris
r_{XY}	0.44 $\sum X = 85.70$ $\sum X^2 = 361.69$ $\sum Y = 297.77$ $\sum Y^2 = 4397.04$ $\sum XY = 1235.38$ $n = 21$	0.74 $\sum X = 192.70$ $\sum X^2 = 1814.43$ $\sum Y = 297.77$ $\sum Y^2 = 4397.04$ $\sum XY = 2798.74$ $n = 21$
T	2.15	4.77
p	0.04498	0.00013

Table H.11: Correlation between time measurements from round 1, round 3 and round 5 at basin 2. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

- 2.A) From table H.11 the $r_{XY} \approx 0.44 > 0.433$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a weak positive linear correlation that is significant between walking through a water depth of 0.0 m without submerged debris and 0.6 m with submerged debris at basin 2.

- 2.B) From table H.11 the $r_{XY} \approx 0.74 > 0.433$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a strong positive linear correlation that is significant between walking through water depth of 0.6 with and without submerged debris at basin 2.

IV) Difference

Test statistic and probability of the comparison of walking through water depths of d = 0.0 and d = 0.6 meter with and without submerged debris at basin 2		
	2.A	**2.B**
	X: d = 0.0 Y: d = 0.6, with submerged debris	X: d = 0.6 Y: d = 0.6, with submerged debris
T	17.11 $\overline{Z} = 10.10$ $\mu_z = 0$ $n = 21$ $s = \sigma_z = 2.705$	10.91 $\overline{Z} = 5.00$ $\mu_z = 0$ $n = 21$ $s = \sigma_z = 2.101$
p	$2.085 * 10^{-13}$	$7.146 * 10^{-10}$

Table H.12: Test statistic and probability.

- 2.A) The p-value ($p = 2.085 * 10^{-13}$), see table H.12, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking through water depths of 0.0 m without submerged debris and 0.6 m with submerged debris at basin 2.

- 2.B) The p-value ($p = 7.146 * 10^{-10}$), see table H.12, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking through water depth of 0.6 m with and without submerged debris at basin 2.

V) Relation

Relation between walking through water depths of d = 0.0 and d = 0.6 meter with and without submerged debris at basin 2		
	2.A	**2.B**
Reduction	70% $\frac{\sum \frac{\lvert \text{round 1} - \text{round 5} \rvert}{\text{round 5}}}{n} * 100\%$	34% $\frac{\sum \frac{\lvert \text{round 3} - \text{round 5} \rvert}{\text{round 5}}}{n} * 100\%$
Factor	$\frac{\sum \frac{\text{round 5}}{\text{round 1}}}{n} = 3.54$	$\frac{\sum \frac{\text{round 5}}{\text{round 3}}}{n} = 1.55$

Table H.13: Relation between rounds and factor.

- 2.A) The reduction in speed in case of d = 0.6 m with submerged debris, compared to 0.0 m without debris, is approximately 70%.

  Least squares linear regression: $\text{Time}_{d=0.6\text{ m;submerged debris}} \approx 1.69\ \text{Time}_{d=0.0\text{ m}} + 7.29$
  Least squares intercept free linear regression: $\text{Time}_{d=0.6\text{ m;submerged debris}} \approx 3.42\ \text{Time}_{d=0.0\text{ m}}$
  Mean slope linear relation: $\text{Time}_{d=0.6\text{ m;submerged debris}} \approx 3.54\ \text{Time}_{d=0.0\text{ m}}$

- 2.B) The reduction in speed in case of d = 0.6 m with submerged debris, compared to 0.6 m without debris, is approximately 34%.

  Least squares linear regression: $\text{Time}_{d=0.6\text{ m;submerged debris}} \approx 0.92\ \text{Time}_{d=0.6\text{ m}} + 4.65$
  Least squares intercept free linear regression: $\text{Time}_{d=0.6\text{ m;submerged debris}} \approx 1.54\ \text{Time}_{d=0.6\text{ m}}$
  Mean slope linear relation: $\text{Time}_{d=0.6\text{ m;submerged debris}} \approx 1.55\ \text{Time}_{d=0.6\text{ m}}$

VI) Graphs

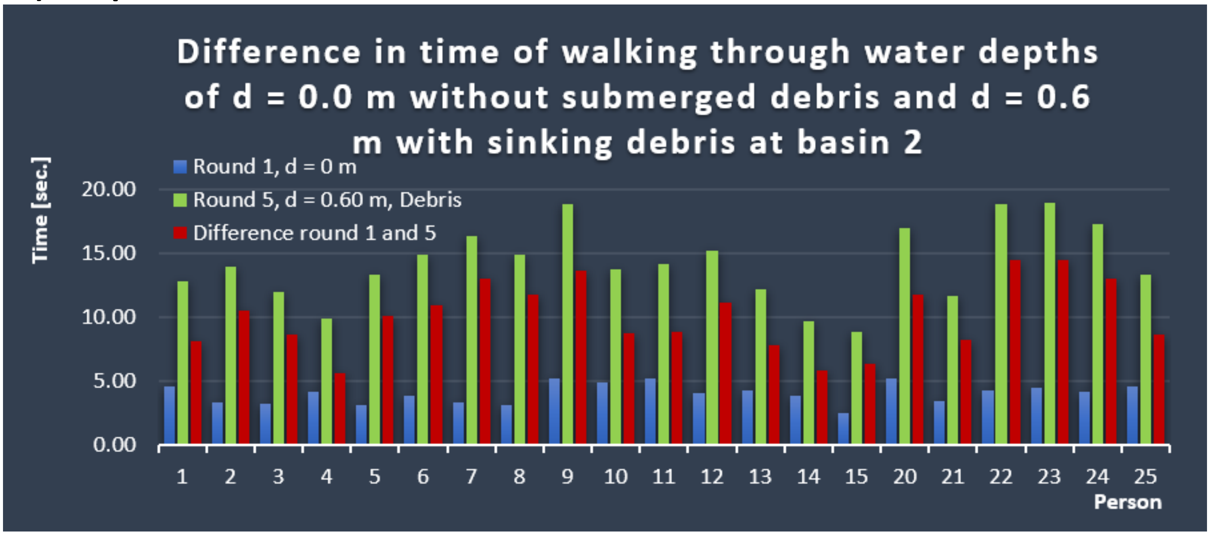


Figure H.5: Difference between round 1 and round 5 at basin 2.

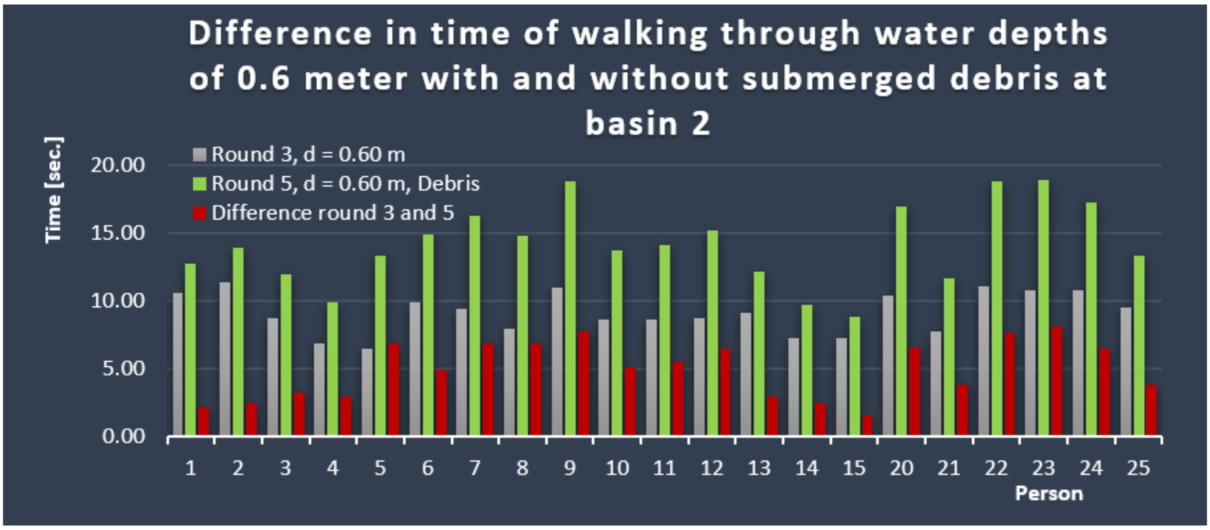


Figure H.6: Difference between round 3 and round 5 at basin 2.

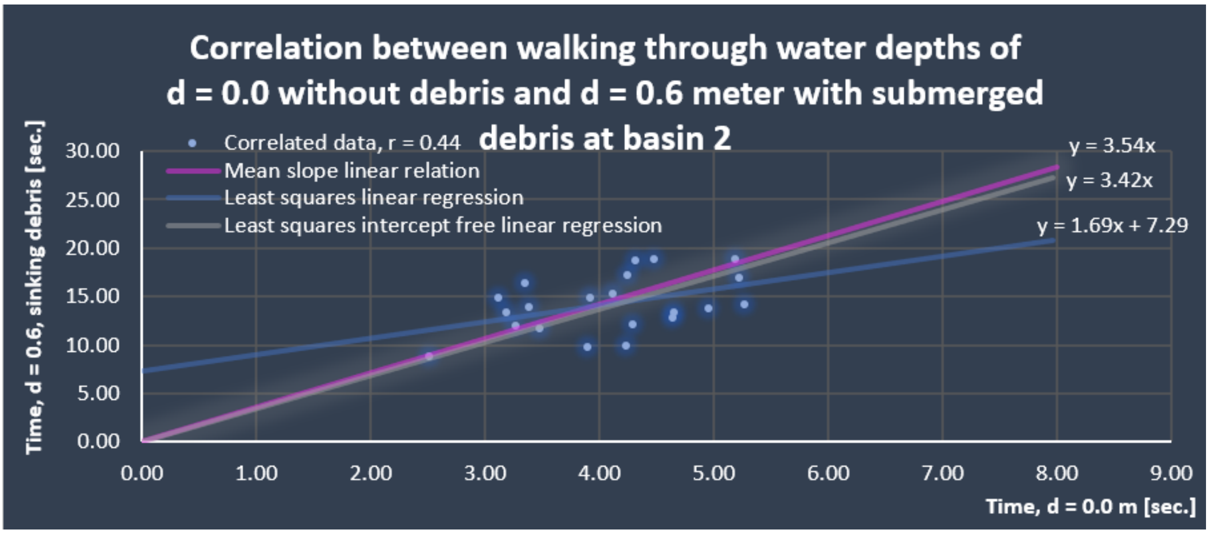


Figure H.7: Correlation between round 1 and round 5 at basin 2.

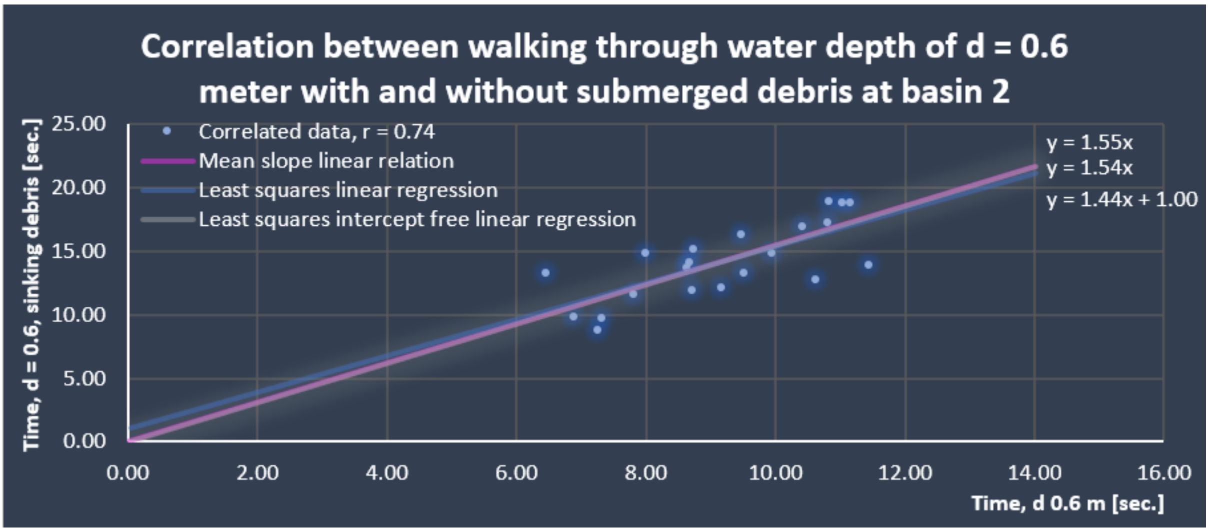


Figure H.8: Correlation between round 3 and round 5 at basin 2.

H.3. Overview of walking through debris

Basin		Round	Water depth	Correlation (Pearson T-test)			Difference (T-test)		Relation
				r_{XY}	T	p	T	p	
1)	A	1 and 5	0.0 m 0.2 m	0.56	2.96	0.00810	8.76	$2.77 * 10^{-8}$	$t_{d=0.2\ m;\ floating\ debris} \approx 2.13\ t_{d=0.0\ m}$
	B	Mean of 2&3 and 5	0.2 m 0.2 m	0.66	3.88	0.00101	4.97	$7.43 * 10^{-5}$	$t_{d=0.2\ m;\ floating\ debris} \approx 1.34\ t_{d=0.2\ m}$
2)	A	1 and 5	0.0 m 0.6 m	0.44	2.15	0.04498	17.11	$2.09 * 10^{-13}$	$t_{d=0.6\ m;\ submerged\ debris} \approx 3.42\ t_{d=0.0\ m}$
	B	3 and 5	0.6 m 0.6 m	0.74	4.77	0.00013	10.91	$7.15 * 10^{-10}$	$t_{d=0.6\ m;\ submerged\ debris} \approx 1.54\ t_{d=0.6\ m}$

Table H.14: Overview results.

Correlation
- r_{XY} = correlation coefficient. A large value for r_{XY} gives a low probability p and a strong linear correlation.
- T = test statistic. A large value for T gives a low probability p.
- p = probability of finding no correlation between variable X and Y ($r_{XY} = 0$). If there is no correlation, variable X does not increase when variable Y increases and vice versa.

Difference
- T = test statistic. A large value for T gives a low probability p.
- p = probability of finding a zero-mean difference between variable X and Y ($\mu_z = 0$). If the mean difference is zero, variable X and Y are equal and there is no difference the time measurements.

Relation
The relation of the least squares intersect free linear regression method is displayed in this table as this seems to be the most accurate method.

I. Experiment: walking – Influence of air mattress

- **What is the influence of different means of transport such as walking, bicycling, with floating objects, by car or navigating with a boat on the fleeing speed?**

In this appendix, the part of walking with a floating object is considered to see what the influence is on the fleeing speed. As floating object an air mattress is used during the experiment and the participants showed that there are several ways to bring the air mattress with them, namely;

- Dragging the air mattress behind or next to the participant as a kind of boat on the water
- Carrying the air mattress on the head of the participant
- Carrying the air mattress under one arm of the participant

Overview

Table I.1 gives an overview of which rounds will be compared to each other. Each basin has its own paragraph with the following structure: Data (I), Variables (II), Correlation (III), Difference (IV), Relation (V).

Basin	Round	Water depth
1	Mean of 2&3 and 4	0.2 m and 0.2 m
2	3 and 4	0.6 m and 0.6 m
3	Mean of 3&5 and 4	0.4 m and 0.4 m

Table I.1: Overview.

Number of samples: n = 6
Degrees of freedom (2-tailed): df = 4

Correlation

Hypothesis: $H_0: r_{XY} = 0$
$H_1: r_{XY} \neq 0$

Formula:
$$r_{XY} = \frac{n(\sum XY)-(\sum X)(\sum Y)}{\sqrt{n(\sum X^2)-(\sum X)^2}\sqrt{n(\sum Y^2)-(\sum Y)^2}}$$
$$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1-r_{XY}^2}} \text{ with } df = n - 2$$

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
4	0.729	0.811	0.917

Table I.2: Table of critical values for the correlation coefficient with n = 6.

See table I.2, for $df = 4$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.811 \leq r_{XY} \leq 0.811$ and 5% probability of finding a correlation outside this range.

Difference

Hypothesis: $H_0: \mu_z = 0$

$H_1: \mu_z \neq 0$

Formula: $T = \frac{\bar{Z}-\mu_z}{S}\sqrt{n}$

Table of critical values for test statistic T										
df	**α**									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
4	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610

Table I.3: Table of critical values for test statistic T with n = 6.

See table I.3, for $df = 4$ with critical value $\alpha = 0.05$, the null hypothesis ($\mu_z = 0$) is rejected with a certainty of more than 95% if the p-value from the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

I.1. Basin 1: Walking through water depths of 0.0 and 0.2 meter with and without an air mattress

I) Data

Time measurements of walking with and without an air mattress through basin 1		
Person	**Time mean round 2&3 [sec.]**	**Time round 4 [sec.]**
5	5.87	9.75
8	8.47	7.86
11	9.35	12.76
13	8.66	8.85
22	16.84	16.93
24	12.34	12.12

Table I.4: Time measurements in seconds of the mean of round 2&3 and round 4 at basin 1.

II) Variables

Variables of walking with and without an air mattress through basin 1	
X	Time mean round 2&3, d = 0.2 m [sec.]
Y	Time round 4, d = 0.2 m [sec.]

Table I.5: Variables X and Y.

III) Correlation

Correlation of walking through a water depth of 0.2 meter with and without an air mattress at basin 1								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
0.86	61.52	704.33	68.25	830.90	754.07	6	3.32	0.02933

Table I.6: Correlation between time measurements from the mean of round 2&3 and round 4 at basin 1. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

From table I.6 the $r_{XY} \approx 0.86 > 0.811$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a strong positive linear correlation that is significant between walking with and without an air mattress at a water depth of d = 0.2 meter at basin 1.

IV) Difference

Test statistic and probability of the comparison of walking through water depth of 0.2 m with and without an air mattress at basin 1					
T	$\overline{Z}$	μ_Z	n	$s = \sigma_Z$	p
1.39	1.12	0	6	1.978	0.22387

Table I.7: Test statistic and probability.

The p-value ($p = 0.22387$), see table I.7, is higher than the critical value ($\alpha = 0.05$). This means that the null hypothesis is not rejected with a certainty of more than 95%. There is no significant difference in time measurements between walking with and without an air mattress at a water depth of 0.2 meter at basin 1.

V) Relation

There is a strong positive linear correlation that is significant between walking with and without an air mattress at a water depth of d = 0.2 meter at basin 1. However, the difference between the time measurements of walking with and without an air mattress is small.

VI) Graphs

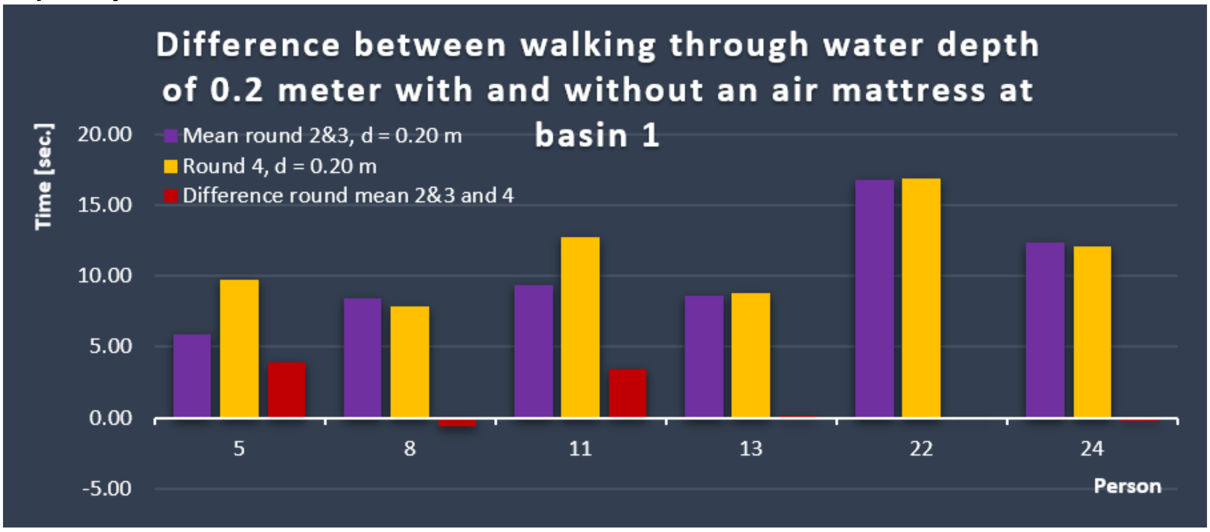


Figure I.1: Difference between the mean of round 2&3 and round 4 at basin 1.

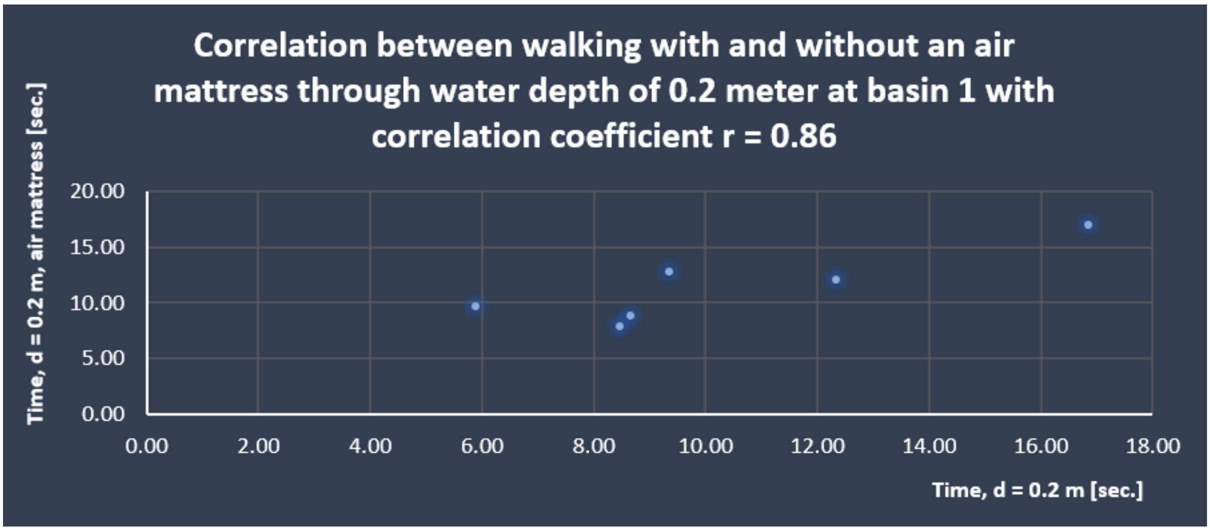


Figure I.2: Correlation between the mean of round 2&3 and round 4 at basin 1.

I.2. Basin 2: Walking through water depths of 0.0 and 0.6 meter with and without an air mattress

I) Data

Time measurements of walking with and without an air mattress through basin 2		
Person	**Time round 3 [sec.]**	**Time round 4 [sec.]**
5	6.45	7.47
8	7.99	7.90
11	8.66	9.15
13	9.17	9.79
22	11.14	11.81
24	10.81	10.64

Table I.8: Time measurements in seconds of round 3 and round 4 at basin 2.

II) Variables

Variables of walking with and without and air mattress through basin 2	
X	Time round 3, d = 0.6 m [sec.]
Y	Time round 4, d = 0.6 m [sec.]

Table I.9: Variables X and Y.

III) Correlation

Correlation of walking through a water depth of 0.6 meter with and without an air mattress at basin 2								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
0.97	54.21	505.20	56.76	550.35	526.70	6	7.43	0.00175

Table I.10: Correlation between time measurements from round 3 and round 4 at basin 2. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

From table I.10 the $r_{XY} \approx 0.97 > 0.811$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a very strong positive linear correlation that is significant between walking with and without an air mattress at a water depth of 0.6 meter at basin 2.

IV) Difference

Test statistic and probability of the comparison of walking through water depth of 0.6 meter with and without an air mattress at basin 2					
T	$\overline{Z}$	μ_z	n	$s = \sigma_z$	p
2.26	0.43	0	6	0.461	0.07366

Table I.11 Test statistic and probability.

The p-value ($p = 0.07366$), see table I.11, is higher than the critical value ($\alpha = 0.05$). This means that the null hypothesis is not rejected with a certainty of more than 95%. There is no significant difference in time measurements between walking with and without an air mattress at a water depth of 0.6 meter at basin 2.

V) Relation

There is a very strong positive linear correlation that is significant between walking with and without an air mattress at a water depth of 0.6 meter at basin 2. However, the difference between the time measurements of walking with and without an air mattress is very small.

VI) Graphs

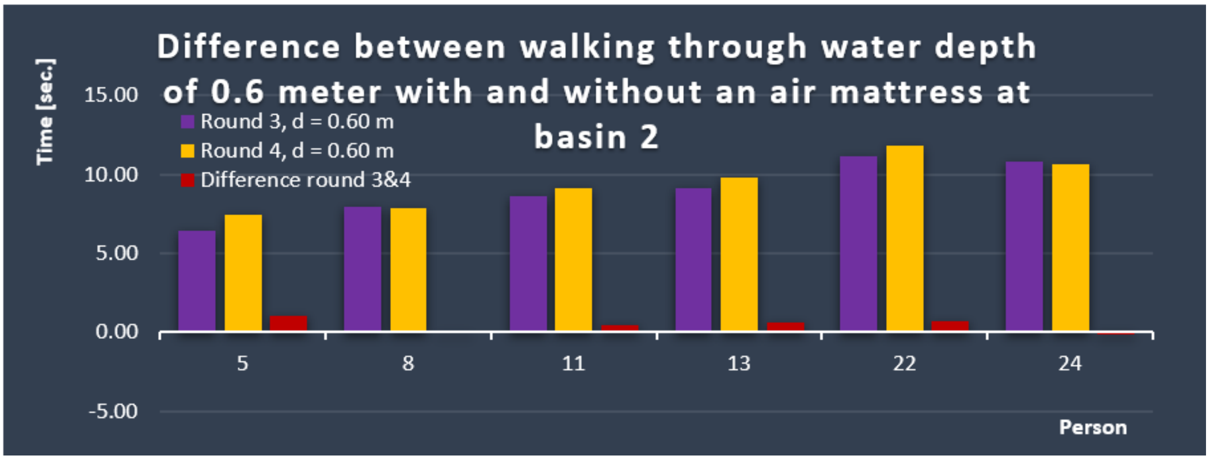


Figure I.3: Difference between round 3 and round 4.

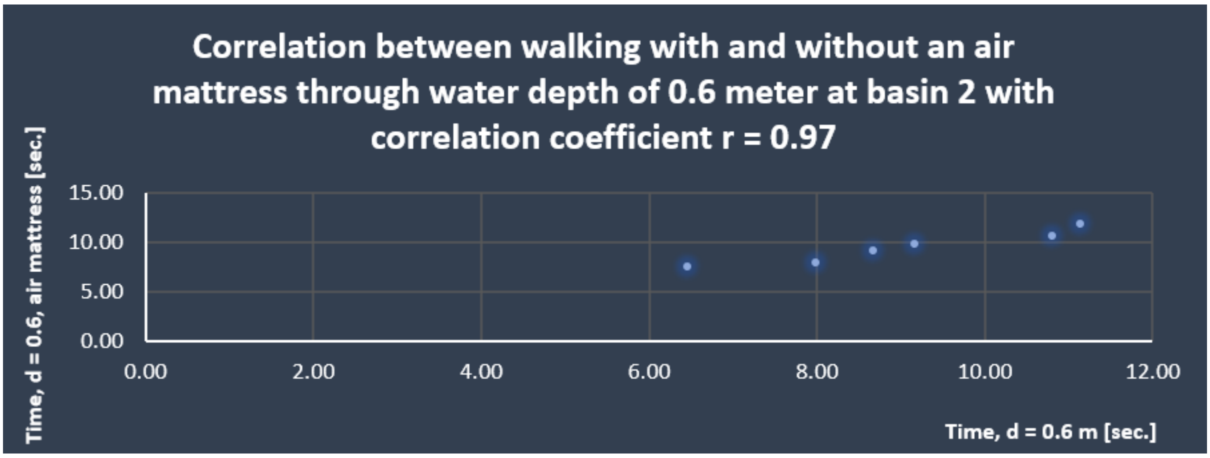


Figure I.4: Correlation between round 3 and round 4.

I.3. Basin 3: Walking through water depths of 0.0 and 0.4 meter with and without an air mattress

I) Data

Time measurements of walking with and without an air mattress through basin 3		
Person	**Time mean round 3&5 [sec.]**	**Time round 4 [sec.]**
5	5.51	8.92
8	7.30	8.58
11	7.45	7.81
13	7.91	8.16
22	12.44	13.22
24	9.65	9.76

Table I.12: Time measurements in seconds of the mean of round 3&5 and round 4 at basin 3.

II) Variables

Variables of walking with and without an air mattress through basin 3	
X	Time mean round 3&5, d = 0.6 m [sec.]
Y	Time round 4, d = 0.6 m [sec.]

Table I.13: Variables X and Y.

III) Correlation

Correlation of walking through a water depth of 0.4 meter with and without an air mattress at basin 3								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
0.86	50.25	449.41	56.45	550.71	493.02	6	3.30	0.02997

Table I.14: Correlation between time measurements from the mean of round 3&5 and round 4 at basin 3. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

From table I.14 the $r_{XY} \approx 0.86 > 0.707$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a strong positive linear correlation that is significant between walking with and without an air mattress at a water depth of 0.4 meter at basin 3.

IV) Difference

Test statistic and probability of the comparison of walking through water depth of 0.4 meter with and without an air mattress at basin 3					
T	$\overline{Z}$	μ_Z	n	$s = \sigma_Z$	p
2.04	1.03	0	6	1.241	0.09706

Table I.15: Test statistic and probability.

The p-value ($p = 0.09706$), see table I.15, is higher than the critical value ($\alpha = 0.05$). This means that the null hypothesis is not rejected with a certainty of more than 95%. There is no significant difference in time measurements between walking with and without an air mattress at a water depth of 0.4 meter at basin 3.

V) Relation

There is a strong positive linear correlation that is significant between walking with and without an air mattress at a water depth of 0.4 meter at basin 3. However, the difference between the time measurements of walking with and without an air mattress is very small.

VI) Graphs

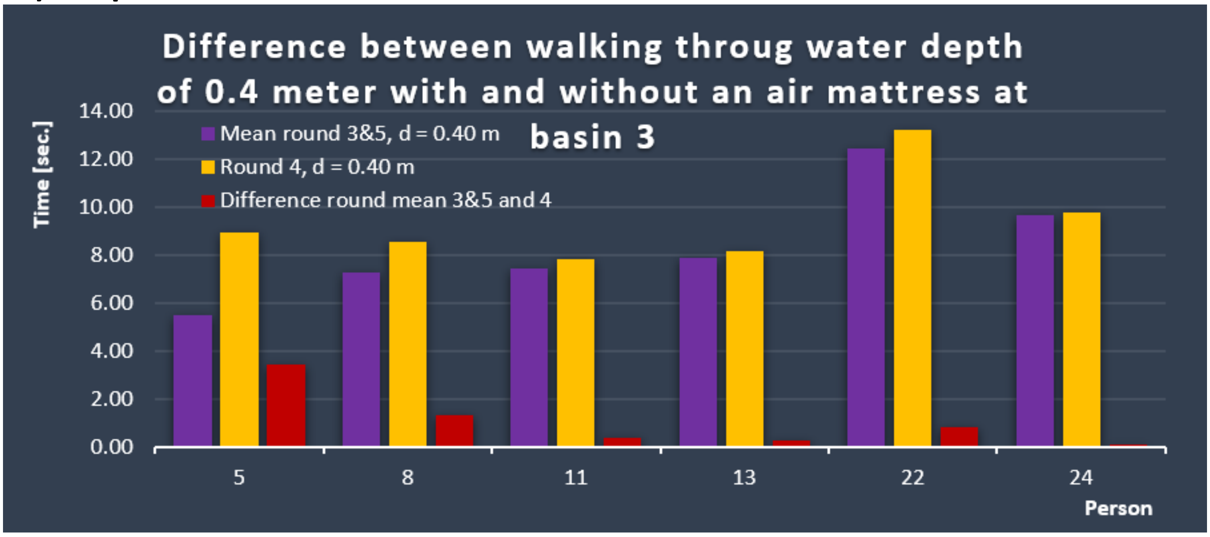


Figure I.5: Difference between the mean of round 3&5 and round 4 at basin 3.

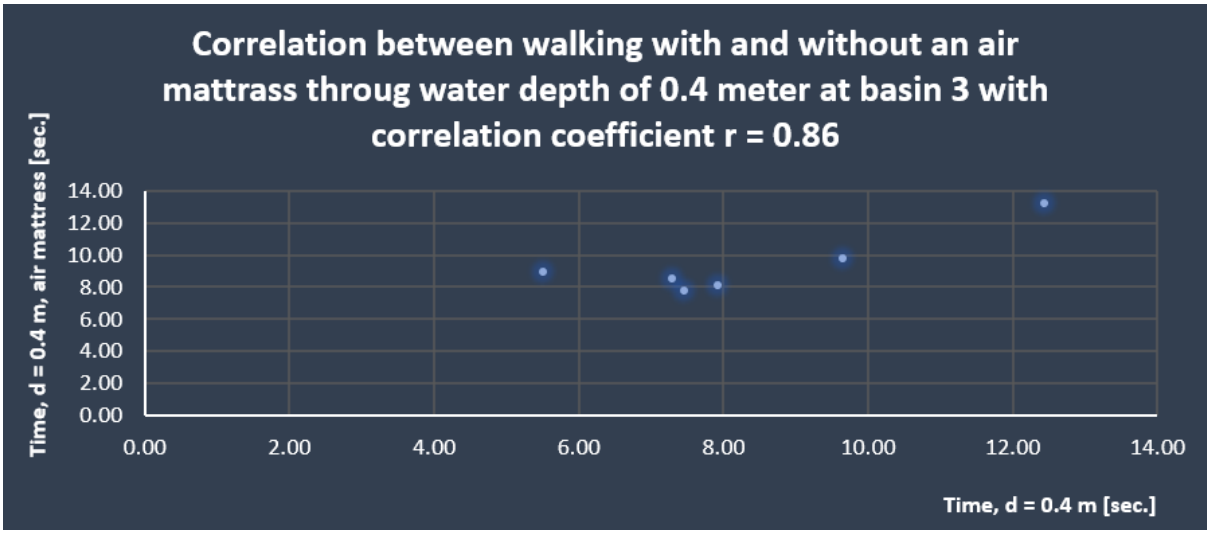


Figure I.6: Correlation between the mean of round 3&5 and round 4 at basin 3.

I.4. Overview of walking with an air mattress

Basin	Round	Water depth	Correlation (Pearson T-test)			Difference (T-test)		Relation
			r_{XY}	T	p	T	p	
1	Mean of 2&3 and 4	0.2 m 0.2 m	0.86	3.32	0.02933	1.39	0.22387	$t_{d=0.2\text{ m; air mattress}} \approx t_{d=0.2\text{ m}}$
2	3 and 4	0.6 m 0.6 m	0.97	7.43	0.00175	2.26	0.07366	$t_{d=0.6\text{ m; air mattress}} \approx t_{d=0.6\text{ m}}$
3	Mean of 3&5 and 4	0.4 m 0.4 m	0.86	3.30	0.02997	2.04	0.09706	$t_{d=0.4\text{ m; air mattress}} \approx t_{d=0.4\text{ m}}$

Table I.16: Overview results.

Correlation
- r_{XY} = correlation coefficient. A large value for r_{XY} gives a low probability p and a strong linear correlation.
- T = test statistic. A large value for T gives a low probability p.
- p = probability of finding no correlation between variable X and Y ($r_{XY} = 0$). If there is no correlation, variable X does not increase when variable Y increases and vice versa.

Difference
- T = test statistic. A large value for T gives a low probability p.
- p = probability of finding a zero-mean difference between variable X and Y ($\mu_z = 0$). If the mean difference is zero, variable X and Y are equal and there is no difference the time measurements.

Conclusion
All relations given in table I.16 have a strong or very strong positive linear correlation which is significant and the test statistic T is not large enough to notice a significant difference between each compared variable. This means that walking with an air mattress and walking without an air mattress takes approximately the same time.

J. Experiment: walking – Influence bringing luggage

- **What is the influence of bringing luggage on the fleeing speed in case of walking?**

As personal belonging a bag of 10 kg and a bag of 20 kg is used in the experiment. The difficulty of walking the parcourse with a backpack differs from person to person as it depends on how strong a person is. During the experiment only males carried the 20 kg bag and except from one male, the females carried the 10 kg bags. Because in general males are physical stronger than females and by looking at the dataset, the time measurements with both backpack types are analysed as one dataset.

Overview

Table J.1 gives an overview of which rounds will be compared to each other. Each basin has its own paragraph with the following structure: Data (I), Variables (II), Correlation (III), Difference (IV), Relation (V).

Basin	Round	Water depth
1	Mean of 2&3 and 4	0.2 m and 0.2 m
2	3 and 4	0.6 m and 0.6 m
3	Mean of 3&5 and 4	0.4 m and 0.4 m

Table J.1: Overview.

Number of samples: n = 8
Degrees of freedom (2-tailed): df = 6

Correlation

Hypothesis: $H_0: r_{XY} = 0$
$H_1: r_{XY} \neq 0$

Formula: $$r_{XY} = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{n(\sum X^2) - (\sum X)^2}\sqrt{n(\sum Y^2) - (\sum Y)^2}}$$

$$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1 - r_{XY}^2}} \text{ with } df = n - 2$$

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
6	0.621	0.707	0.834

Table J.2: Table of critical values for the correlation coefficient with n = 8.

See table J.2, for $df = 6$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.707 \leq r_{XY} \leq 0.707$ and 5% probability of finding a correlation outside this range.

Difference

Hypothesis: $H_0: \mu_z = 0$
$H_1: \mu_z \neq 0$

Formula: $$T = \frac{\bar{Z} - \mu_z}{S}\sqrt{n}$$

Table of critical values for test statistic T										
df	α									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
6	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959

Table J.3: Table of critical values for test statistic T with n = 8.

See table J.3, for $df = 6$ with critical value $\alpha = 0.05$, the null hypothesis ($\mu_z = 0$) is rejected with a certainty of more than 95% if the p-value from the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

J.1. Basin 1: Walking through water depths of 0.0 and 0.2 meter with and without a bag

I) Data

Time measurements of walking with and without a bag through basin 1				
Weight bag [kg]	**Person**	**Time mean round 2&3 [sec.]**	**Time round 4 [sec.]**	**Gender**
10	**2**	12.22	14.11	F
	6	11.47	11.93	F
	9	17.93	23.11	F
	12	8.22	8.36	M
	20	10.44	10.88	F
20	**1**	12.63	13.68	M
	4	6.30	9.63	M
	15	7.93	8.55	M

Table J.4: Time measurements in seconds of the mean of round 2&3 and round 4 at basin 1.

II) Variables

Variables of walking with and without a bag through basin 1	
X	Time mean round 2&3, d = 0.2 m [sec.]
Y	Time round 4, d = 0.2 m [sec.]

Table J.5: Variables X and Y.

III) Correlation

Correlation of walking through a water depth of 0.2 meter with and without a bag at basin 1								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
0.95	87.12	1040.66	100.24	1416.52	1206.88	8	7.37	0.00032

Table J.6: Correlation between time measurements from the mean of round 2&3 and round 4 at basin 1. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

From table J.6 the $r_{XY} \approx 0.95 > 0.707$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a very strong positive linear correlation that is significant between walking with and without a bag at a water depth of 0.2 meter at basin 1.

IV) Difference

Test statistic and probability of the comparison of walking through water depth of 0.2 meter with and without a bag at basin 1					
T	$\overline{Z}$	μ_z	n	$s = \sigma_z$	p
2.62	1.64	0	8	1.769	0.10505

Table J.7: Test statistic and probability.

The p-value ($p = 0.10505$), see table J.7, is higher than the critical value ($\alpha = 0.05$). This means that the null hypothesis is not rejected with a certainty of more than 95%. There is no significant difference in time measurements between walking with and without a bag at basin 1.

V) Relation

There is a very strong positive linear correlation that is significant between walking with and without a bag at a water depth of 0.2 meter at basin 1. However, the difference between the time measurements of walking with a bag and without a bag is very small.

VI) Graphs

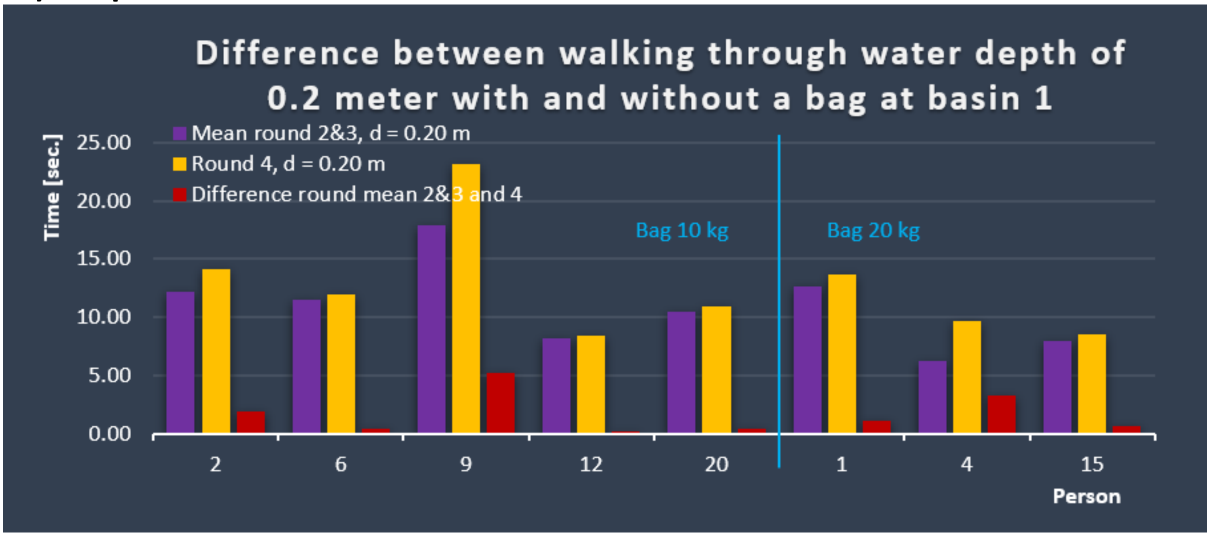


Figure J.1: Difference between the mean of round 2&3 and round 4 at basin 1.

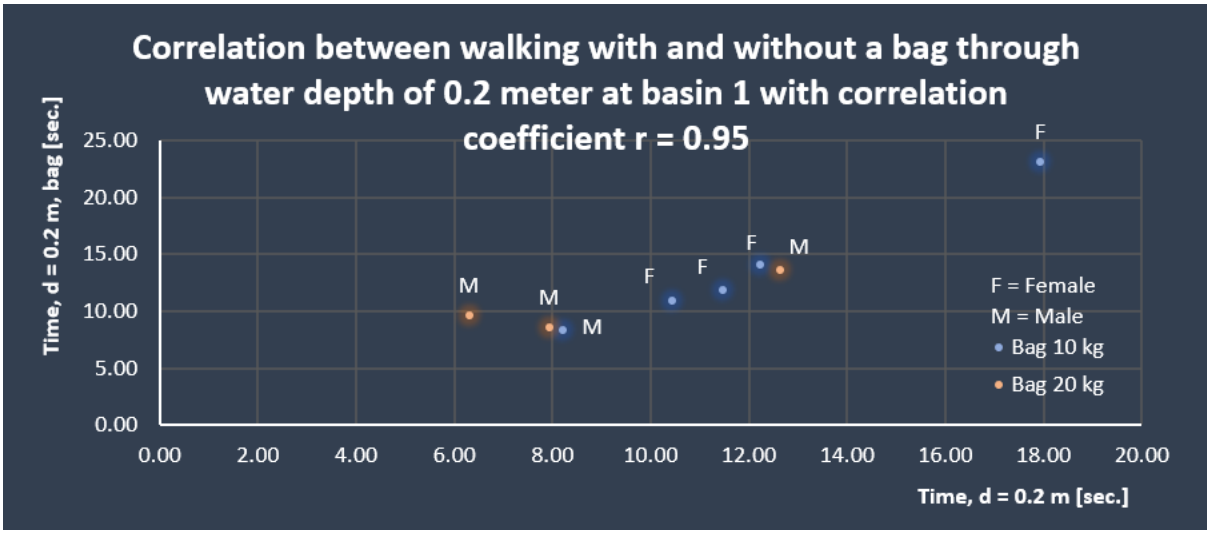


Figure J.2: Correlation between the mean of round 2&3 and round 4 at basin 1.

J.2. Basin 2: Walking through water depths of 0.0 and 0.6 meter with and without a bag

I) Data

Time measurement of walking with and without a bag through basin 2			
Weight bag [kg]	**Person**	**Time round 3 [sec.]**	**Time round 4 [sec.]**
10	**2**	11.43	12.26
	6	9.94	9.89
	9	11.02	14.86
	12	8.74	9.00
	20	10.42	10.67
20	**1**	10.61	11.62
	4	6.89	7.33
	15	7.25	7.28

Table J.8: Time measurements in seconds of round 3 and round 4 at basin 2.

II) Variables

Variables of walking with and without a bag through basin 2	
X	Time round 3, d = 0.6 m [sec.]
Y	Time round 4, d = 0.6 m [sec.]

Table J.9: Variables X and Y.

III) Correlation

Correlation of walking through a water depth of 0.6 meter with and without a bag at basin 2								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
0.90	76.27	747.81	82.90	905.33	818.17	8	5.03	0.00237

Table J.10: Correlation between time measurements from round 3 and round 4 at basin 2.

From table J.10 the $r_{XY} \approx 0.90 > 0.707$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a strong positive linear correlation that is significant between walking with and without a bag at basin 2.

IV) Difference

Test statistic and probability of the comparison of walking through water depth of 0.2 meter with and without a bag at basin 2					
T	$\overline{Z}$	μ_z	n	$s = \sigma_z$	p
1.85	0.83	0	8	1.270	0.14017

Table J.11: Test statistic and probability.

The p-value ($p = 0.14017$), see table J.11, is higher than the critical value ($\alpha = 0.05$). This means that the null hypothesis is not rejected with a certainty of more than 95%. There is no significant difference in time measurements between walking with and without a bag at basin 2.

V) Relation

There is a strong positive linear correlation that is significant between walking with and without a bag at basin 2. However, the difference between the time measurements of walking with a bag and without a bag is very small.

VI) Graphs

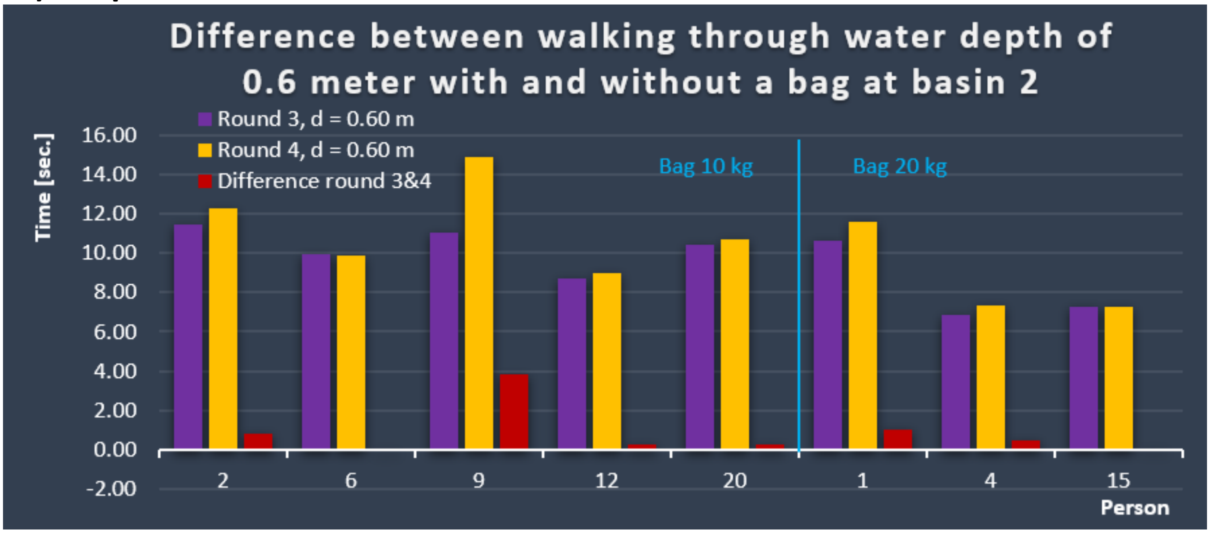


Figure J.3: Difference between round 3 and round 4 at basin 2.

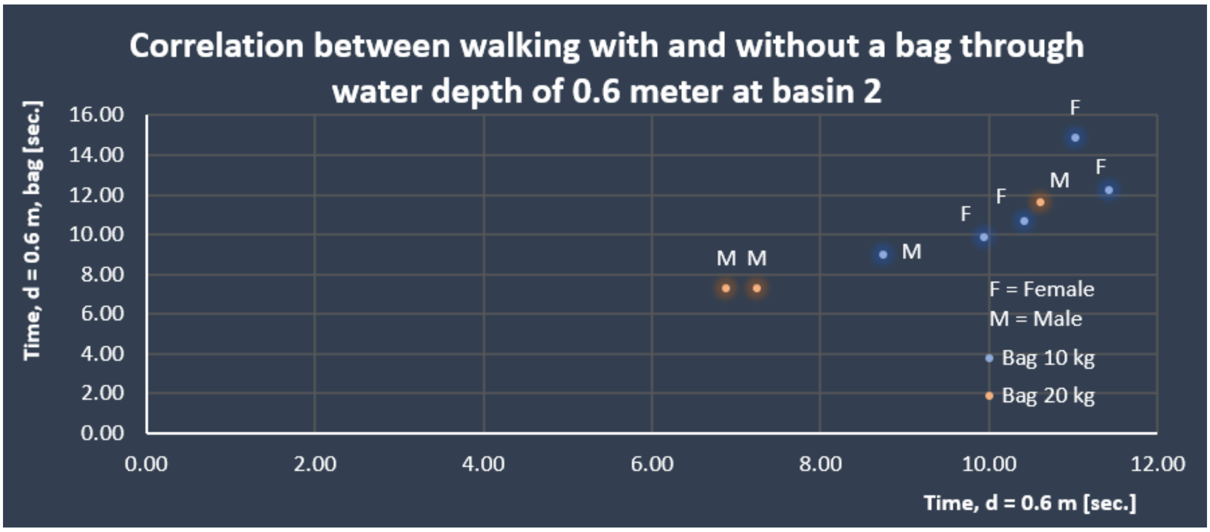


Figure J.4: Correlation between round 3 and round 4 at basin 2.

J.3. Basin 3: Walking through water depths of 0.0 and 0.4 meter with and without a bag

I) Data

Time measurement of walking with and without a bag through basin 3			
Weight bag [kg]	**Person**	**Time mean round 3&5 [sec.]**	**Time round 4 [sec.]**
10	**2**	9.96	13.75
	6	9.70	11.33
	9	12.87	16.86
	12	8.73	10.34
	20	10.65	11.02
20	**1**	9.17	13.08
	4	5.74	7.63
	15	6.27	7.72

Table J.12: Time measurements in seconds of the mean of round 3&5 and round 4 at basin 3.

II) Variables

Variables of walking with and without a bag through basin 3	
X	Time mean round 3&5, d = 0.4 m [sec.]
Y	Time round 4, d = 0.4 m [sec.]

Table J.13: Variables X and Y.

III) Correlation

Correlation of walking through a water depth of 0.4 meter with and without a bag at basin 3								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
0.91	73.07	704.55	91.72	1118.71	883.29	8	5.45	0.00159

Table J.14: Correlation between time measurements from the mean of round 3&5 and round 4 at basin 3. $r_{XY} =$ correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

From table J.14 the $r_{XY} \approx 0.91 > 0.707$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a very strong positive linear correlation that is significant between walking with and without a bag at basin 3.

IV) Difference

Test statistic and probability of the comparison of walking through water depth of 0.4 meter with and without a bag at basin 3					
T	$\overline{Z}$	μ_z	n	$s = \sigma_z$	p
4.80	2.33	0	8	1.373	0.00986

Table J.15: Test statistic and probability.

The p-value ($p = 0.00986$), see table J.15, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference in time measurements between walking with and without a bag at basin 3.

V) Relation

Relation between walking through water depth of 0.4 meter with and without a bag at basin 3	
Reduction	20% $\frac{\sum \frac{\lvert \text{mean round 2\&3} - \text{round 4} \rvert}{\text{round 4}}}{n} * 100\%$
Factor	$\frac{\sum \frac{\text{round 4}}{\text{mean round 2\&3}}}{n} = 1.26$

Table J.16: Relation between round and factor.

There is a very strong positive linear correlation that is significant between walking with and without a bag at basin 3. Also, there is a non-zero difference between these rounds.

The reduction in speed in case of d = 0.4 m with and without a bag is approximately 20%.

Least squares linear regression:	$\text{Time}_{d=0.4\text{ m;bag}} \approx 1.23\ \text{Time}_{d=0.4\text{ m}} + 0.27$
Least squares intercept free linear regression:	$\text{Time}_{d=0.4\text{ m;bag}} \approx 1.25\ \text{Time}_{d=0.4\text{ m}}$
Mean slope linear relation:	$\text{Time}_{d=0.4\text{ m;bag}} \approx 1.26\ \text{Time}_{d=0.4\text{ m}}$

VI) Graphs

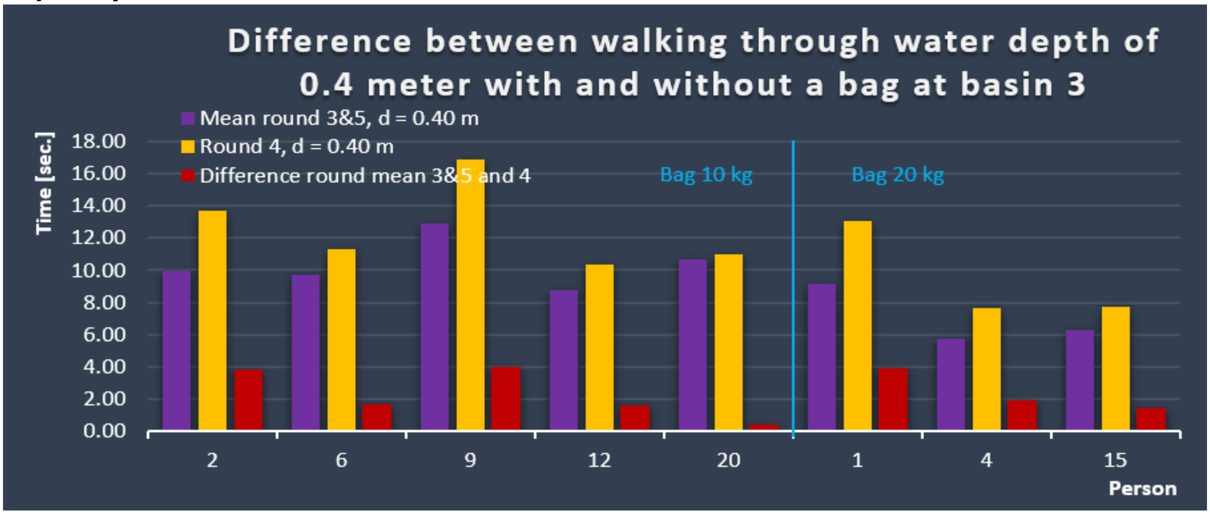


Figure J.5: Difference between the mean of round 3&5 and round 4 at basin 3.

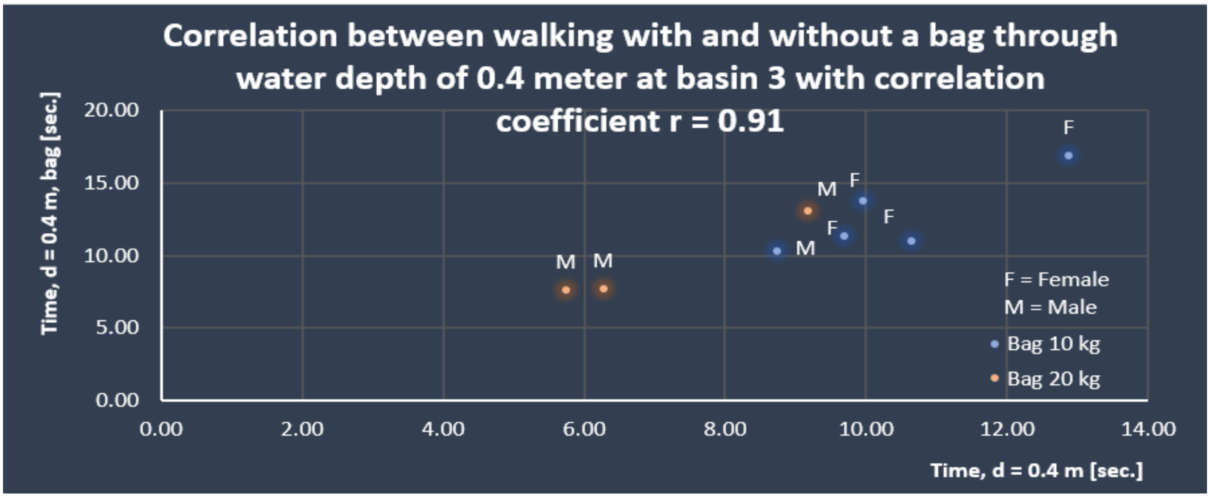


Figure J.6: Correlation between the mean of round 3&5 and round 4 at basin 3.

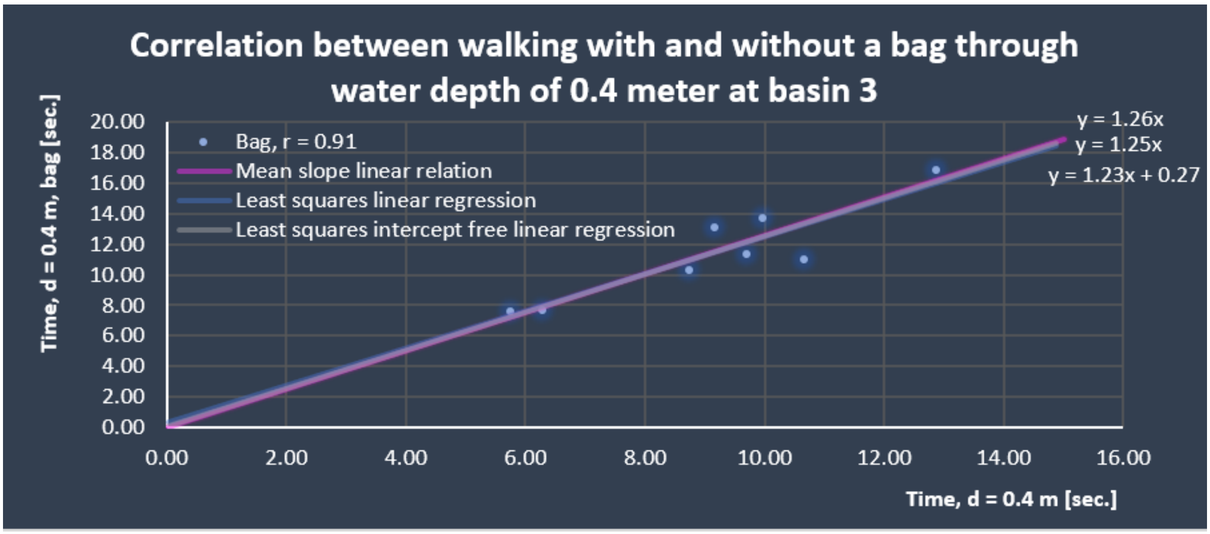


Figure J.7: Correlation between the mean of round 3&5 and round 4 at basin 3.

J.4. Overview results

Basin	Round	Water depth	Correlation (Pearson T-test)			Difference (T-test)		Relation
			r_{XY}	T	p	T	p	
1	Mean of 2&3 and 4	0.2 m 0.2 m	0.95	7.37	0.00032	2.62	0.10505	$t_{d=0.2\ m;\ bag} \approx t_{d=0.2\ m}$
2	3 and 4	0.6 m 0.6 m	0.90	5.03	0.00237	1.85	0.14017	$t_{d=0.6\ m;\ bag} \approx t_{d=0.6\ m}$
3	Mean of 3&5 and 4	0.4 m 0.4 m	0.91	5.45	0.00159	4.80	0.00986	$t_{d=0.4\ m;\ bag} \approx 1.25\ t_{d=0.4\ m}$

Table J.17: Overview results.

Correlation

- r_{XY} = correlation coefficient. A large value for r_{XY} gives a low probability p and a strong linear correlation.
- T = test statistic. A large value for T gives a low probability p.
- p = probability of finding no correlation between variable X and Y ($r_{XY} = 0$). If there is no correlation, variable X does not increase when variable Y increases and vice versa.

Difference

- T = test statistic. A large value for T gives a low probability p.
- p = probability of finding a zero mean difference between variable X and Y ($\mu_z = 0$). If the mean difference is zero, variable X and Y are equal and there is no difference the time measurements.

Relation

The relation of the least squares intersect free linear regression method is displayed in this table as this seems to be the most accurate method. In this case all relations are almost the same, see table J.17.

K. Experiment: walking – Influence of bringing a dog

- **What is the influence of bringing a domestic animal on the fleeing speed in case of walking?**

I) Overview

Basin	Round	Water depth
1	Mean of 2&3 and 4	0.2 m and 0.2 m
2	3 and 4	0.6 m and 0.6 m
3	Mean of 3&5 and 4	0.4 m and 0.4 m

Table K.1: Overview.

Number of samples: $n = 7$
Degrees of freedom (2-tailed): $df = 5$

II) Correlation

Hypothesis: $H_0: r_{XY} = 0$
$H_1: r_{XY} \neq 0$

Formula: $r_{XY} = \frac{n(\sum XY)-(\sum X)(\sum Y)}{\sqrt{n(\sum X^2)-(\sum X)^2}\sqrt{n(\sum Y^2)-(\sum Y)^2}}$

$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1-r_{XY}^2}}$ with $df = n - 2$

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
5	0.669	0.754	0.875

Table K.2: Table of critical values for the correlation coefficient with n = 7.

For $df = 5$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.754 \leq r_{XY} \leq 0.754$ and 5% probability of finding a correlation outside this range.

III) Difference

Hypothesis: $H_0: \mu_z = 0$
$H_1: \mu_z \neq 0$

Formula: $T = \frac{\overline{Z}-\mu_z}{S}\sqrt{n}$

Table of critical values for test statistic T										
df	α									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
5	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869

Table K.3: Table of critical values for test statistic T with n = 7.

For $df = 5$ with critical value $\alpha = 0.05$, the null hypothesis ($\mu_z = 0$) is rejected with a certainty of more than 95% if the p-value from the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

K.1. Basin 1: Walking through water depths of 0.0 and 0.2 meter with and without a dog

I) Data

Time measurement of walking with and without a dog through basin 1			
Person	**Time mean round 2&3 [sec.]**	**Time round 4 [sec.]**	**Used to a dog**
3	9.95	12.50	No
7	5.87	16.30	No
10	9.01	12.83	No
14	7.90	15.10	No
21	6.12	6.39	Yes
23	14.87	15.81	Yes
25	11.98	12.41	Yes

Table K.4: Time measurements in seconds of the mean of round 2&3 and round 4 at basin 1.

II) Variables

Variables of walking with and without a dog through basin 1	
X	Time mean round 2&3, d = 0.2 m [sec.]
Y	Time round 4, d = 0.2 m [sec.]

Table K.5: Variables X and Y.

III) Correlation

Correlation of walking through a water depth of 0.2 meter with and without a dog at basin 1								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
0.31	65.69	679.04	92.64	1306.07	891.43	7	0.73	0.49585

Table K.6: Correlation between time measurements from the mean of round 2&3 and round 4 at basin 1. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

From table K.6 the $r_{XY} \approx 0.31 < 0.754$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is that there is a weak positive linear correlation that is not significant between walking through a water depth of 0.2 meter with and without a dog at basin 1.

IV) Difference

Test statistic and probability of the comparison of walking through water depth of 0.2 meter with and without a dog at basin 1					
T	$\overline{Z}$	μ_Z	n	$s = \sigma_Z$	p
2.51	3.85	0	7	4.053	0.04678

Table K.1: Test statistic and probability.

The p-value ($p = 0.04678$), see table K.7, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference in time measurements between walking with and without a dog at basin 1.

V) Relation

There is a weak positive linear correlation that is not significant, so there cannot be stated a relationship for the influence of walking with a dog. However, there is a difference between walking with a dog and walking without a dog through water. From figure K.1 it is seen that walking with a dog reduces the speed for persons 3, 7, 10 and 14. Further, there can be noticed from this figure that the time measurements for persons 21, 23 and 25 during walking with a dog and without a dog does not differ much. These participants are used to the dog.

VI) Graphs

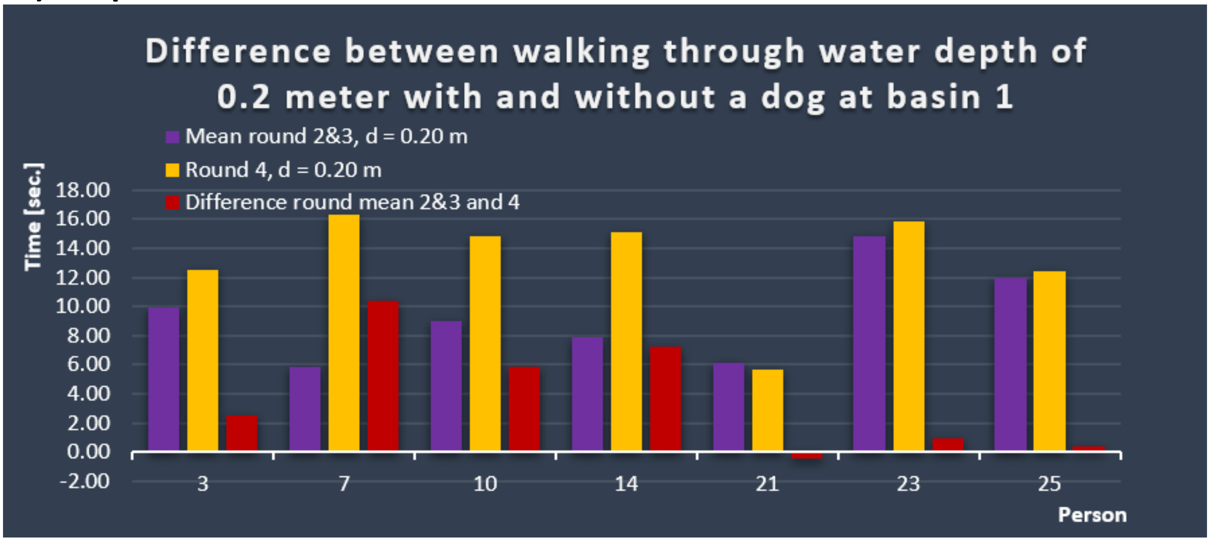


Figure K.1: Difference between the mean of round 2&3 and round 4 at basin 1.

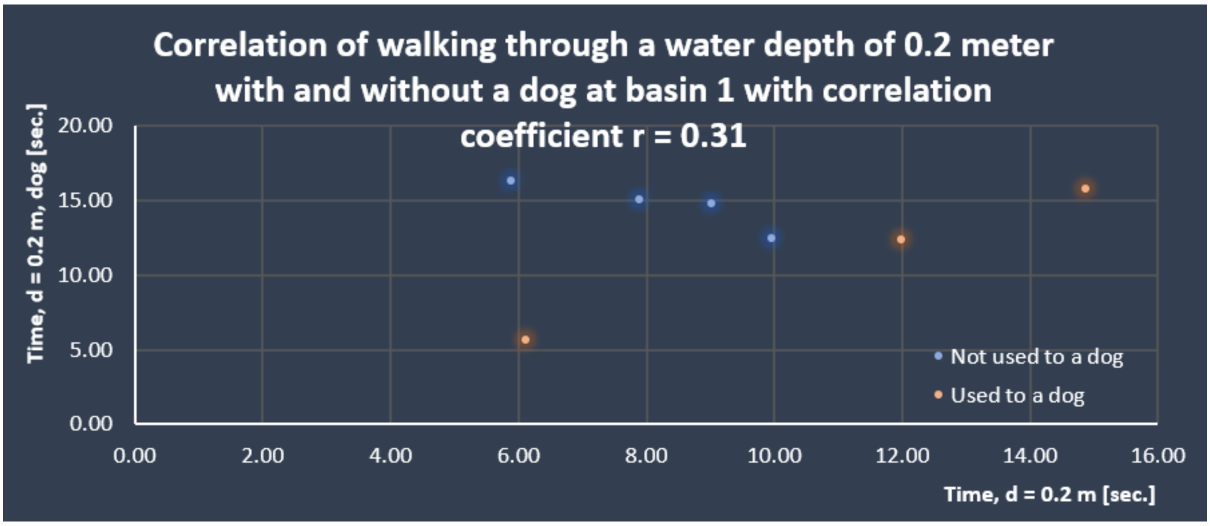


Figure K.2: Correlation between the mean of round 2&3 and round 4 at basin 1.

K.2. Basin 2: Walking through water depths of 0.0 and 0.6 meter with and without a dog

I) Data

Time measurement of walking with and without a dog through basin 2			
Person	**Time round 3 [sec.]**	**Time round 4 [sec.]**	**Used to a dog**
3	8.71	10.03	No
7	9.46	11.66	No
10	8.62	11.94	No
14	7.32	10.70	No
21	7.81	7.99	Yes
23	10.82	10.91	Yes
25	9.51	9.75	Yes

Table K.8: Time measurements in seconds of round 3 and round 4 at basin 2.

II) Variables

Variables of walking with and without a dog through basin 2	
X	Time round 3, d = 0.6 m [sec.]
Y	Time round 4, d = 0.6 m [sec.]

Table K.9: Variables X and Y.

III) Correlation

Correlation of walking through a water depth of 0.6 meter with and without a dog at basin 2								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
0.33	62.23	561.42	72.96	771.14	651.72	7	0.79	0.46771

Table K.10: Correlation between time measurements from round 3 and round 4 at basin 2. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

From table K.10 the $r_{XY} \approx 0.33 < 0.754$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is that there is a weak positive linear correlation that is not significant between walking through a water depth of 0.6 meter with and without a dog at basin 2.

IV) Difference

Test statistic and probability of the comparison of walking through water depth of 0.6 meter with and without a dog at basin 2					
T	$\overline{Z}$	μ_Z	n	$s = \sigma_Z$	p
2.79	1.53	0	7	1.454	0.03302

Table K.11: Test statistic and probability.

The p-value ($p = 0.03302$), see table K.11, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference in time measurements between walking with and without a dog at basin 2.

V) Relation

There is a weak correlation that is not significant, so there cannot be stated a relationship for the influence of walking with a dog. However, there is a difference between walking with a dog and walking without a dog through water. From figure K.3 it is seen that walking with a dog reduces the speed for persons 3, 7, 10 and 14. Further, there can be noticed from this figure that the time measurements for persons 21, 23 and 25 during walking with a dog and without a dog does not differ much. These participants are used to the dog.

VI) Graphs

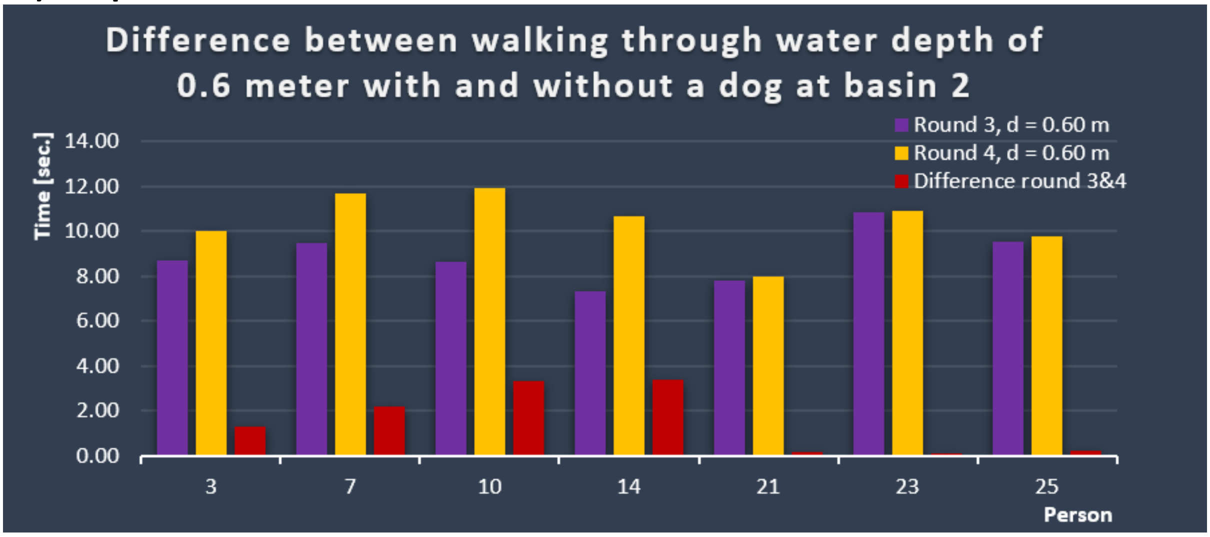


Figure K.3: Difference between round 3 and round 4 at basin 2.

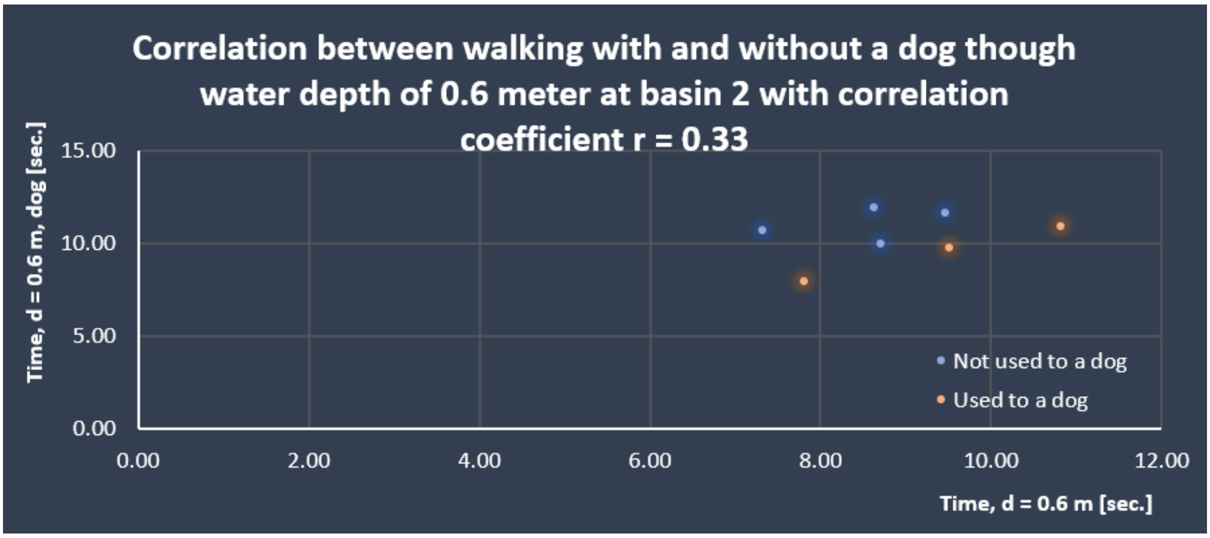


Figure K.4: Correlation between round 3 and round 4.

K.3. Basin 3: Walking through water depths of 0.0 and 0.4 meter with and without a dog

I) Data

Time measurement of walking with and without a dog through basin 3			
Person	**Time mean round 3&5 [sec.]**	**Time round 4 [sec.]**	**Used to a dog**
3	8.15	10.59	No
7	6.16	13.04	No
10	7.72	11.50	No
14	7.09	9.54	No
21	8.03	8.26	Yes
23	12.38	12.65	Yes
25	7.41	8.56	Yes

Table K.12: Time measurements in seconds of the mean of round 3&5 and round 4 at basin 3.

II) Variables

Variables of walking with and without a dog through basin 3	
X	Time mean round 3&5, d = 0.4 m [sec.]
Y	Time round 4, d = 0.4 m [sec.]

Table K.13: Variables X and Y.

III) Correlation

Correlation walking through a water depth of 0.4 meter with and without a dog at basin 3								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
0.28	56.93	486.77	74.13	806.77	609.25	7	0.65	0.54445

Table K.14: Correlation between time measurements from the mean of round 3&5 and round 4 at basin 3. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

From table K.14 the $r_{XY} \approx 0.28 < 0.754$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is there is a weak positive linear correlation that is not significant between walking through a water depth of 0.4 meter with and without a dog at basin 3.

IV) Difference

Test statistic and probability of the comparison of walking through water depth of 0.4 meter with and without a dog at basin 3					
T	$\overline{Z}$	μ_Z	n	$s = \sigma_Z$	p
2.78	2.46	0	7	2.338	0.04606

Table K.15: Test statistic and probability.

The p-value ($p = 0.04606$), see table K.15, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference in time measurements between mean round 3&5 and round 4 at basin 3.

V) Relation

There is a weak positive linear correlation that is not significant, so there cannot be stated a relationship for the influence of walking with a dog. However, there is a difference between walking with a dog and walking without a dog through water. From figure K.5 it can be seen that walking with a dog reduces the speed for persons 3, 7, 10 and 14. Further, there can be noticed from this figure that the time measurements for persons 21, 23 and 25 during walking with a dog and without a dog does not differ much. These participants are used to the dog.

VI) Graphs

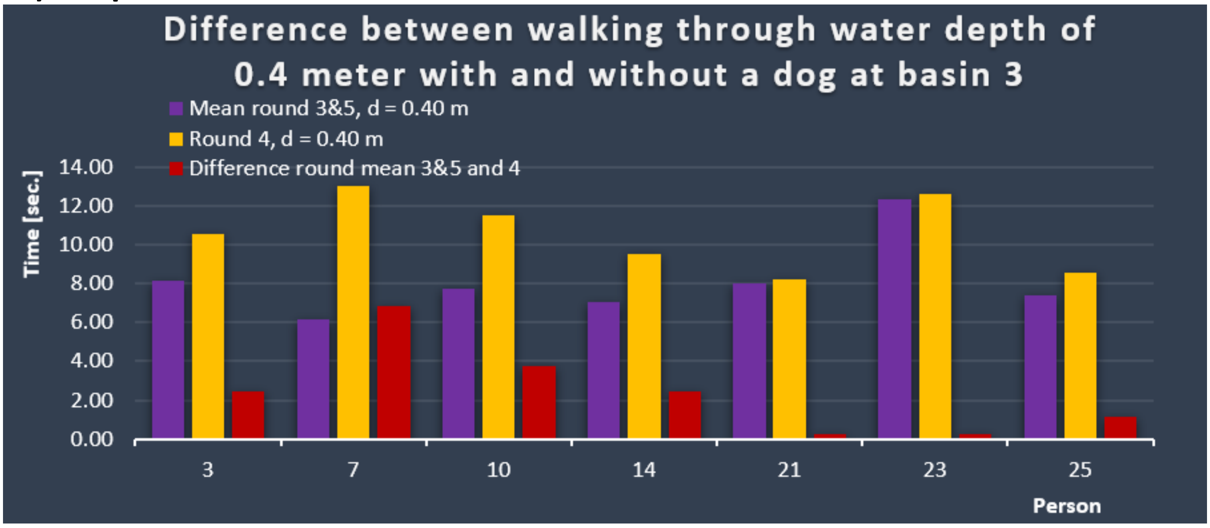


Figure K.5: Difference between the mean of round 3&5 and round 4 at basin 3.

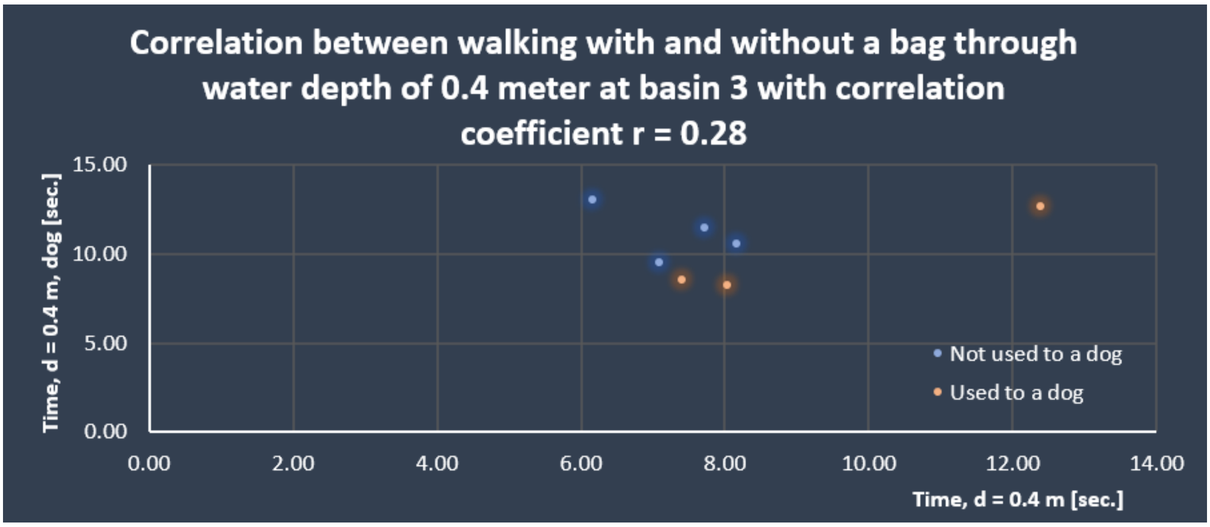


Figure K.6: Correlation between the mean of round 3&5 and round 4 at basin 3.

K.4. Overview results

Basin	Round	Water depth	Correlation (Pearson T-test)			Difference (T-test)		Relation
			r_{XY}	T	p	T	p	
1	Mean of 2&3 and 4	0.2 m 0.2 m	0.31	0.73	0.49585	2.51	0.04678	-
2	3 and 4	0.6 m 0.6 m	0.33	0.79	0.46771	2.79	0.03302	-
3	Mean of 3&5 and 4	0.4 m 0.4 m	0.28	0.65	0.54445	2.78	0.04606	-

Table K.16: Overview results.

Correlation

- r_{XY} = correlation coefficient. A large value for r_{XY} gives a low probability p and a strong linear correlation.
- T = test statistic. A large value for T gives a low probability p.
- p = probability of finding no correlation between variable X and Y ($r_{XY} = 0$). If there is no correlation, variable X does not increase when variable Y increases and vice versa.

Difference

- T = test statistic. A large value for T gives a low probability p.
- p = probability of finding a zero mean difference between variable X and Y ($\mu_z = 0$). If the mean difference is zero, variable X and Y are equal and there is no difference the time measurements.

There is only a weak correlation that is not significant between walking with and without a dog, so there cannot be stated a relationship for the influence of walking with a dog. However, walking with a dog reduces the speed for persons 3, 7, 10 and 14. Further, there can be noticed that the time measurements for persons 21, 23 and 25 during walking with a dog and without a dog does not differ much. These participants are the owner of the dog or have a own dog at home.

Person	Used to a dog	Factor Basin 1	Factor Basin 2	Factor Basin 3
3	No	1.26	1.05	1.30
7	No	2.78	1.23	2.12
10	No	1.65	1.39	1.49
14	No	1.91	1.49	1.35
21	Yes	0.93	1.02	1.03
23	Yes	1.06	0.87	1.02
25	Yes	1.04	1.03	1.16

Table K.17: Comparison between walking through water and walking with a dog through water.

L. Walking – Influence of darkness

- **What is the influence of darkness on the fleeing speed?**

I) Data

Time measurements of walking during day and in the darkness										
	Part 1 (Basin 1)		Part 2		Part 3 (Basin 2)		Part 4		Part 5 (Basin 3)	
	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark
Round 1										
Person A	7.72	9.20	6.43	10.27	5.22	8.50	6.02	7.76	5.78	7.14
Person B	3.27	6.91	3.90	7.25	3.48	6.58	3.94	7.21	3.13	4.85
Round 2										
Person A	10.63	14.12	7.88	12.71	8.64	10.83	7.93	10.98	9.27	13.30
Person B	6.10	9.09	4.31	7.37	6.67	8.42	5.59	7.28	3.71	7.34
Round 3										
Person A	10.25	13.87	7.35	14.15	10.42	12.76	8.33	12.73	11.11	18.76
Person B	6.14	9.51	4.19	8.60	7.81	10.58	5.70	9.39	7.20	11.48
Round 4										
Person A	10.88	13.55	7.88	13.74	10.67	13.21	9.16	16.36	11.02	18.44
Person B	5.69	9.34	4.50	7.57	7.99	11.95	6.67	9.62	8.26	12.77
Round 5										
Person A	13.11	18.28	8.32	14.39	16.96	31.20	9.63	10.99	10.19	17.76
Person B	9.47	13.90	5.57	10.81	11.68	20.96	5.81	9.15	8.86	11.25

Table L.1: Data of walking during daylight and darkness.

II) Variables

Variables of walking during daylight and darkness	
X	Time during daylight [sec.]
Y	Time during darkness [sec.]

Table L.2: Variables X and Y.

III) Correlation

Hypothesis: $H_0: r_{XY} = 0$

$H_1: r_{XY} \neq 0$

Formula: $$r_{XY} = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{n(\sum X^2) - (\sum X)^2}\sqrt{n(\sum Y^2) - (\sum Y)^2}}$$

$$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1 - r_{XY}^2}} \text{ with } df = n - 2$$

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
23	0.337	0.396	0.505

Table L.3: Table of critical values for the correlation coefficient with n = 25.

For $df = 23$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.396 \leq r_{XY} \leq 0.396$ and 5% probability of finding a correlation outside this range.

Correlation of walking during daylight and darkness				
Person	r_{XY}	n	T	p
A	0.88	25	8.97	$5.7 * 10^{-9}$
B	0.92	25	11.16	$9.3 * 10^{-11}$

Table L.4: Correlation between time measurements from walking during daylight and darkness of persons 17 = person 20 and person 18 = person 21. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

From table L.4 the $r_{XY} \approx 0.88 > 0.396$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a strong positive linear correlation that is significant between walking during daylight and in the darkness.

From table L.4 the $r_{XY} \approx 0.92 > 0.396$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a very strong positive linear correlation that is significant between walking during daylight and in the darkness.

IV) Difference

Hypothesis: $H_0: \mu_z = 0$

$H_1: \mu_z \neq 0$

Formula: $T = \frac{\bar{Z}-\mu_z}{s}\sqrt{n}$

Table of critical values for test statistic T										
df	α									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
23	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768

Table L.5: Table of critical values for test statistic T with n = 25.

See table L.5, for $df = 23$ with critical value $\alpha = 0.05$, the null hypothesis of $\mu_z = 0$ is rejected with a certainty of more than 95% if the p-value from the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

Difference between walking during daylight and by darkness						
Person	T	$\bar{Z}$	μ_z	n	$s = \sigma_z$	p
A	7.92	4.57	0	25	2.885	$3.8 * 10^{-8}$
B	5.61	3.58	0	25	3.191	$1.0 * 10^{-11}$

Table L.6: Test statistic and probability for the difference between walking during daylight and by darkness.

The p-values ($p = 3.8 * 10^{-8}$ and $p = 1.0 * 10^{-11}$), see table L.6, are lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis of $\mu_z = 0$ is rejected with a certainty of more than 95%. The difference between walking during daylight and darkness is significant.

V) Relation

Person	Correlation (Pearson T-test)			Difference (T-test)		Relation
	r_{XY}	T	p	T	p	
A	0.88	8.97	$5.73 * 10^{-9}$	7.92	$3.80 * 10^{-8}$	$t_{darkness} \approx 1.51\, t_{daylight}$
B	0.92	11.16	$9.3 * 10^{-11}$	5.61	$1.00 * 10^{-11}$	$t_{darkness} \approx 1.57\, t_{daylight}$

Table L.7: Relations.

Relations of person A and B together:

Least squares linear regression: $\text{Time}_{darkness} \approx 1.47\, \text{Time}_{daylight} + 0.49$

Least squares intercept free linear regression: $\text{Time}_{darkness} \approx 1.53\, \text{Time}_{daylight}$

Mean slope linear relation: $\text{Time}_{darkness} \approx 1.57\, \text{Time}_{daylight}$

VI) Graphs

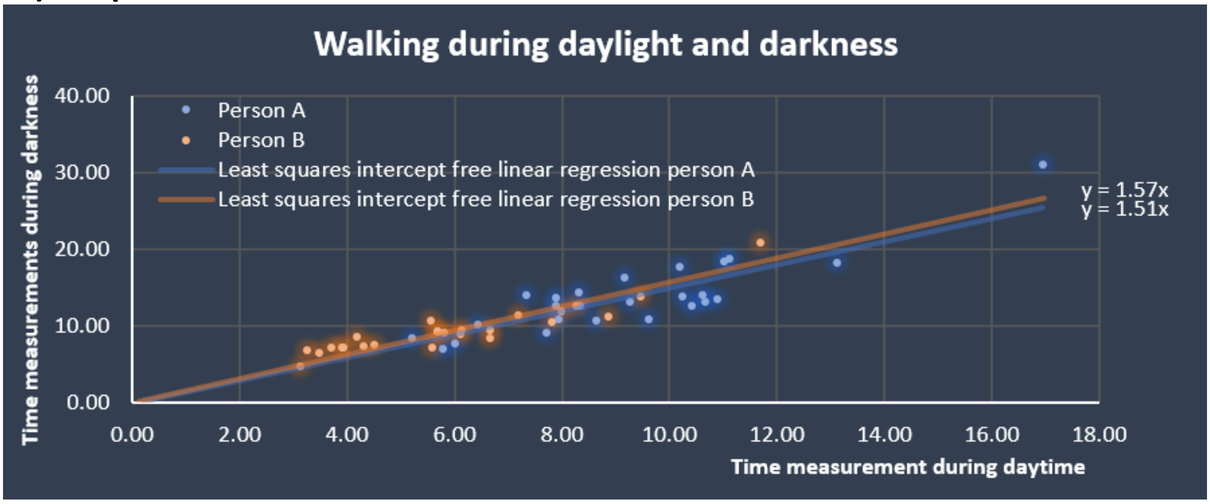


Figure L.1: Correlation between walking during daylight and darkness of person A and B separately.

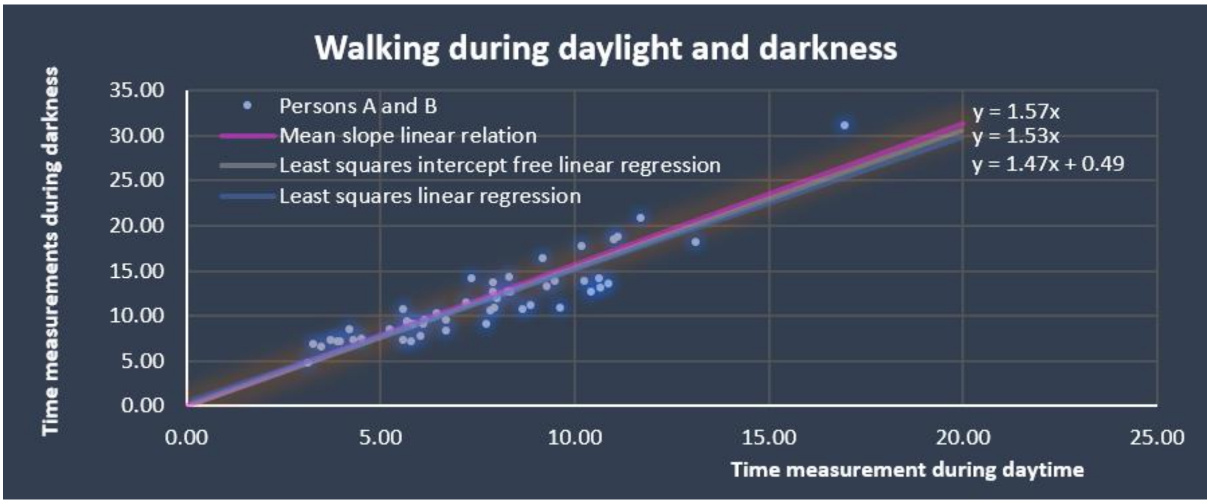


Figure L.2: Correlation between walking during daylight and darkness of person A and B together.

M. Experiment: bicycling – General

In this part the influence of the wader on the time measurements is checked in paragraph M.1. Further at the end of paragraph C.3, the following is noticed which will be elaborated in paragraph M.2 and M.3:

- Round 2 has the same circumstances as round 3 for part 1 (Basin 1)
- Round 3 has the same circumstances as round 5 for part 5 (Basin 3)

M.1. Influence of bicycling with a wader

In this part the influence of bicycling with a wader is considered. It is expected that a wader does not influence the time measurements. Only two persons participated at round 0. Because of this small number of participants for this round, the Pearson product moment correlation and the paired T-test are not performed for this part. However, there can be looked at the difference between bicycling with and without a wader.

Time measurements of walking with and without a wader												
	Part 1 (Basin 1)		Part 2		Part 3 (Basin 2)		Part 4		Part 5 (Basin 3)		Total parcourse	
Round	0	1	0	1	0	1	0	1	0	1	0	1
Person 22	6.64	6.51	2.50	2.45	3.55	3.64	6.58	6.55	5.02	4.82	24.29	23.97
Person 23	10.74	10.80	10.78	10.71	4.20	4.73	8.06	7.58	5.34	5.47	39.12	39.29

Table M.1: Time measurements of bicycling between round 0 (without wader) and round 1 (with wader).

Difference between time measurements of walking with and without a wader						
	Part 1 (Basin 1)	Part 2	Part 3 (Basin 2)	Part 4	Part 5 (Basin 3)	Total parcourse
Person 22	-0.13	-0.05	0.09	-0.03	-0.20	-0.32
Person 23	0.06	-0.07	0.53	-0.48	0.13	0.17
Mean	-0.04	-0.06	0.31	-0.26	-0.07	-0.08

Table M.2: Differences of bicycling between round 0 (without wader) and round 1 (with wader).

As seen from table M.2, the differences are small and there is assumed that wearing a wader instead of other clothes does not influence the time measurements.

M.2. Comparison of round 2 and round 3 at basin 1

As mentioned at the beginning of this appendix, round 2 has the same circumstances as round 3 at basin 1. The time measurements of each round are compared to each other to see if it is a good approximation to use the mean of both rounds for each person in further calculations.

Time measurements of bicycling through the same water depth of d = 0.2 meter at basin 1					
	Person	**Round 2**	**Round 3**		**Mean round 2 and 3**
Bicycling	**4**	4.50	3.74		4.12
	5	4.77	4.97		4.87
	12	4.40	4.14		4.27
	14	5.54	5.58		5.56
	15	4.47	4.69		4.58
	21	4.12	3.17		3.65
	16 (darkness)	5.62	4.72		5.17
	18 (darkness)	5.42	5.37		5.40
	19 (darkness)	4.28	4.67		4.48
Different methods	**2**	11.32	14.34		12.83
	10	9.78	5.81		7.80
	11	9.45	7.34		8.40
Walking with bicycle	**1**	11.92	11.20		11.56
	3	9.25	10.70		9.98
	6	11.40	10.24		10.82
	7	8.01	-		-
	9	18.08	17.67		17.88
	13	7.36	9.33		8.35
	20	9.45	9.89		9.67
	22	12.50	11.90		12.20
	23	11.87	13.34		12.61
	24	12.83	12.56		12.70
	25	10.41	13.20		11.81
	17 (darkness)	12.24	11.01		11.63
Stepping	**8**	6.36	8.44		7.40

Table M.3: Time measurements in seconds of round 2 and round 3 at basin 1.

Notes:

- Person 2 walked with the bicycle during round 2 and carried the bicycle during round 3.
- Person 7 did not complete round 3.
- Person 10 and person 11 walked with the bicycle during round 2 and were bicycling at round 3.

II) Variables

Variables of bicycling through the same water depth of d = 0.2 meter at basin 1	
X	Time round 2, d = 0.2 m [sec.]
Y	Time round 3, d = 0.2 m [sec.]

Table M.4: Variables X and Y.

III) Correlation

Hypothesis: $H_0: r_{XY} = 0$
$H_1: r_{XY} \neq 0$

Formula: $r_{XY} = \frac{n(\sum XY)-(\sum X)(\sum Y)}{\sqrt{n(\sum X^2)-(\sum X)^2}\sqrt{n(\sum Y^2)-(\sum Y)^2}}$

$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1-r_{XY}^2}}$ with $df = n - 2$

Correlation between bicycling through the same water depth of d = 0.2 meter at different rounds at basin 1								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	p
0.92	207.34	2110.74	208.02	2171.09	2112.74	24	11.29	$7.44 * 10^{-11}$

Table M.5: Correlation between time measurements from round 2 and round 3. r_{XY} = correlation coefficient, T = Test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
22	0.344	0.404	0.515

Table M.6: Table of critical values for the correlation coefficient with n = 24.

See table M.6, for $df = 22$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.404 \leq r_{XY} \leq 0.404$ and 5% probability of finding a correlation outside this range.

Conclusion

From table M.5 the $r_{XY} \approx 0.92 > 0.396$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a very strong positive relation that is significant between walking through the same water depth of 0.2 meter at basin 1.

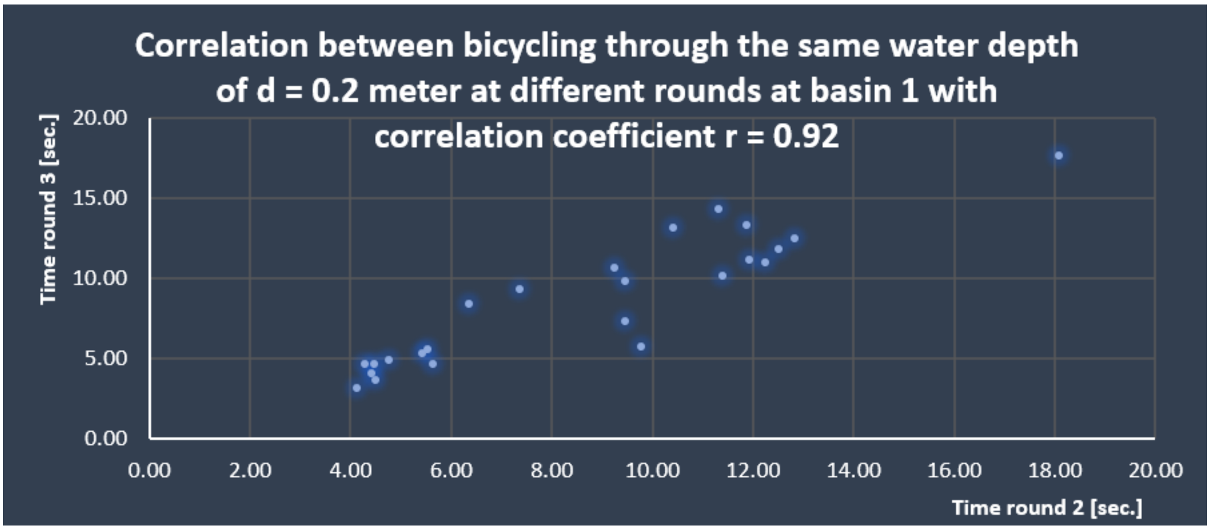


Figure M.1: Correlation between round 2 and round 3 at basin 1.

IV) Difference

Hypothesis: $H_0: \mu_z = 0$
$H_1: \mu_z \neq 0$

Formula: $T = \frac{\bar{Z}-\mu_z}{s}\sqrt{n}$

Difference between bicycling through the same water depth at different rounds at basin 1					
T	$\bar{Z}$	μ_z	n	$s = \sigma_z$	p
0.09	0.03	0	24	1.565	0.930

Table M.7: Test statistic and probability for the difference between round 2 and round 3 at basin 1.

Table of critical values for test statistic T										
df	**α**									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
22	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792

Table M.8: Table of critical values for test statistic T with n = 24.

See table M.8, for $df = 22$ with critical value $\alpha = 0.05$, the null hypothesis of $\mu_z = 0$ is rejected with a certainty of more than 95% if the p-value from the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

Conclusion
The p-value ($p = 0.930$), see table M.7, is higher than the critical value ($\alpha = 0.05$). This means that the null hypothesis of $\mu_z = 0$ is not rejected with a certainty of more than 95%. The difference between round 2 and 3 at basin 1 is approximately zero.

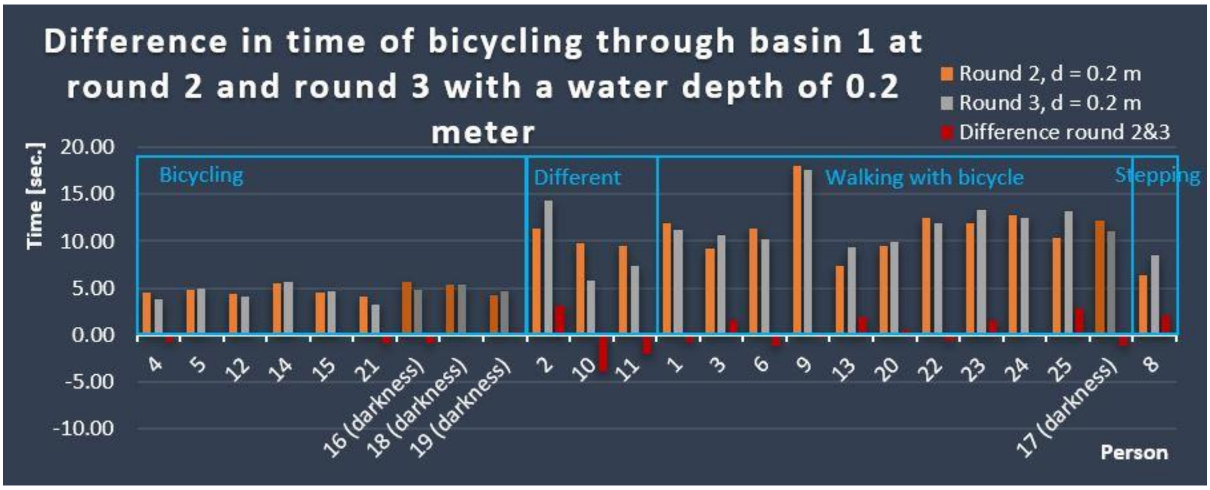


Figure M.2: Difference between round 2 and round 3 at basin 1.

V) Conclusion

There is a very strong positive linear relationship that is significant between round 2 and round 3 at basin 1. The difference between the time measurements of round 2 and round 3 is approximately zero which implies the time measurements from round 2 and round 3 are almost equal. Because of the equality, the mean of round 2 and round 3 of each person is used for basin 1 in further calculations.

M.3. Comparison of round 3 and round 5 at basin 3

As mentioned at the beginning of this appendix, round 3 has the same circumstances as round 5 at basin 2. The time measurements of each round are compared to each other to see if it is a good approximation to use the mean of both rounds for each person in further calculations.

I) Data

Time measurements of bicycling through the same water depth of d = 0.4 meter at basin 3					
	Person	**Round 3**	**Round 5**		**Mean round 3 and 5**
Bicycling	**4**	6.20	-		6.20
	5	9.43	-		9.43
	12	9.68	9.52		9.60
	14	7.93	7.79		7.86
	15	9.40	9.86		9.63
	21	9.88	9.65		9.77
	16 (darkness)	12.46	12.83		12.65
	18 (darkness)	14.01	14.02		14.02
	19 (darkness)	10.50	10.46		10.48
Carrying bicycle	**2**	12.60	-		12.60
	11	8.40	8.41		9.41
	13	10.02	11.50		10.76
Walking with bicycle	**1**	10.82	-		10.82
	3	12.17	-		12.17
	6	15.37	-		15.37
	7	-	-		-
	9	15.35	-		15.35
	10	11.88	12.13		12.01
	20	15.30	15.07		15.19
	22	13.26	13.26		13.26
	23	13.87	13.82		13.85
	24	16.43	16.56		16.50
	25	13.10	13.33		13.22
	17 (darkness)	19.69	19.80		19.75
Stepping	**8**	16.46	-		16.46

Table M.9: Time measurements in seconds of round 3 and round 5 at basin 3. The dark blue values are used in this paragraph as for all other rows time measurements are missing.

Notes:

- Persons 1 – 8 did not complete the bicycling part at round 5, to limit the amount of time during the experiment.
- Person 2 carried the bicycle during round 3.
- Person 7 did not complete round 3 and round 5.
- Person 11 and person 13 were walking with the bicycle at round 3 and carried the bicycle at round 5.

II) Variables

Variables of bicycling through the same water depth of d = 0.4 meter at basin 3	
X	Time round 3, d = 0.4 m [sec.]
Y	Time round 5, d = 0.4 m [sec.]

Table M.10: Variables X and Y.

III) Correlation

Hypothesis: $H_0: r_{XY} = 0$
$H_1: r_{XY} \neq 0$

Formula: $r_{XY} = \frac{n(\sum XY)-(\sum X)(\sum Y)}{\sqrt{n(\sum X^2)-(\sum X)^2}\sqrt{n(\sum Y^2)-(\sum Y)^2}}$

$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1-r_{XY}^2}}$ with $df = n - 2$

Correlation between bicycling through the same water depth of d = 0.4 meter at different rounds at basin 3								
r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
0.99	195.81	2547.98	199.01	2618.06	2581.09	16	25.64	$3.63 * 10^{-13}$

Table M.11: Correlation between time measurements from round 3 and round 5. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
14	0.426	0.497	0.623

Table M.12: Table of critical values for the correlation coefficient with n = 16.

See table M.12, for $df = 14$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.497 \leq r_{XY} \leq 0.497$ and 5% probability of finding a correlation outside this range.

Conclusion
From table M.11 the $r_{XY} \approx 0.99 > 0.426$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a very strong positive relation that is significant between round 3 and round 5 at basin 3.

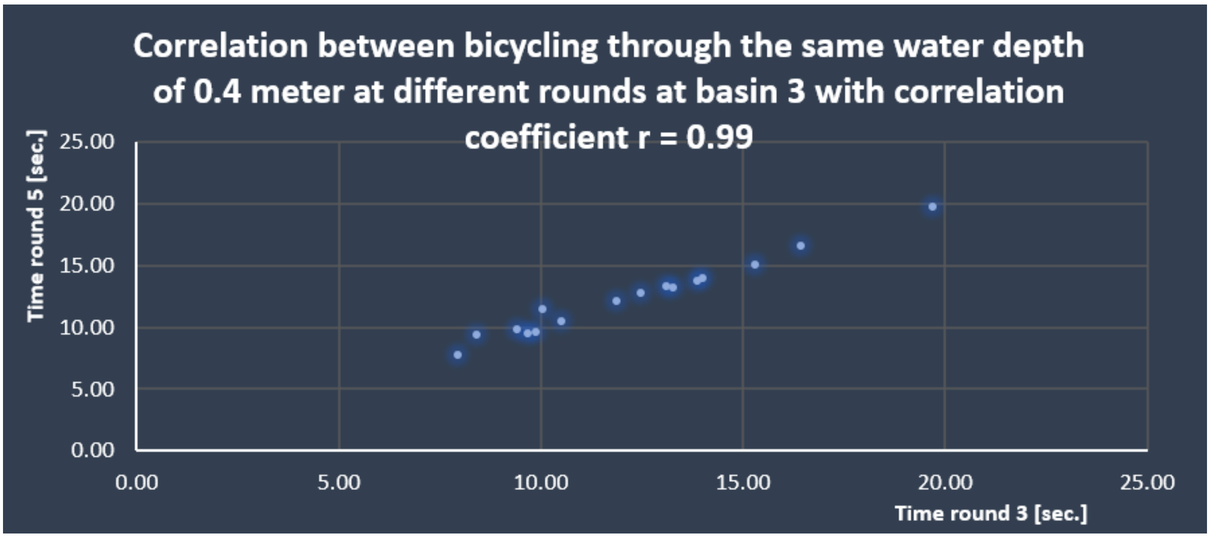


Figure M.3: Correlation between round 3 and round 5 at basin 3.

IV) Difference

Hypothesis: $H_0: \mu_z = 0$
$H_1: \mu_z \neq 0$

Formula: $T = \frac{\bar{Z} - \mu_z}{s}\sqrt{n}$

Test statistic and probability of the comparison of bicycling through the same water depth at different rounds at basin 3					
T	$\bar{Z}$	μ_z	n	$s = \sigma_z$	p
1.73	0.20	0	16	0.463	0.172

Table M.13: Test statistic and probability for the difference between round 3 and round 5 at basin 3.

Table of critical values for test statistic T										
df	**A**									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
14	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140

Table M.14: Table of critical values for test statistic T with n = 16.

See table M.14, for $df = 14$ with critical value $\alpha = 0.05$, the null hypothesis of $\mu_z = 0$ is rejected with a certainty of more than 95% if the p-value from the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

Conclusion
The p-value ($p = 0.172$), see table M.13, is higher than the critical value ($\alpha = 0.05$). This means that the null hypothesis of $\mu_z = 0$ is not rejected with a certainty of more than 95%. The difference between round 3 and 5 at basin 3 is approximately zero.

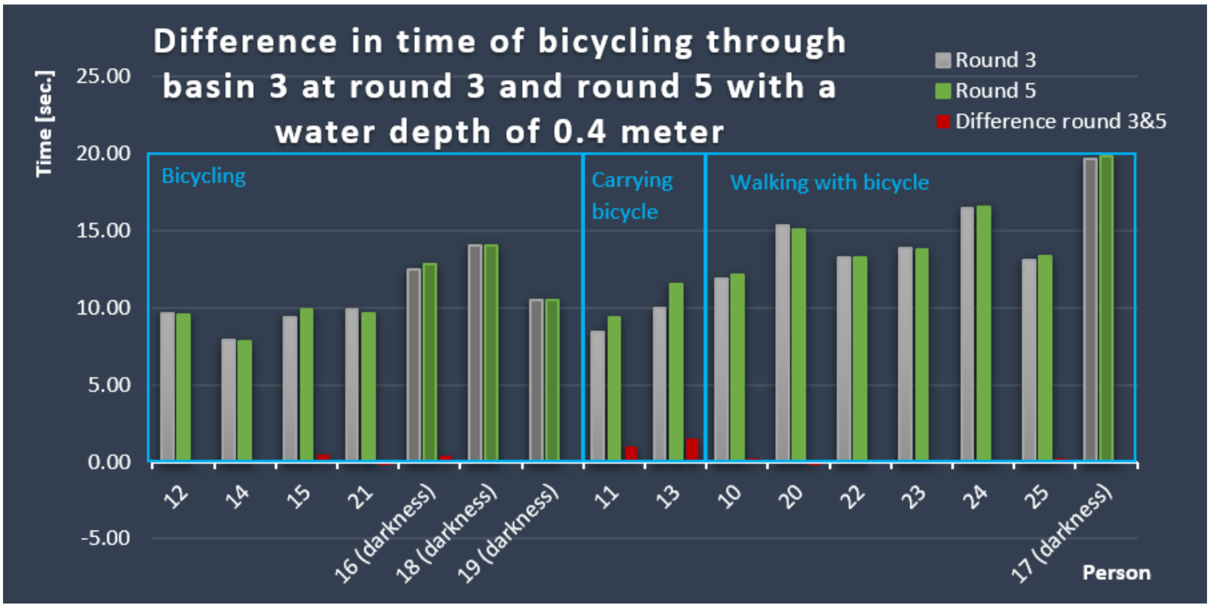


Figure M.4: Difference between round 3 and round 5 at basin 3.

V) Conclusion

There is a very strong positive linear relationship that is significant between round 3 and round 5 at basin 3. The difference between the time measurements of round 3 and round 5 is approximately zero which implies the time measurements from round 3 and round 5 are almost equal. Because of the equality, the mean of round 3 and round 5 of each person is used for basin 3 in further calculations.

N. Experiment: bicycling – Influence of water depth

- **What is the influence of water depth on the fleeing speed?**

Overview

Table N.1 gives an overview of which rounds with corresponding water depths will be compared to each other. Each basin has its own paragraph with the following structure: Data (I), Variables (II), Correlation (III), Difference (IV), Relation (V), and Graphs (VI).

		Round	Water depth
1.A)	**Basin 1**	1 and mean of 2&3	0.0 m and 0.2 m
2.A)	**Basin 2**	1 and 2	0.0 m and 0.4 m
2.B)		1 and 3	0.0 m and 0.6 m
3.A)	**Basin 3 – Bend**	1 and 2	0.0 m and 0.2 m
3.B)		1 and mean of 3&5	0.0 m and 0.4 m

Table N.1: Overview.

Bicycling:	Number of samples: Degrees of freedom (2-tailed):	n = 6 df = 4
Walking with bicycle:	Number of samples: Degrees of freedom (2-tailed):	n = 9 df = 7
Stepping:	There was only 1 person who used the bicycle as a step.	

Table N.2: Number of samples and degrees of freedom.

Correlation

Hypothesis: $H_0: r_{XY} = 0$
$H_1: r_{XY} \neq 0$

Formula: $$r_{XY} = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{n(\sum X^2) - (\sum X)^2}\sqrt{n(\sum Y^2) - (\sum Y)^2}}$$

$$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1 - r_{XY}^2}} \text{ with } df = n - 2$$

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
4	0.729	0.811	0.917
6	0.621	0.707	0.834
7	0.584	0.666	0.798

Table N.3: Table of critical values for the correlation coefficient with n = 21.

See table N.3, for $df = 4$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.811 \leq r_{XY} \leq 0.811$ and 5% probability of finding a correlation outside this range.

See table N.3, for $df = 6$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.707 \leq r_{XY} \leq 0.707$ and 5% probability of finding a correlation outside this range.

See table N.3, for $df = 7$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.666 \leq r_{XY} \leq 0.666$ and 5% probability of finding a correlation outside this range.

Difference

Hypothesis: $H_0: \mu_z = 0$
$H_1: \mu_z \neq 0$

Formula: $T = \frac{\bar{Z}-\mu_z}{S}\sqrt{n}$

Table of critical values for test statistic T										
df	**α**									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
4	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
6	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408

Table N.4: Table of critical values for test statistic T with n = 21.

See table N.4, with critical value $\alpha = 0.05$, the null hypothesis of $\mu_z = 0$ is rejected with a certainty of more than 95% if the p-value from the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

N.1. Basin 1: Bicycling and walking with a bicycle through water depths of 0.0 and 0.2 meter

I) Data

Time measurements of bicycling, walking with a bicycle and stepping through water depths of 0.0 and 0.2 meter at basin 1			
	Person	Time round 1 [sec.]	Time mean round 2&3 [sec.]
Bicycling	**4**	3.84	4.12
	5	4.80	4.87
	12	4.96	4.27
	14	4.58	5.56
	15	3.79	4.58
	21	3.90	3.65
Walking with bicycle	**3**	5.75	9.98
	6	6.42	10.82
	7	7.06	8.01
	9	14.56	17.88
	20	8.69	9.67
	22	6.51	12.20
	23	10.80	12.61
	24	10.70	12.70
	25	8.73	11.81
Stepping	**8**	4.33	7.40

Table N.5: Time measurements in seconds of round 1 and the mean of round 2&3 at basin 1. Persons 16 – 19 are not considered as this experiment took place in the dark. The time measurements of persons 1, 2, 10, 11, 13 cannot be taken into account, as these participants did not complete the rounds with the same method.

II) Variables

Variables of bicycling and walking with a bicycle through water at basin 1	
X	Time round 1, d = 0.0 m [sec.]
Y	Time mean round 2 and round 3, d = 0.2 m [sec.]

Table N.6: Variables X and Y.

III) Correlation

Correlation between walking through water depths of d = 0.0 and d = 0.2 meter at basin 1									
	r_{XY}	$\sum X$	$\sum X^2$	$\sum Y$	$\sum Y^2$	$\sum XY$	n	T	P
Bicycling	0.46	25.87	112.94	27.05	124.10	117.41	6	1.04	0.3583
Walking with bicycle	0.83	79.22	761.36	105.66	1302.00	982.11	9	3.93	0.0057

Table N.7: Correlation between time measurements from round 1 and the mean of round 2&3 at basin 1. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

From table N.7 the $r_{XY} \approx 0.46 < 0.811$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is that there is a weak positive relationship that is not significant between bicycling through water depths of 0.0 ad 0.2 meter at basin 1.

From table N.7 the $r_{XY} \approx 0.83 > 0.666$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a strong positive relationship that is significant between walking with a bicycling through water depths of 0.0 ad 0.2 meter at basin 1.

IV) Difference

Test statistic and probability of the comparison of walking through water depths of 0.0 and 0.2 meter at basin 1						
	T	$\bar{Z}$	μ_Z	n	$s = \sigma_Z$	p
Bicycling	0.76	0.20	0	6	0.63	0.4802
Walking with bicycle	5.38	2.94	0	9	1.64	0.0007

Table N.8: Test statistic and probability.

The p-value ($p = 0.4802$), see table N.8, is higher than the critical value ($\alpha = 0.05$). This means that the null hypothesis is not rejected with a certainty of more than 95%. There is no significant difference between bicycling through water depths of 0.0 and 0.2 meter at basin 1.

The p-value ($p = 0.0007$), see table N.8, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a significant difference between bicycling through water depths of 0.0 and 0.2 meter at basin 1.

V) Relation

Bicycling

There is a weak positive relationship that is not significant. No relation will be derived for this part.

Walking with bicycle

Reduction in speed:

$$\text{Reduction in speed} = \frac{\sum \frac{|\text{round 1} - \text{mean round 2\&3}|}{\text{mean round 2\&3}}}{\text{n}} * 100\% = 25.1\%$$

The reduction in speed in case of d = 0.2 m, compared to 0.0 m, is approximately 25.1%.

Least squares linear regression:	$\text{Time}_{d=0.2\text{ m}} \approx 0.81\ \text{Time}_{d=0.0\text{ m}} + 4.58$
Least squares intercept free linear regression:	$\text{Time}_{d=0.2\text{ m}} \approx 1.29\ \text{Time}_{d=0.0\text{ m}}$
Mean slope linear relation:	$\text{Time}_{d=0.2\text{ m}} \approx 1.39\ \text{Time}_{d=0.0\text{ m}}$

VI) Graphs

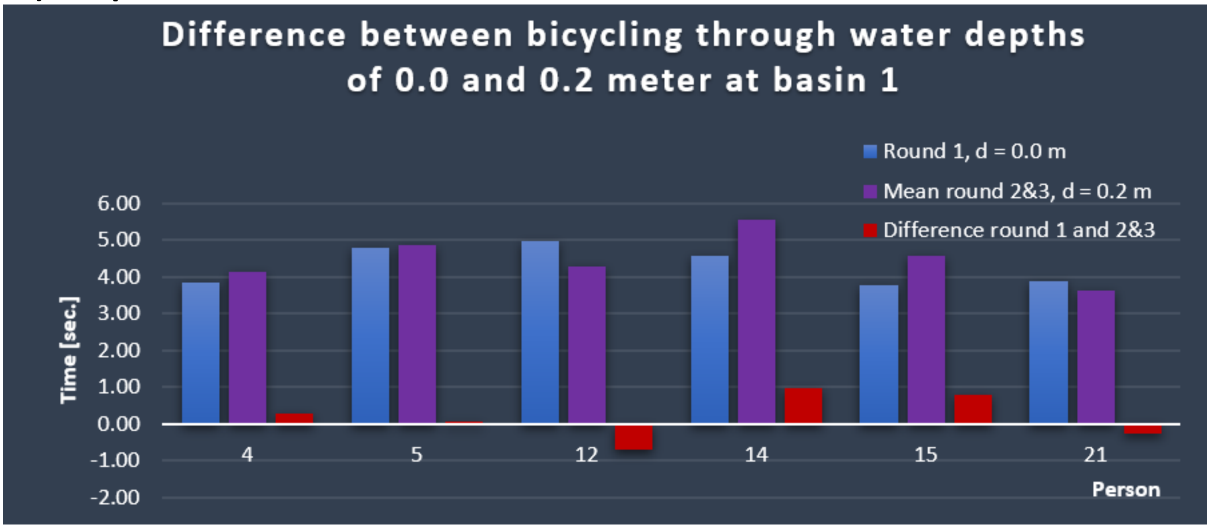


Figure N.1: Difference between round 1 and the mean of round 2&3 at basin 1.

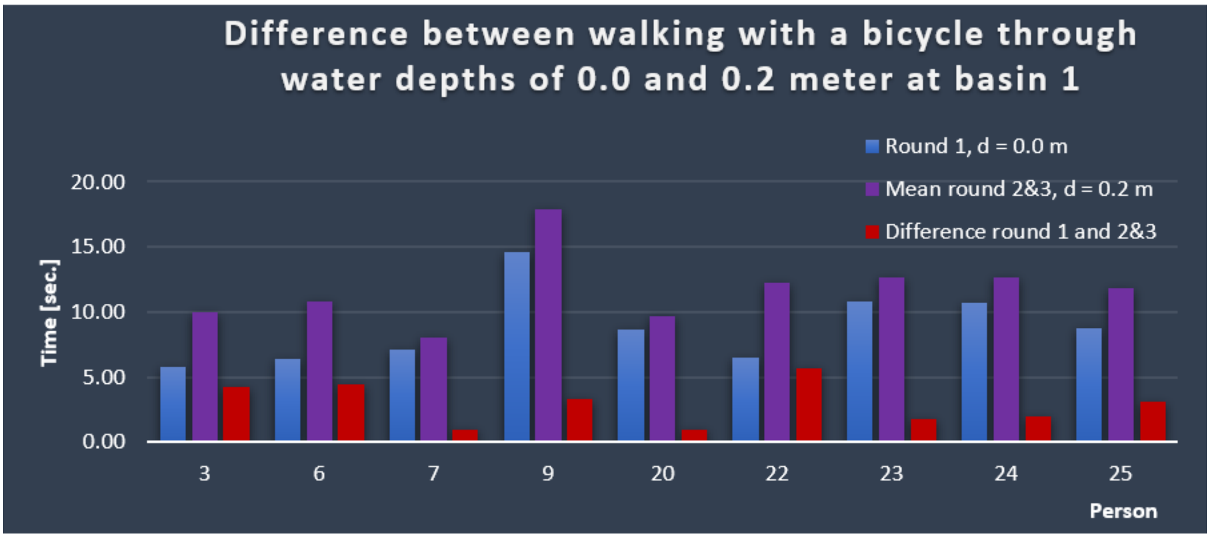


Figure N.2: Difference between round 1 and the mean of round 2&3 at basin 1.

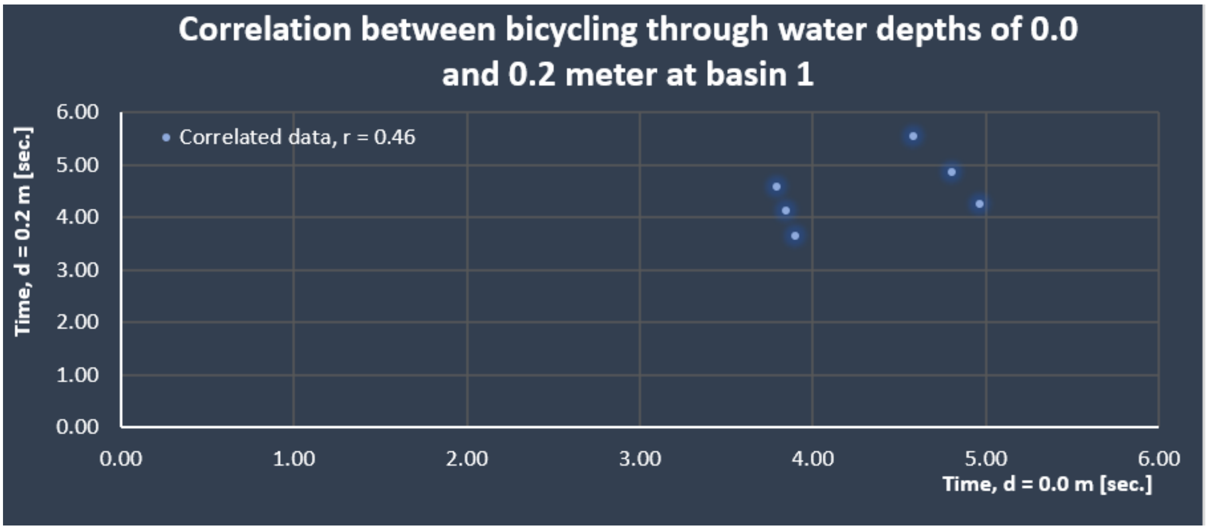


Figure N.3: Correlation between round 1 and the mean of round 2&3 at basin 1.

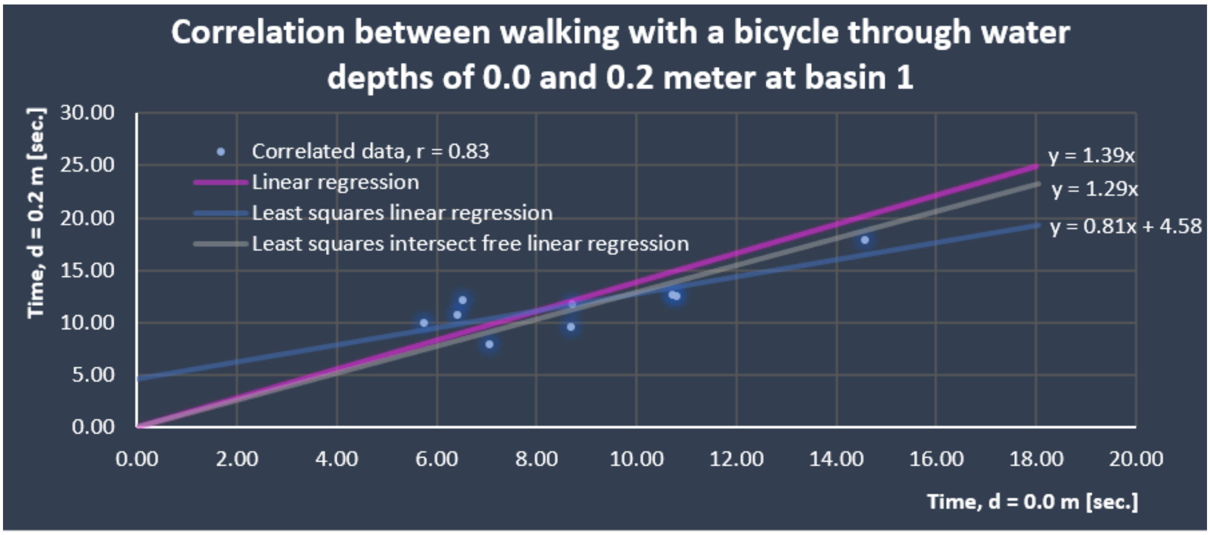


Figure N.4: Correlation between round 1 and the mean of round 2&3 at basin 1.

N.2. Basin 2: Bicycling and walking with a bicycle through water depths of 0.0, 0.4 and 0.6 meter

I) Data

Time measurements of bicycling, walking with a bicycle and stepping through water depths of 0.0, 0.4 and 0.6 meter at basin 2				
	Person	**Time round 1 [sec.]**	**Time round 2 [sec.]**	**Time round 3 [sec.]**
Bicycling	**4**	2.82	5.54	6.50
	5	2.53	4.53	14.14
	12	2.77	8.75	9.36
	14	5.43	7.93	7.84
	15	2.74	6.68	7.68
	21	4.35	10.89	11.68
Walking with bicycle	**3**	3.02	7.39	8.66
	6	2.61	8.47	8.94
	7	3.16	5.64	-
	9	8.23	14.53	16.33
	20	5.23	7.74	9.85
	22	3.64	11.57	11.00
	23	4.73	8.19	10.94
	24	5.51	8.85	10.07
	25	4.78	8.38	11.40
Stepping	**8**	4.09	7.44	8.54

Table N.9: Time measurements in seconds of round 1, round 2 and round 3 at basin 2. Persons 16 – 19 are not considered as this experiment took place in the dark. The time measurements of persons 1, 2, 10, 11, 13 cannot be taken into account, as these participants did not complete the rounds with the same method. Further, person 7 did not compete round 3.

II) Variables

Variables of bicycling and walking with a bicycle through water at basin 2		
	2.A	**2.B**
X	Time round 1, d = 0.0 m [sec.]	Time round 1, d = 0.0 m [sec.]
Y	Time round 2, d = 0.4 m [sec.]	Time round 3, d = 0.6 m [sec.]

Table N.10: Variables X and Y.

III) Correlation

Correlation between bicycling and walking with a bicycle through water depths of d = 0.0, d = 0.4 and d = 0.6 meter at basin 2				
	2.A		**2.B**	
	X: d = 0.0 m Y: d = 0.4 m		X: d = 0.0 m Y: d = 0.6 m	
	Bicycling	Walking with bicycle	Bicycling	Walking with bicycle
r_{XY}	0.56 $\sum X = 20.64$ $\sum X^2 = 77.94$ $\sum Y = 44.32$ $\sum Y^2 = 353.87$ $\sum XY = 160.06$ $n = 6$	0.69 $\sum X = 40.91$ $\sum X^2 = 209.93$ $\sum Y = 80.76$ $\sum Y^2 = 778.68$ $\sum XY = 391.98$ $n = 9$	-0.14 $\sum X = 20.64$ $\sum X^2 = 77.94$ $\sum Y = 57.20$ $\sum Y^2 = 586.67$ $\sum XY = 194.45$ $n = 6$	0.87 $\sum X = 37.75$ $\sum X^2 = 199.85$ $\sum Y = 87.19$ $\sum Y^2 = 990.66$ $\sum XY = 437.16$ $n = 8$
T	1.35	2.54	-0.28	4.30
p	0.2477	0.0385	-	0.0051

Table N.11: Correlation between time measurements from round 1, round 2 and round 3 at basin 2. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

Bicycling:

- 2.A) From table N.11 the $r_{XY} \approx 0.56 < 0.811$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is that there is a moderate positive relationship which is not significant between bicycling through water depths of 0.0 and 0.4 meter at basin 2.

- 2.B) From table N.11 the $r_{XY} \approx -0.14 < 0.433$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is that there is a very weak negative relationship which is not significant between bicycling through water depths of 0.0 and 0.6 meter at basin 2.

Walking with bicycle:

- 2.A) From table N.11 the $r_{XY} \approx 0.69 > 0.666$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a moderate positive relationship which is significant between walking with a bicycle through water depths of 0.0 and 0.4 meter at basin 2.

- 2.B) From table N.11 the $r_{XY} \approx 0.87 > 0.707$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a very strong positive relationship which is significant between walking with a bicycle through water depths of 0.0 and 0.6 meter at basin 2.

IV) Difference

Test statistic and probability of the comparison of walking through water depths of d = 0.0, d = 0.4 and d = 0.6 meter at basin 2				
	2.A		**2.B**	
	X: d = 0.0 m Y: d = 0.4 m		X: d = 0.0 m Y: d = 0.6 m	
	Bicycling	Walking with bicycle	Bicycling	Walking with bicycle
T	5.06 $\overline{Z} = 3.95$ $\mu_z = 0$ $n = 6$ $s = \sigma_z = 1.91$	7.09 $\overline{Z} = 4.43$ $\mu_z = 0$ $n = 9$ $s = \sigma_z = 1.87$	4.59 $\overline{Z} = 6.09$ $\mu_z = 0$ $n = 6$ $s = \sigma_z = 3.25$	14.17 $\overline{Z} = 6.18$ $\mu_z = 0$ $n = 8$ $s = \sigma_z = 1.23$
p	0.0039	0.0001	0.0059	$2 * 10^{-6}$

Table N.12: Test statistic and probability.

Bicycling

- 2.A) The p-value ($p = 0.0039$), see table N.12, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between bicycling through water depths of 0.0 and 0.4 meter at basin 2.

- 2.B) The p-value ($p = 0.0059$), see table N.12, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between bicycling through water depths of 0.0 and 0.6 meter at basin 2.

Walking with bicycle

- 2.A) The p-value ($p = 0.0001$), see table N.12, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking with a bicycle through water depths of 0.0 and 0.4 meter at basin 2.

- 2.B) The p-value ($p = 2 * 10^{-6}$), see table N.12, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking with a bicycle through water depths of 0.0 and 0.6 meter at basin 2.

V) Relation

Relation between walking with a bicycle through water depths of d = 0.0, d = 0.4 and d = 0.6 meter at basin 2		
	2.A	**2.B**
Reduction	$\frac{\sum \frac{\lvert round\ 1 - round\ 2 \rvert}{round\ 2}}{n} * 100\% = 48.8\%$	$\frac{\sum \frac{\lvert round\ 1 - round\ 3 \rvert}{round\ 3}}{n} * 100\% = 57.4\%$
Factor	$\frac{\sum \frac{round\ 2}{round\ 1}}{n} = 2.11$	$\frac{\sum \frac{round\ 3}{round\ 1}}{n} = 2.46$

Table N.13: Relation between rounds and factor.

Bicycling

There is a very weak negative relationship and a moderate positive relationship that both are not significant. No relation will be derived for this part.

Walking with bicycle

- 2.A) The reduction in speed in case of d = 0.4 m, compared to 0.0 m, is approximately 48.8%.
  - Least squares linear regression: $\text{Time}_{\text{d=0.4 m}} \approx 1.04\ \text{Time}_{\text{d=0.0 m}} + 4.24$
  - Least squares intercept free linear regression: $\text{Time}_{\text{d=0.4 m}} \approx 1.87\ \text{Time}_{\text{d=0.0 m}}$
  - Mean slope linear relation: $\text{Time}_{\text{d=0.4 m}} \approx 2.11\ \text{Time}_{\text{d=0.0 m}}$

- 2.B) The reduction in speed in case of d = 0.60 m, compared to 0 m, is approximately 57.4%.
  - Least squares linear regression: $\text{Time}_{\text{d=0.6 m}} \approx 1.19\ \text{Time}_{\text{d=0.0 m}} + 5.31$
  - Least squares intercept free linear regression: $\text{Time}_{\text{d=0.6 m}} \approx 2.19\ \text{Time}_{\text{d=0.0 m}}$
  - Mean slope linear relation: $\text{Time}_{\text{d=0.6 m}} \approx 2.46\ \text{Time}_{\text{d=0.0 m}}$

VI) Graphs

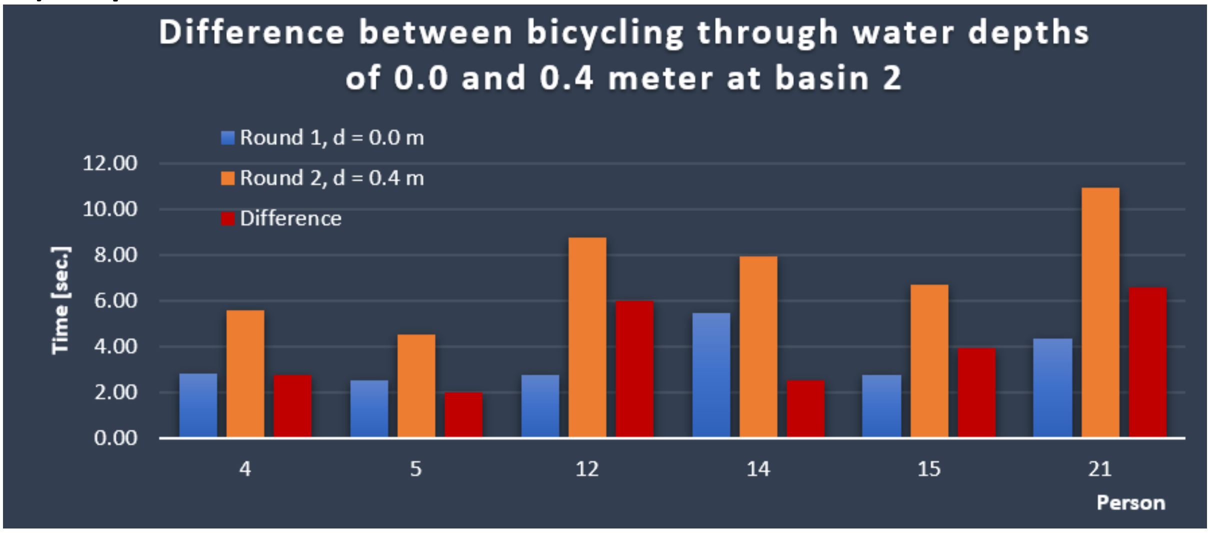


Figure N.5: Difference between round 1 and round 2 at basin 2.

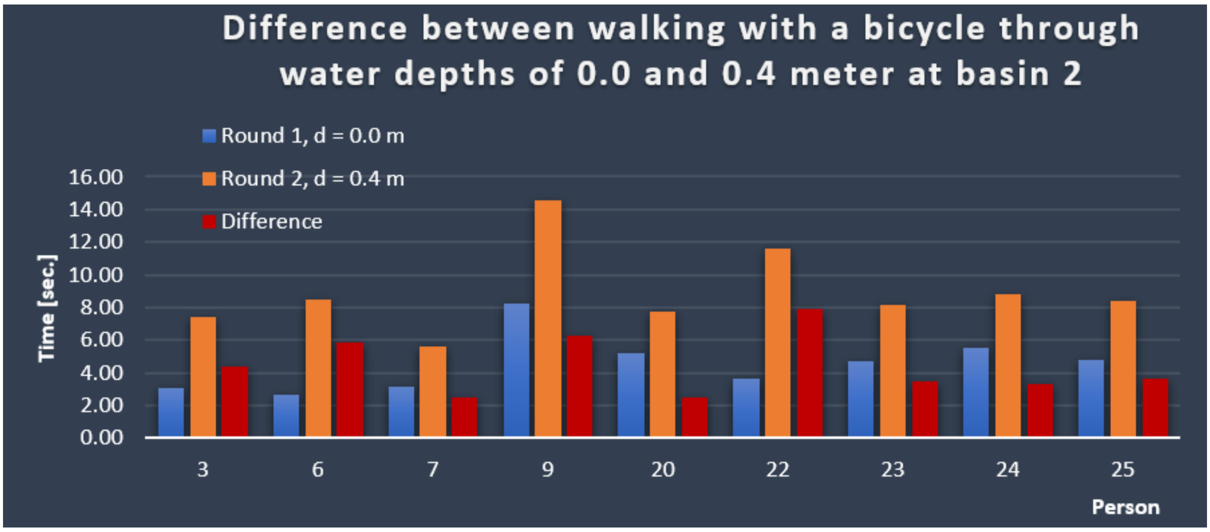


Figure N.6: Difference between round 1 and round 2 at basin 2.

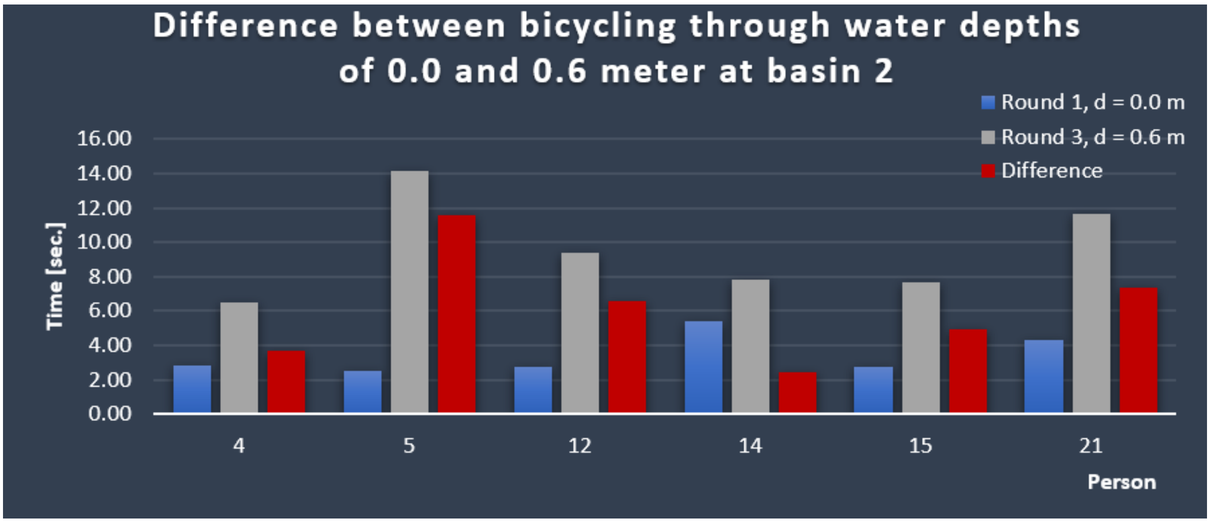


Figure N.7: Difference between round 1 and round 2 at basin 2.

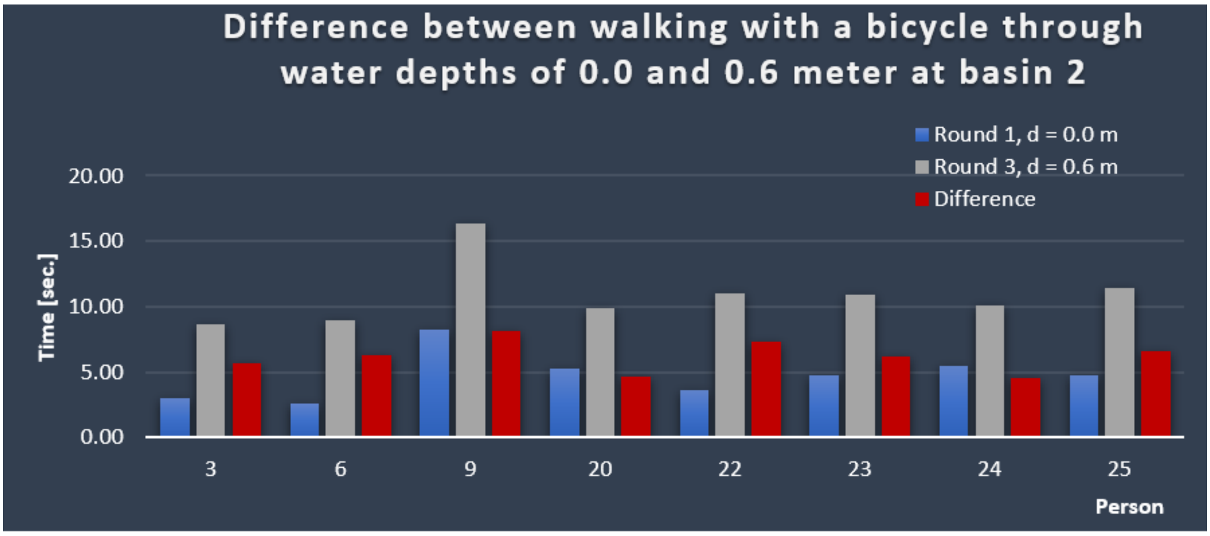


Figure N.8: Difference between round 1 and round 2 at basin 2.

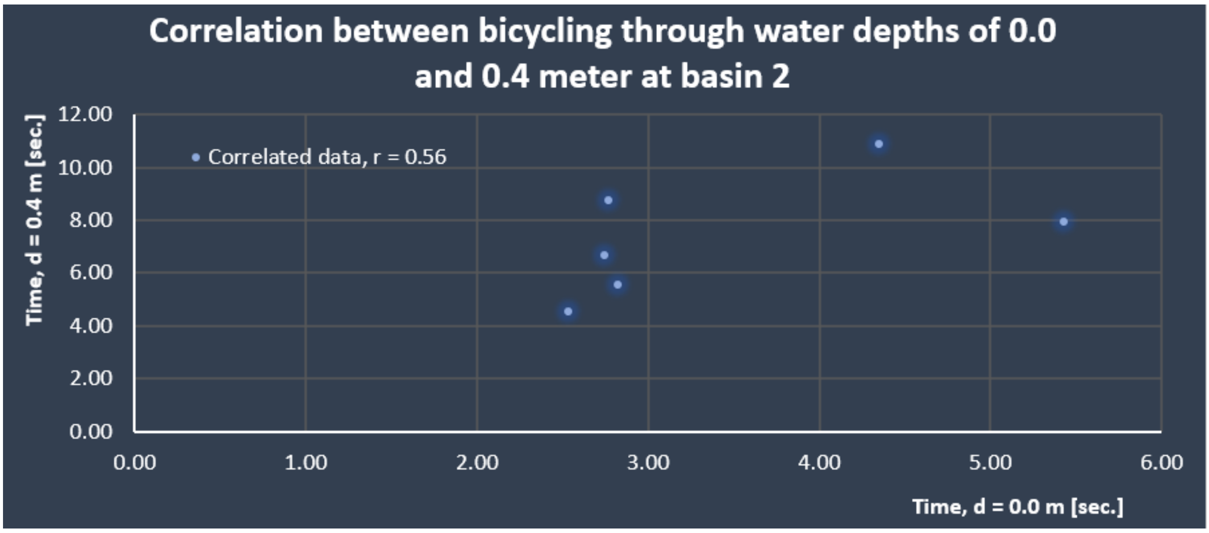


Figure N.9: Correlation between round 1 and round 2 at basin 2.

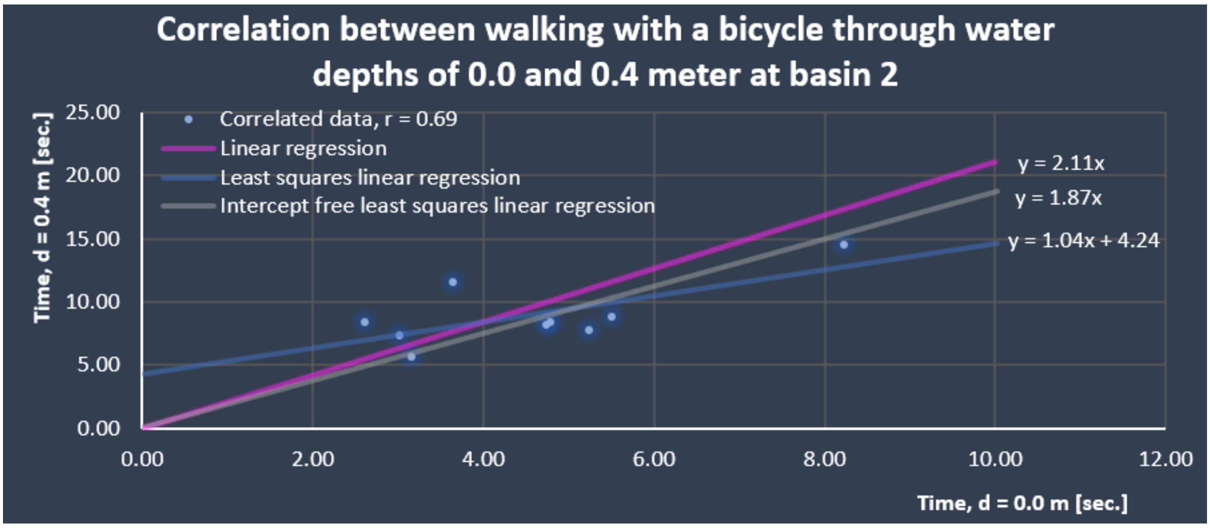


Figure N.10: Correlation between round 1 and round 2 at basin 2.

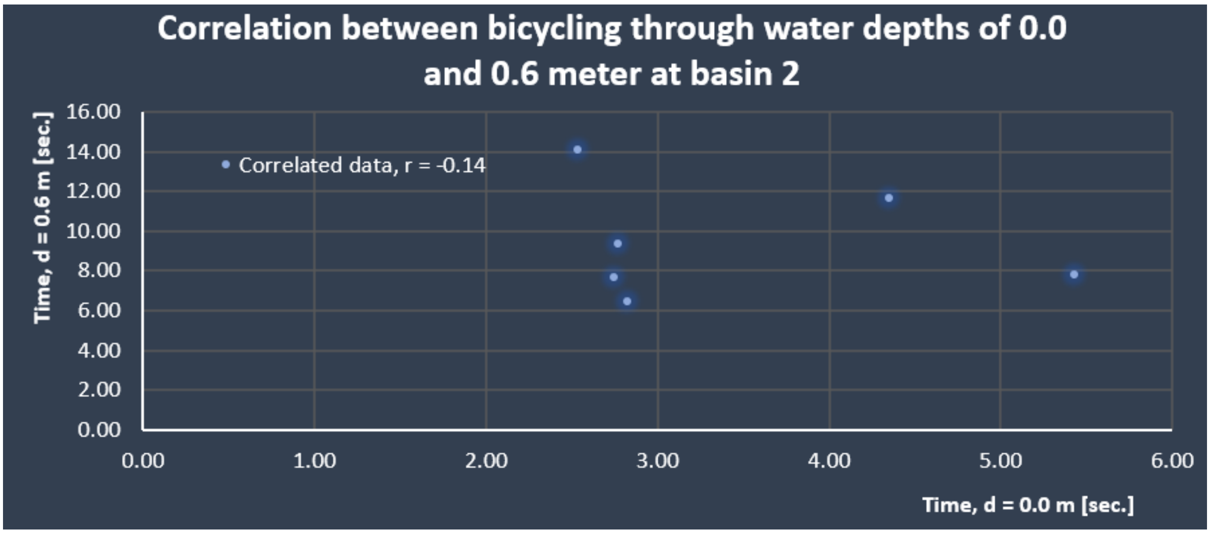


Figure N.11: Correlation between round 2 and round 3 at basin 2.

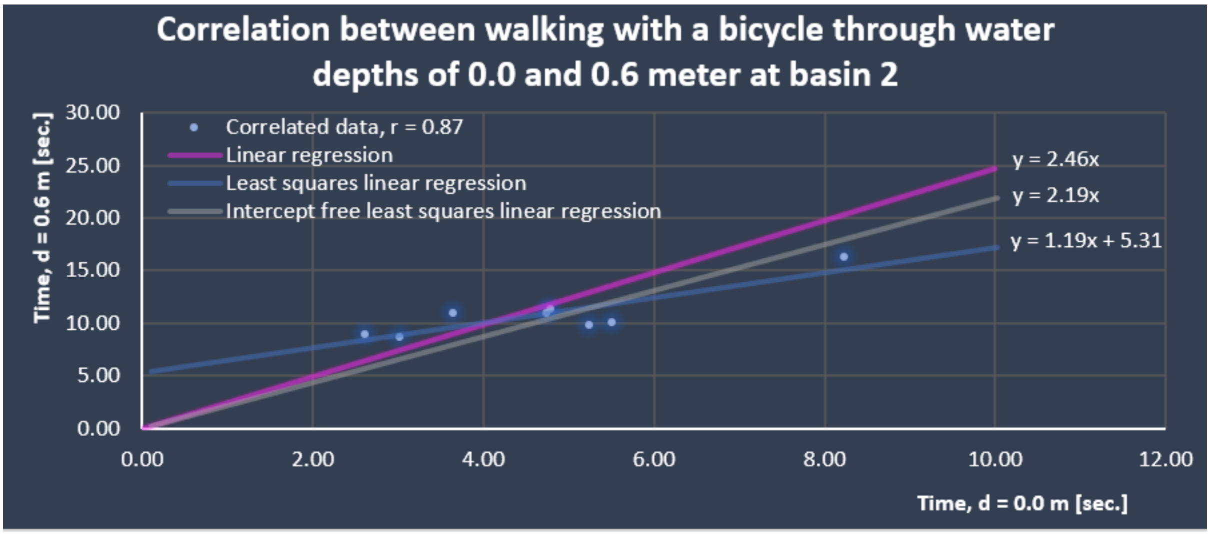


Figure N.12: Correlation between round 2 and round 3 at basin 2.

N.3. Basin 3: Bicycling and walking with a bicycle through water depths of 0.0, 0.2 and 0.4 meter

I) Data

	Time measurements of walking through basin 3			
	Person	**Time round 1 [sec.]**	**Time round 2 [sec.]**	**Time mean round 3&5 [sec.]**
Bicycling	**4**	2.59	3.92	6.20
	5	4.87	7.59	9.43
	12	3.36	4.08	9.60
	14	2.71	6.42	7.86
	15	6.47	6.59	9.63
	21	3.63	8.89	9.77
Walking with bicycle	**3**	5.99	6.48	12.17
	6	3.72	6.85	15.37
	7	3.95	6.62	-
	9	7.54	10.89	15.35
	20	6.06	10.68	15.19
	22	4.82	12.26	13.26
	23	5.47	12.81	13.85
	24	7.40	14.83	16.50
	25	6.42	7.77	13.22
Stepping	**8**	3.70	9.44	16.46

Table N.14: Time measurements in seconds of round 1, round 2 and the mean of round 3&5. Persons 16 – 19 are not considered as this experiment took place in the dark. The time measurements of persons 1, 2, 10, 11, 13 cannot be taken into account, as these participants did not complete the rounds with the same method. Further, person 7 did not compete round 3.

II) Variables

	Variables of walking through basin 3	
	3.A	**3.B**
X	Time round 1, d = 0.0 m [sec.]	Time round 1, d = 0.0 m [sec.]
Y	Time round 2, d = 0.2 m [sec.]	Time mean round 3&5, d = 0.4 m [sec.]

Table N.15: Variables X and Y.

III) Correlation

Correlation between walking through different water depths at basin 3				
	3.A)		**3.B)**	
	X: d = 0.0 m Y: d = 0.2 m		X: d = 0.0 m Y: d = 0.4 m	
	Bicycling	Walking with bicycle	Bicycling	Walking with bicycle
r_{XY}	0.38 $\sum X = 23.63$ $\sum X^2 = 104.10$ $\sum Y = 37.49$ $\sum Y^2 = 253.30$ $\sum XY = 153.13$ $n = 6$	0.51 $\sum X = 51.37$ $\sum X^2 = 308.03$ $\sum Y = 89.19$ $\sum Y^2 = 960.10$ $\sum XY = 526.07$ $n = 9$	0.62 $\sum X = 23.63$ $\sum X^2 = 104.10$ $\sum Y = 52.49$ $\sum Y^2 = 469.40$ $\sum XY = 213.29$ $n = 6$	0.26 $\sum X = 47.42$ $\sum X^2 = 292.42$ $\sum Y = 114.89$ $\sum Y^2 = 1664.79$ $\sum XY = 684.38$ $n = 8$
T	0.82	1.55	1.57	0.66
p	0.4597	0.1650	0.1906	0.5338

Table N.16: Correlation between time measurements from round 1, round 2 and round 3 at basin 3. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

Bicycling

- 3.A) From table N.16 the $r_{XY} \approx 0.38 < 0.811$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is that there is a weak positive linear relationship that is not significant between bicycling through water depths of 0.0 and 0.20 meter at basin 3.

- 3.B) From table N.16 the $r_{XY} \approx 0.62 < 0.811$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is that there is a moderate positive linear relationship that is not significant between bicycling through water depths of 0.0 and 0.4 meter at basin 3.

Walking with bicycle

- 3.A) From table N.16 the $r_{XY} \approx 0.51 < 0.666$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is that there is a moderate positive linear relationship that is not significant between walking with a bicycle through water depths of 0.0 and 0.20 meter at basin 3.

- 3.B) From table N.16 the $r_{XY} \approx 0.26 < 0.707$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is that there is a weak positive linear relationship that is not significant between walking with a bicycle through water depths of 0.0 and 0.4 meter at basin 3.

IV) Difference

Comparison of walking through different water depths at basin 3				
	3.A)		**3.B)**	
	X: d = 0.0 m Y: d = 0.2 m		X: d = 0.0 m Y: d = 0.4 m	
	Bicycling	Walking with bicycle	Bicycling	Walking with bicycle
T	2.89 $\overline{Z} = 2.31$ $\mu_z = 0$ $n = 6$ $s = \sigma_z = 1.96$	4.72 $\overline{Z} = 4.20$ $\mu_z = 0$ $n = 9$ $s = \sigma_z = 2.67$	9.23 $\overline{Z} = 4.81$ $\mu_z = 0$ $n = 6$ $s = \sigma_z = 1.28$	14.32 $\overline{Z} = 8.43$ $\mu_z = 0$ $n = 8$ $s = \sigma_z = 1.67$
p	0.0340	0.0015	0.00025	$1.9 * 10^{-6}$

Table N.17: Test statistic and probability.

Bicycling

- 3.A) The p-value ($p = 0.034$), see table N.17, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a relationship between bicycling through water depths of 0.0 and 0.2 meter at basin 3.

- 3.B) The p-value ($p = 0.00025$), see table N.17, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a relationship between bicycling through water depths of 0.0 and 0.4 meter at basin 3.

Walking with bicycle

- 3.A) The p-value ($p = 0.0015$), see table N.17, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a relationship between walking with a bicycle through water depths of 0.0 and 0.2 meter at basin 3.

- 3.B) The p-value ($p = 1.9 * 10^{-6}$), see table N.17, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a relationship between walking with a bicycle through water depths of 0.0 and 0.4 meter at basin 3.

V) Relation

There is a difference between bicycling or walking with a bicycle at water depths of 0, 0.2, 0.4 and 0.6 meter. However the correlation coefficient is not significant which means that no relation can be stated out.

VI) Graphs

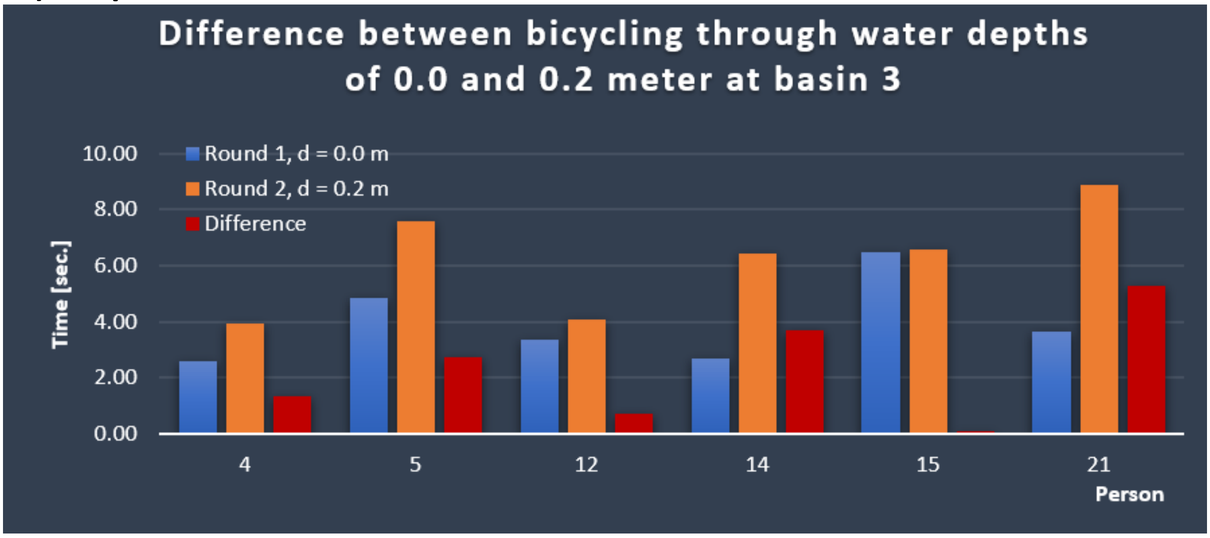


Figure N.13: Difference between round 1 and round 2 at basin 3.

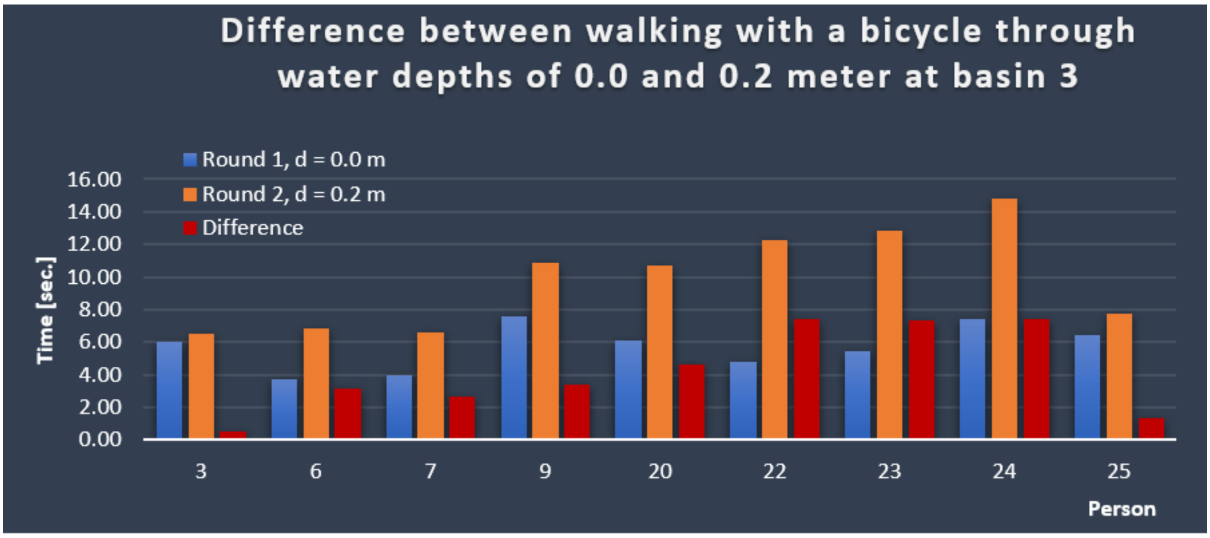


Figure N.14: Difference between round 1 and round 2 at basin 3.

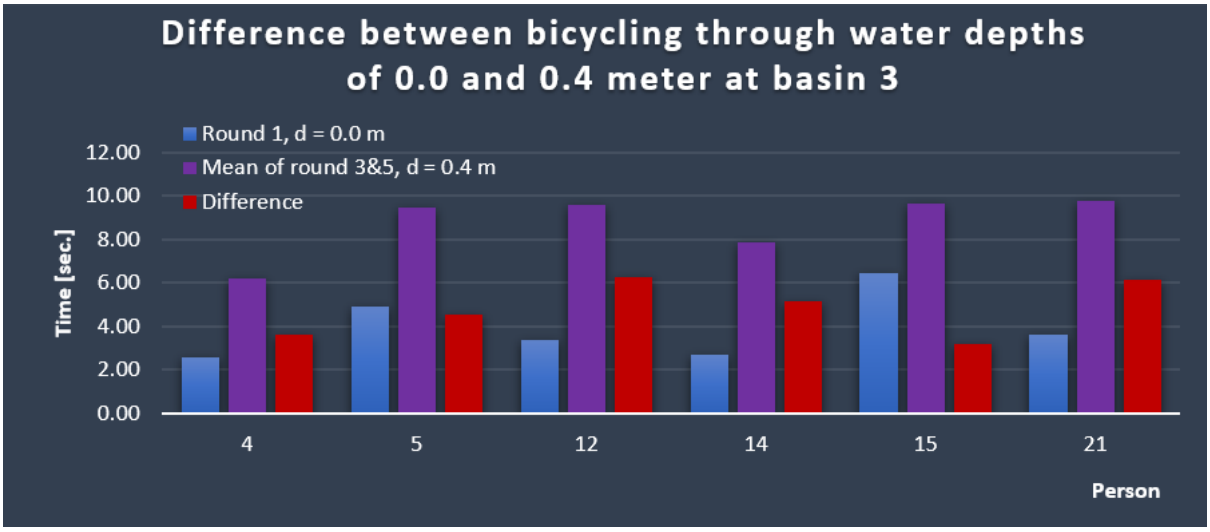


Figure N.15: Difference between round 2 and the mean of round 3&5 at basin 3.

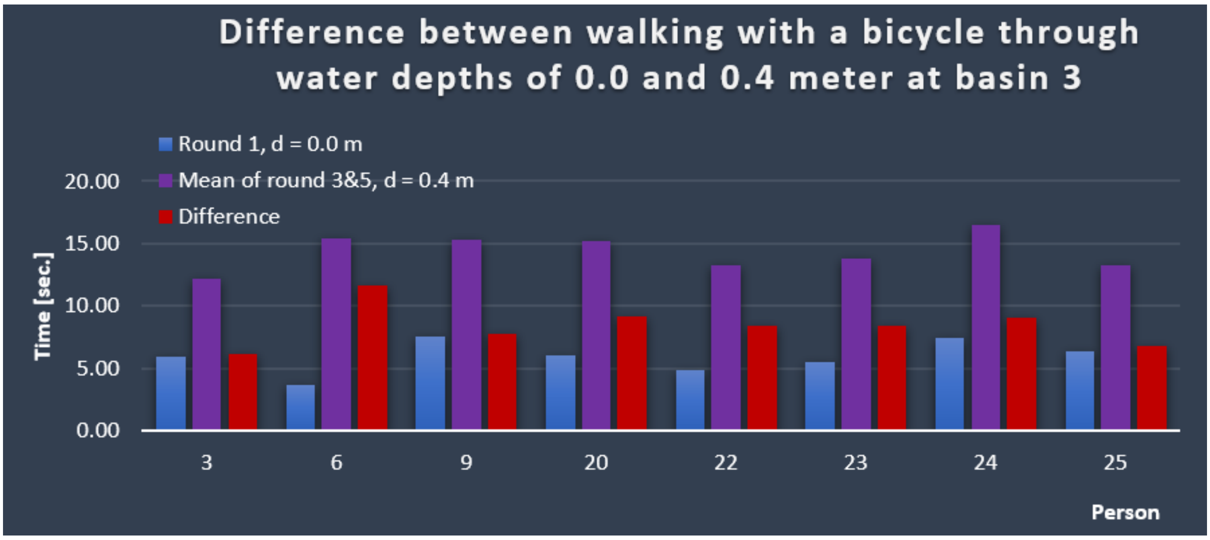


Figure N.16: Difference between round 2 and the mean of round 3&5 at basin 3.

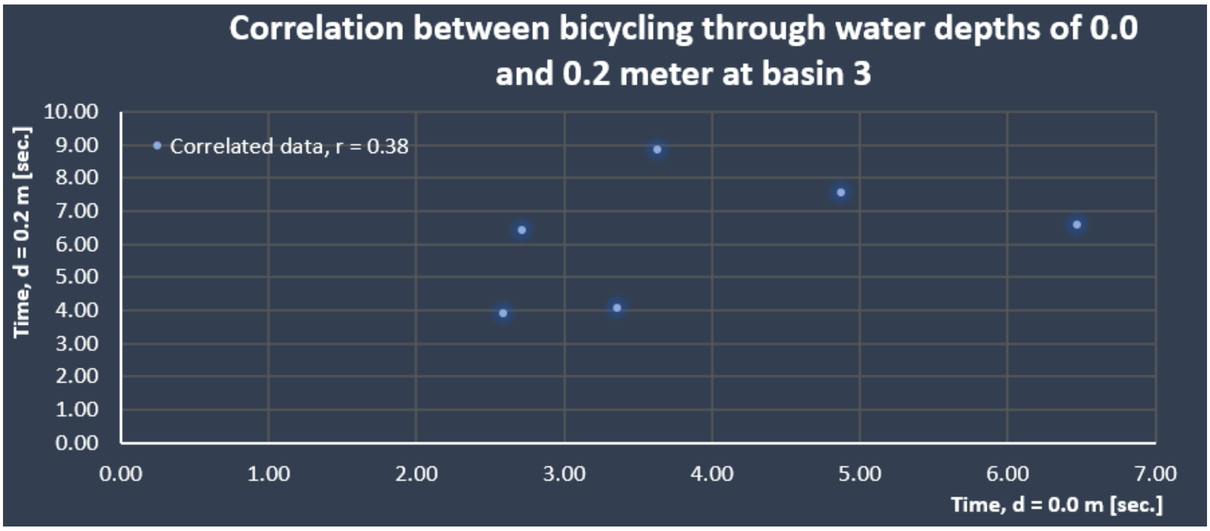


Figure N.17: Correlation between round 1 and round 2 at basin 3.

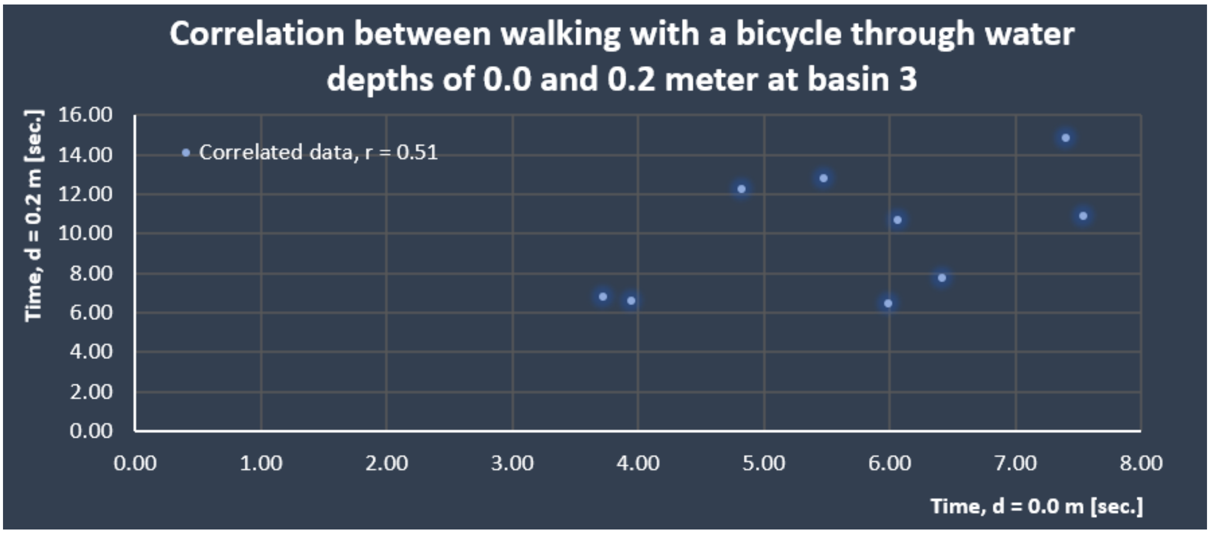


Figure N.18: Correlation between round 1 and round 2 at basin 3.

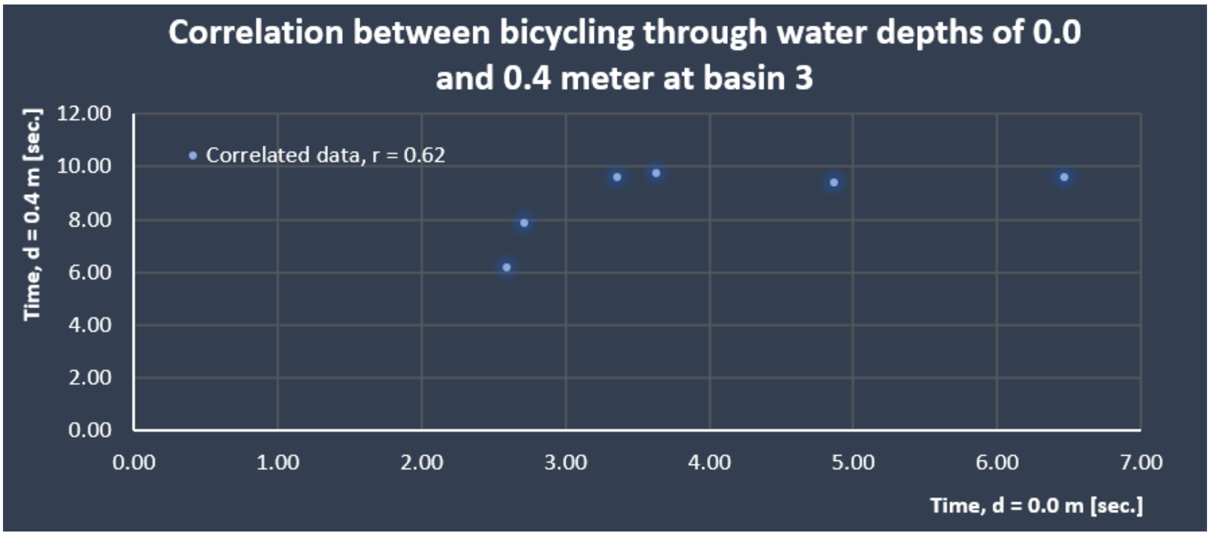


Figure N.19: Correlation between round 1 and the mean of round 3&5 at basin 3.

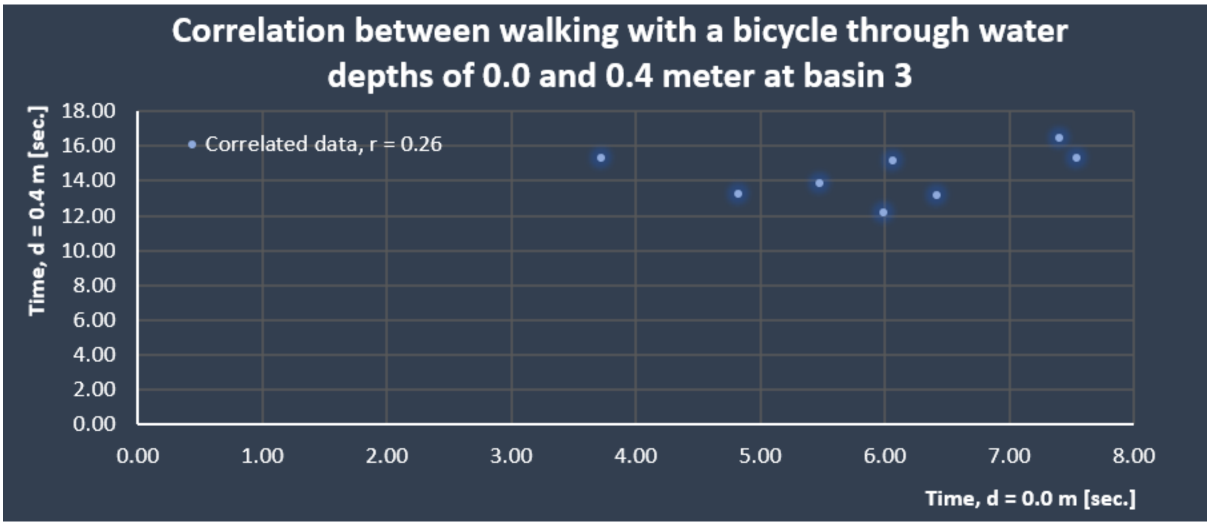


Figure N.20: Correlation between round 1 and the mean of round 3&5 at basin 3.

N.4. Overview of bicycling and walking with a bicycle trough different water depths

Basin		Round	Water depth	Means of transport	Correlation (Pearson T-test)			Difference (T-test)		Relation
					r_{XY}	T	p	T	p	
1)		1 and mean of 2&3	0.0 m 0.2 m	Bicycling	0.46	1.04	0.3583	0.76	0.4802	-
				Walking with bicycle	0.83	3.93	0.0057	5.38	0.0007	$t_{d=0.2\ m} \approx 1.29\ t_{d=0.0\ m}$
2)	A	1 and 2	0.0 m 0.4 m	Bicycling	0.56	1.35	0.2477	5.06	0.0039	-
				Walking with bicycle	0.69	2.54	0.0385	7.09	0.0001	$t_{d=0.4\ m} \approx 1.87\ t_{d=0.0\ m}$
	B	1 and 3	0.0 m 0.6 m	Bicycling	-0.14	-0.28	-	4.59	0.0059	-
				Walking with bicycle	0.87	4.30	0.0051	14.17	$2 * 10^{-6}$	$t_{d=0.6\ m} \approx 2.19\ t_{d=0.0\ m}$
3)	A	1 and 2	0.0 m 0.2 m	Bicycling	0.38	0.82	0.4597	2.89	0.0340	-
				Walking with bicycle	0.51	1.55	0.1650	4.72	0.0015	-
	B	1 and mean of 3&5	0.0 m 0.4 m	Bicycling	0.62	1.57	0.1906	9.23	0.0003	-
				Walking with bicycle	0.26	0.66	0.5338	14.32	$2 * 10^{-6}$	-

Table N.18: Overview results.

Correlation

- r_{XY} = correlation coefficient. A large value for r_{XY} gives a low probability p and a strong linear correlation.
- T = test statistic. A large value for T gives a low probability p.
- p = probability of finding no correlation between variable X and Y ($r_{XY} = 0$). If there is no correlation, variable X does not increase when variable Y increases and vice versa.

Difference

- T = test statistic. A large value for T gives a low probability p.
- p = probability of finding a zero mean difference between variable X and Y ($\mu_z = 0$). If the mean difference is zero, variable X and Y are equal and there is no difference the time measurements.

Straight part (basin 1 and 2)	
$t_{d=0.2\ m} \approx 1.3\ t_{d=0.0\ m}$	Strong correlation
$t_{d=0.4\ m} \approx 1.9\ t_{d=0.0\ m}$	Moderate correlation
$t_{d=0.6\ m} \approx 2.2\ t_{d=0.0\ m}$	Strong correlation

Table N.19: Overview relations.

O. Experiment: bicycling – Influence of debris

Overview

Table O.1 gives an overview of which rounds with corresponding water depths will be compared to each other. Each basin has its own paragraph with the following structure: Data (I), Variables (II), Correlation (III), Difference (IV), Relation (V), and Graphs (VI).

		Round	Water depth
1.A)	**Basin 1 – Floating debris**	1 and 5	0.0 m and 0.2 m
1.B)		Mean of 2&3 and 5	0.2 m and 0.2 m
2.A)	**Basin 2 – Submerged debris**	1 and 5	0.0 m and 0.6 m
2.B)		3 and 5	0.6 m and 0.6 m

Table O.1: Overview.

Bicycling: Number of samples: n = 4
Degrees of freedom (2-tailed): df = 2

Walking with bicycle: Number of samples: n = 5
Degrees of freedom (2-tailed): df = 3

Correlation

Hypothesis: $H_0: r_{XY} = 0$
$H_1: r_{XY} \neq 0$

Formula: $$r_{XY} = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{n(\sum X^2) - (\sum X)^2}\sqrt{n(\sum Y^2) - (\sum Y)^2}}$$
$$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1 - r_{XY}^2}} \text{ with } df = n - 2$$

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
2	0.900	0.950	0.990
3	0.805	0.878	0.959

Table O.2: Table of critical values for the correlation coefficient with n = 21.

See table O.2, for $df = 2$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.950 \leq r_{XY} \leq 0.950$ and 5% probability of finding a correlation outside this range.

See table O.2, for $df = 3$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.878 \leq r_{XY} \leq 0.878$ and 5% probability of finding a correlation outside this range.

Difference

Hypothesis: $H_0: \mu_z = 0$
$H_1: \mu_z \neq 0$

Formula: $$T = \frac{\bar{Z} - \mu_z}{s}\sqrt{n}$$

Table of critical values for test statistic T										
df	**α**									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
2	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.33	31.599
3	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.21	12.924

Table O.3: Table of critical values for test statistic T with n = 21.

See table O.3, with a critical value $\alpha = 0.05$, the null hypothesis of $\mu_z = 0$ is rejected with a certainty of more than 95% if the p-value from the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

O.1. Basin 1: Bicycling through floating debris with water depths of 0.0 and 0.2 meter

I) Data

Time measurements of bicycling and walking with a bicycle through basin 1				
	Person	**Time round 1 [sec.]**	**Time mean round 2&3 [sec.]**	**Time round 5 [sec.]**
Bicycling	**12**	4.96	4.27	9.38
	14	4.58	5.56	14.14
	15	3.79	4.58	11.77
	21	3.90	3.65	10.52
Walking with bicycle	**20**	8.69	9.67	13.01
	22	6.51	12.20	18.14
	23	10.80	12.61	18.49
	24	10.70	12.70	15.66
	25	8.73	11.81	14.03

Table O.4: Time measurements in seconds of round 1, the mean of round 2&3 and round 5 at basin 1. Persons 16 – 19 are not considered as this experiment took place in the dark.

II) Variables

Variables of bicycling and walking with a bicycle through basin 1		
	1.A	**1.B**
X	Time round 1, d = 0.0 m [sec.]	Time mean round 2&3, d = 0.2 m [sec.]
Y	Time round 5, d = 0.2 m [sec.]	Time round 5, d = 0.2 m [sec.]

Table O.5: Variables X and Y.

III) Correlation

Correlation of bicycling and walking with a bicycle through different water depths at basin 1				
	1.A		**1.B**	
	X: d = 0.0 Y: d = 0.2, with floating debris		X: d = 0.2 Y: d = 0.2, with floating debris	
	Bicycling	Walking with bicycle	Bicycling	Walking with bicycle
r_{XY}	-0.12 $\sum X = 17.23$ $\sum X^2 = 75.15$ $\sum Y = 45.81$ $\sum Y^2 = 537.13$ $\sum XY = 196.92$ $n = 4$	0.01 $\sum X = 45.43$ $\sum X^2 = 425.24$ $\sum Y = 79.33$ $\sum Y^2 = 1282.28$ $\sum XY = 720.88$ $n = 5$	0.85 $\sum X = 18.06$ $\sum X^2 = 83.41$ $\sum Y = 45.81$ $\sum Y^2 = 537.13$ $\sum XY = 210.92$ $n = 4$	0.74 $\sum X = 58.98$ $\sum X^2 = 701.76$ $\sum Y = 45.81$ $\sum Y^2 = 1282.28$ $\sum XY = 944.61$ $n = 5$
T	-0.17	0.01	2.27	1.90
p	-	0.9932	0.1514	0.1532

Table O.6: Correlation between time measurements of round 1, the mean of round 2&3 and round 5 at basin 1. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

Bicycling:

- 1.A) From table O.6 the $r_{XY} \approx -0.12 < 0.950$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is that there is a very weak negative correlation that is not significant between bicycling through a water depth of 0.0 m without floating debris and 0.2 m with floating debris at basin 1.

- 1.B) From table O.6 the $r_{XY} \approx 0.85 < 0.950$. The null hypothesis $r_{XY} = 0$ is not rejected and the conclusion is that there is a strong positive correlation that is not significant between bicycling through a water depth of 0.2 m without floating debris and 0.2 m with floating debris at basin 1.

Walking with bicycle:

- 1.A) From table O.6 the $r_{XY} \approx 0.01 < 0.878$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is that there is a very weak positive correlation that is not significant between walking with a bicycle through a water depth of 0.0 m without floating debris and 0.2 m with floating debris at basin 1.

- 1.B) From table O.6 the $r_{XY} \approx 0.74 < 0.878$. The null hypothesis $r_{XY} = 0$ is not rejected and the conclusion is that there is a strong positive correlation that is not significant between walking with a bicycle through a water depth of 0.2 m without floating debris and 0.2 m with floating debris at basin 1.

IV) Difference

Test statistic and probability of the comparison of bicycling and walking with a bicycle through water depths of d = 0.0 and d = 0.2 meter at basin 1				
	1.A		**1.B**	
	X: d = 0.0 Y: d = 0.2, with floating debris		X: d = 0.2 Y: d = 0.2, with floating debris	
	Bicycling	Walking with bicycle	Bicycling	Walking with bicycle
T	6.56 $\overline{Z} = 7.15$ $\mu_Z = 0$ $n = 4$ $s = \sigma_Z = 2.178$	5.06 $\overline{Z} = 6.78$ $\mu_Z = 0$ $n = 5$ $s = \sigma_Z = 2.996$	9.73 $\overline{Z} = 6.94$ $\mu_Z = 0$ $n = 4$ $s = \sigma_Z = 1.427$	5.27 $\overline{Z} = 4.07$ $\mu_Z = 0$ $n = 5$ $s = \sigma_Z = 1.728$
p	0.0072	0.0072	0.0023	0.0062

Table O.7: Test statistic and probability.

Bicycling:

- 1.A) The p-value ($p = 0.0072$), see table O.7, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between bicycling with a water depth of 0.0 m without debris and 0.2 m with floating debris at basin 1.

- 1.B) The p-value ($p = 0.0023$), see table O.7, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between bicycling with a water depth of 0.2 m without debris and 0.2 m with floating debris at basin 1.

Walking with bicycle:

- 1.A) The p-value ($p = 0.0072$), see table O.7, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking with a bicycle with a water depth of 0.0 m without debris and 0.2 m with floating debris at basin 1.

- 1.B) The p-value ($p = 0.0062$), see table O.7, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking with a bicycle with a water depth of 0.2 m without debris and 0.2 m with floating debris at basin 1.

V) Relation

There is a difference between bicycling or walking with a bicycle at water depths of 0.0 meter without debris and 0.2 meter with floating debris. Also, there is a difference between bicycling or walking with a bicycle at water depth of 0.2 meter with and without floating debris. However, no significant correlation is found.

VI) Graphs

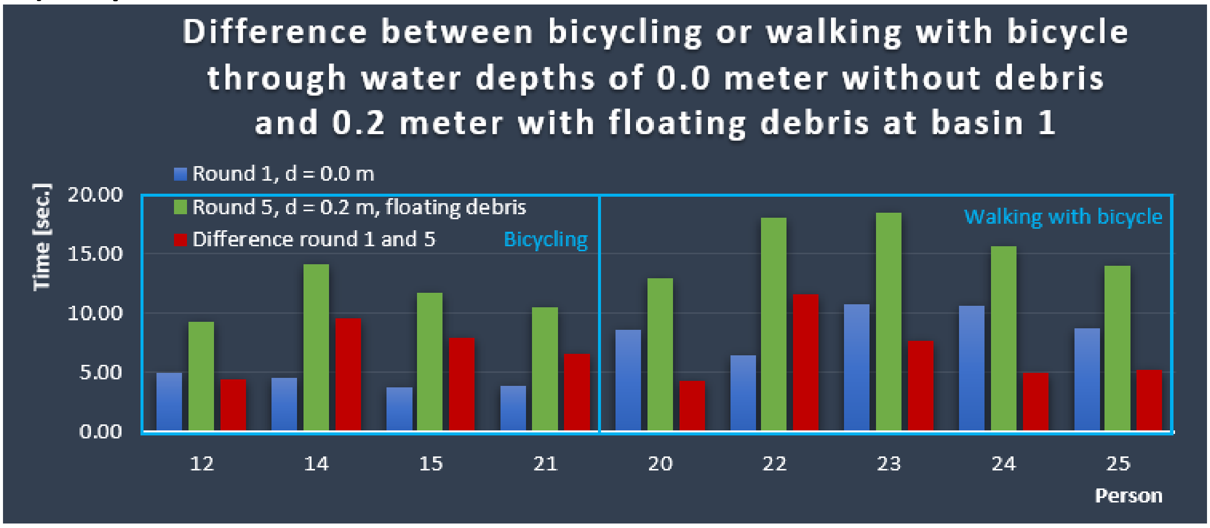


Figure O.1: Difference between round 1 and round 5 at basin 1.

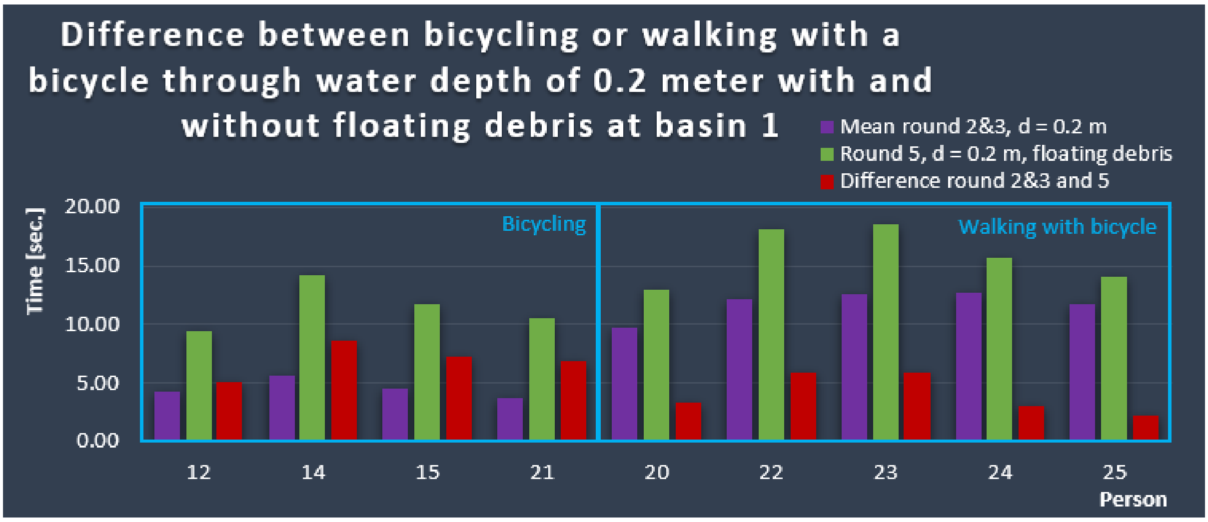


Figure O.2: Difference between the mean of round 2&3 and round 5 at basin 1.

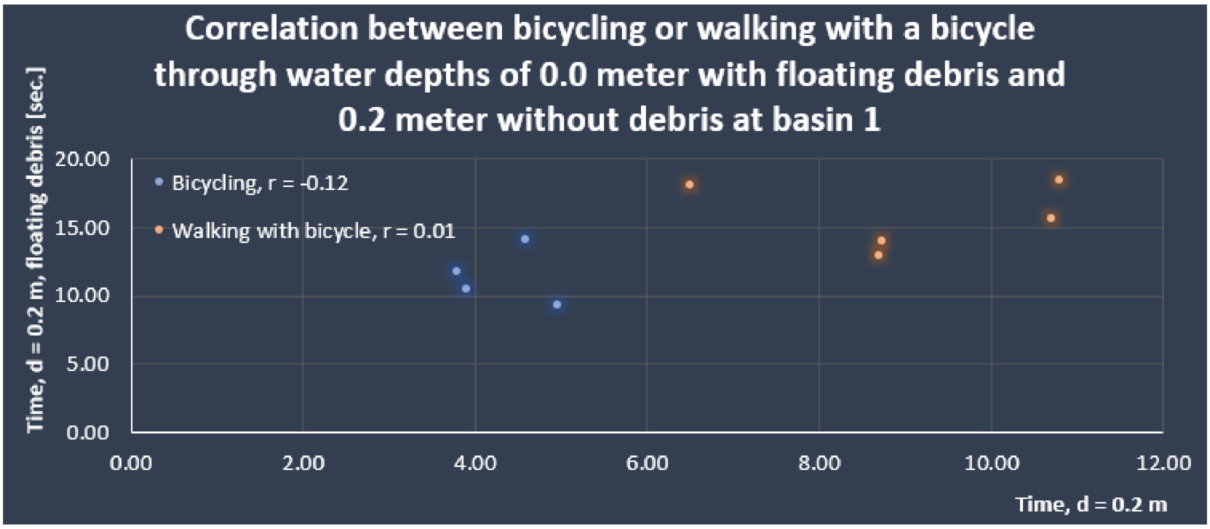


Figure O.3: Correlation between round 1 and round 5 at basin 1.

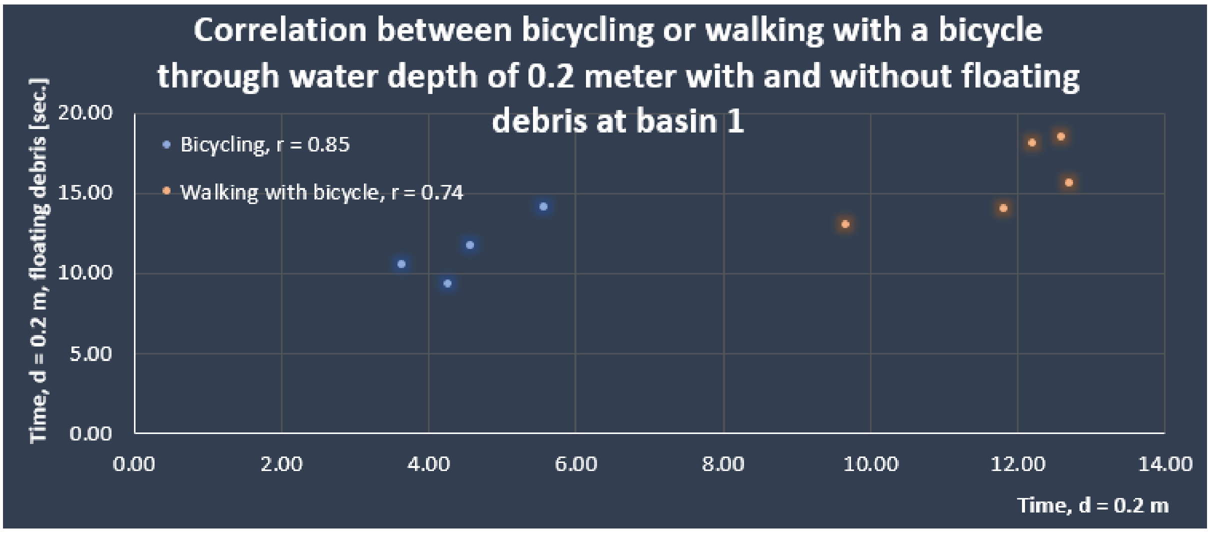


Figure O.4: Correlation between the mean of round 2&3 and round 5 at basin 1.

O.2. Basin 2: Bicycling through submerged debris with water depths of 0.0 and 0.6 meter

I) Data

Time measurements of bicycling and walking with a bicycle through basin 2				
	Person	**Time round 1 [sec.]**	**Time round 3 [sec.]**	**Time round 5 [sec.]**
Bicycling	**12**	2.77	9.36	12.43
	14	5.43	7.84	11.93
	15	2.74	7.68	11.76
	21	4.35	11.68	16.73
Walking with bicycle	**20**	5.23	9.85	14.15
	22	3.64	11.00	16.34
	23	4.73	10.94	14.18
	24	5.51	10.07	25.73
	25	4.78	11.40	16.46

Table O.8: Time measurements in seconds of round 1, the mean of round 2&3 and round 5 at basin 1. Persons 16 – 19 are not considered as this experiment took place in the dark.

II) Variables

Variables of bicycling and walking with a bicycle through basin 2		
	2.A	**2.B**
X	Time round 1, d = 0.0 m [sec.]	Time round 3, d = 0.6 m [sec.]
Y	Time round 5, d = 0.6 m [sec.]	Time round 5, d = 0.6 m [sec.]

Table O.9: Variables X and Y.

III) Correlation

Correlation of bicycling and walking with a bicycle through different water depths at basin 2				
	2.A		**2.B**	
	X: d = 0.0 Y: d = 0.6, with submerged debris		X: d = 0.6 Y: d = 0.6, with submerged debris	
	Bicycling	Walking with bicycle	Bicycling	Walking with bicycle
r_{XY}	0.24 $\sum X = 15.29$ $\sum X^2 = 63.59$ $\sum Y = 52.85$ $\sum Y^2 = 715.02$ $\sum XY = 204.21$ $n = 4$	0.44 $\sum X = 23.89$ $\sum X^2 = 116.18$ $\sum Y = 86.86$ $\sum Y^2 = 1601.26$ $\sum XY = 421.00$ $n = 5$	0.95 $\sum X = 36.56$ $\sum X^2 = 344.48$ $\sum Y = 52.85$ $\sum Y^2 = 715.02$ $\sum XY = 495.60$ $n = 4$	-0.33 $\sum X = 53.26$ $\sum X^2 = 569.07$ $\sum Y = 86.86$ $\sum Y^2 = 1601.26$ $\sum XY = 920.99$ $n = 5$
T	0.34	0.84	4.54	-0.61
p	0.7640	0.4624	0.0452	-

Table O.10: Correlation between time measurements of round 1, round 3 and round 5 at basin 2. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

Bicycling:

- 1.A) From table O.10 the $r_{XY} \approx 0.24 < 0.950$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is that there is a very weak negative correlation that is not significant between bicycling through a water depth of 0.0 m without debris and 0.6 m with submerged debris at basin 2.

- 1.B) From table O.10 the $r_{XY} \approx 0.9548 > 0.950$. The null hypothesis $r_{XY} = 0$ is rejected and the conclusion is that there is a very strong positive correlation that is significant between bicycling through a water depth of 0.6 m without debris and 0.6 m with submerged debris at basin 2.

Walking with bicycle:

- 1.A) From table O.10 the $r_{XY} \approx 0.44 < 0.878$. The null hypothesis of $r_{XY} = 0$ is not rejected and the conclusion is that there is a weak positive correlation that is not significant between walking with a bicycle through a water depth of 0.0 m without debris and 0.6 m with submerged debris at basin 2.

- 1.B) From table O.10 the $r_{XY} \approx -0.33 < 0.878$. The null hypothesis $r_{XY} = 0$ is not rejected and the conclusion is that there is a weak negative correlation that is not significant between walking with a bicycle through a water depth of 0.6 m without debris and 0.6 m with submerged debris at basin 2.

IV) Difference

Test statistic and probability of the comparison of bicycling and walking with a bicycle through water depths of d = 0.0 and d = 0.6 meter at basin 2				
	1.A		**1.B**	
	X: d = 0.0 Y: d = 0.6, with submerged debris		X: d = 0.6 Y: d = 0.6, with submerged debris	
	Bicycling	Walking with bicycle	Bicycling	Walking with bicycle
T	7.78 $\overline{Z} = 9.39$ $\mu_z = 0$ $n = 4$ $s = \sigma_z = 2.415$	6.21 $\overline{Z} = 12.59$ $\mu_z = 0$ $n = 5$ $s = \sigma_z = 4.538$	10.07 $\overline{Z} = 4.07$ $\mu_z = 0$ $n = 4$ $s = \sigma_z = 0.808$	2.97 $\overline{Z} = 6.72$ $\mu_z = 0$ $n = 5$ $s = \sigma_z = 5.063$
p	0.0044	0.0034	0.0021	0.0412

Table O.11: Test statistic and probability.

Bicycling:

- 1.A) The p-value ($p = 0.0044$), see table O.11, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between bicycling with a water depth of 0.0 m without debris and 0.6 m with submerged debris at basin 2.

- 1.B) The p-value ($p = 0.0034$), see table O.11, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between bicycling with a water depth of 0.6 m without debris and 0.6 m with submerged debris at basin 2.

Walking with bicycle:

- 1.A) The p-value ($p = 0.0021$), see table O.11, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking with a bicycle with a water depth of 0.0 m without debris and 0.6 m with submerged debris at basin 2.

- 1.B) The p-value ($p = 0.0142$), see table O.11, is lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis is rejected with a certainty of more than 95%. There is a difference between walking with a bicycle with a water depth of 0.6 m without debris and 0.6 m with submerged debris at basin 2.

V) Relation

There is a difference between bicycling or walking with a bicycle at water depths of 0.0 meter without debris and 0.6 meter with submerged debris. Also, there is a difference between bicycling or walking with a bicycle at water depth of 0.6 meter with and without submerged debris. However, only the correlation between bicycling through a water depth of 0.6 meter with and without submerged debris is significant.

- 2.B) The reduction in bicycle speed in case of d = 0.6 m with submerged debris, compared to 0.6 m without debris, is approximately 31.0%.

Least squares linear regression: $\text{Time}_{\text{d=0.6 m;submerged debris}} \approx 1.22\ \text{Time}_{\text{d=0.6 m}} + 2.10$

Least squares intercept free linear regression: $\text{Time}_{\text{d=0.6 m;submerged debris}} \approx 1.44\ \text{Time}_{\text{d=0.6 m}}$

Mean slope linear relation: $\text{Time}_{\text{d=0.6 m;submerged debris}} \approx 1.45\ \text{Time}_{\text{d=0.6 m}}$

VI) Graphs

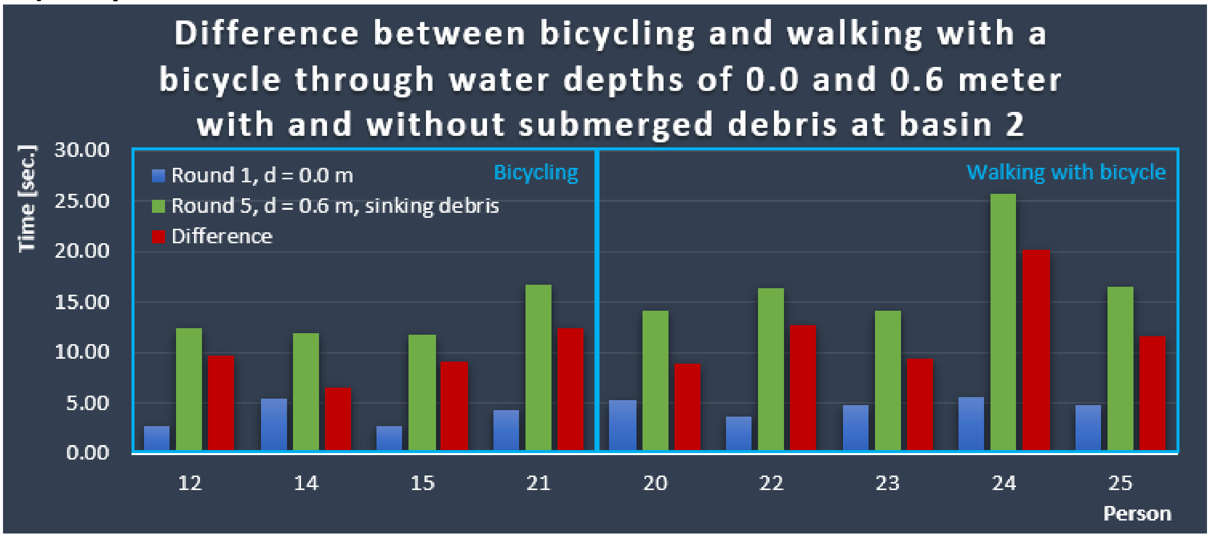


Figure O.5: Difference between round 1 and round 5 at basin 2.

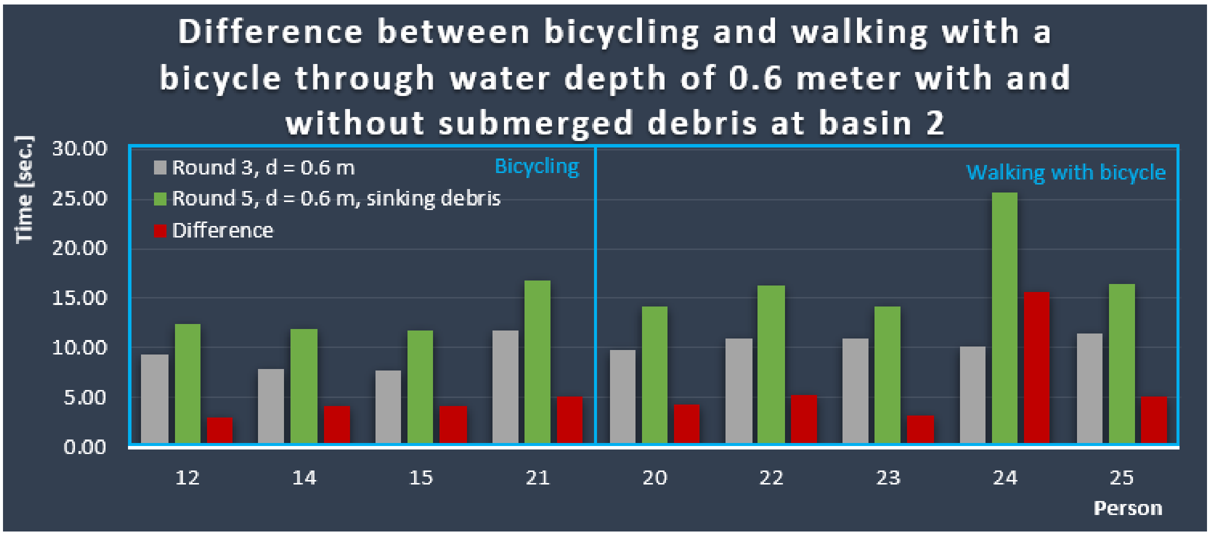


Figure O.6: Difference between round 3 and round 5 at basin 2.

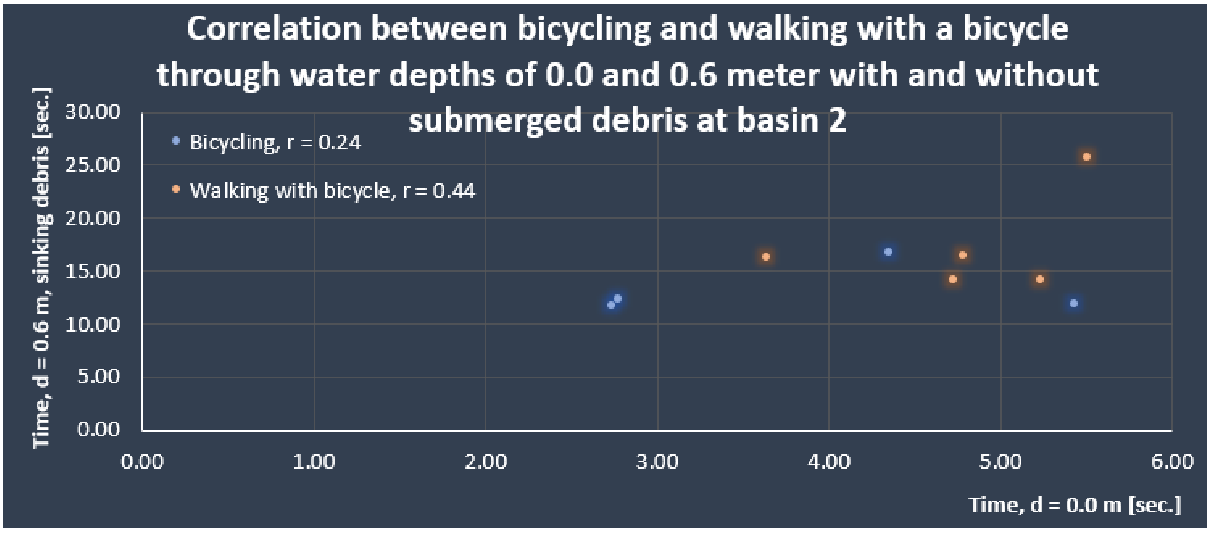


Figure O.7: Correlation between round 1 and round 5 at basin 2.

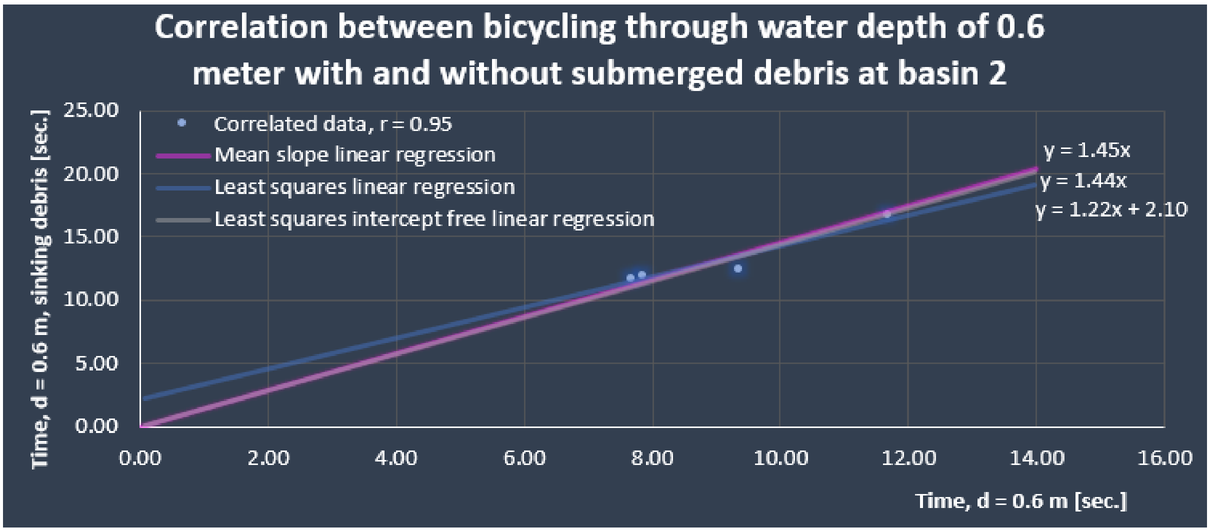


Figure O.8: Correlation between round 3 and round 5 at basin 2.

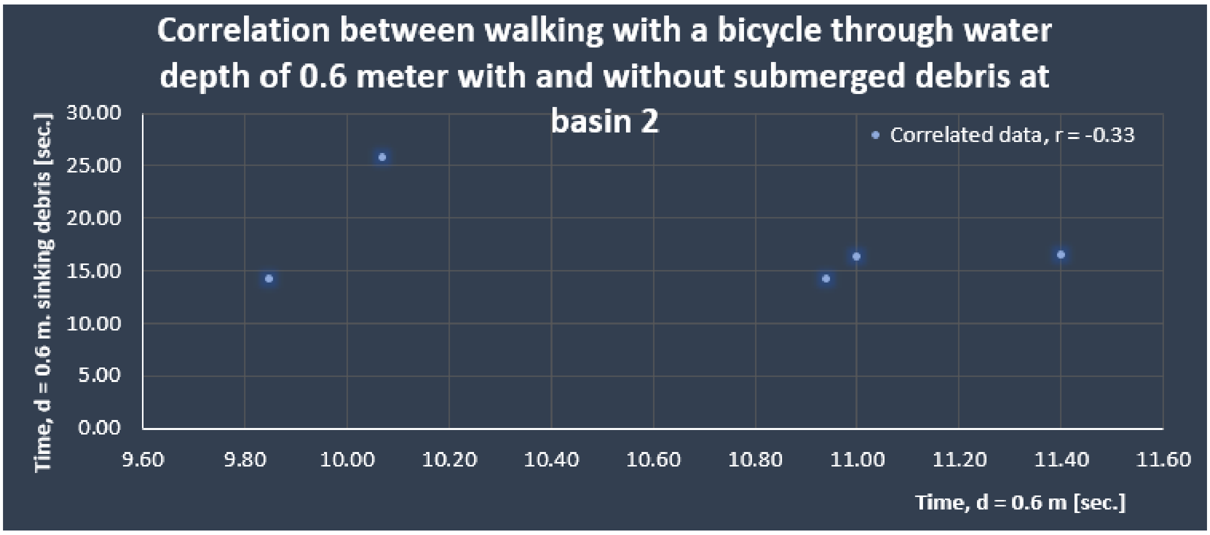


Figure O.9: Correlation between round 3 and round 5 at basin 2.

O.3. Overview of bicycling through debris

Basin		Round	Water depth	Means of transport	Correlation (Pearson T-test)			Difference (T-test)		Relation
					r_{XY}	T	p	T	p	
1)	A	1 and 5	0.0 m 0.2 m	Bicycling	-0.12	-0.17	-	6.56	0.0072	-
				Walking with bicycle	0.01	0.01	0.9932	5.06	0.0072	-
	B	Mean of 2&3 and 5	0.2 m 0.2 m	Bicycling	0.85	2.27	0.1514	9.73	0.0023	-
				Walking with bicycle	0.74	1.90	0.1532	5.27	0.0062	-
2)	A	1 and 5	0.0 m 0.6 m	Bicycling	0.24	0.34	0.7640	7.78	0.0044	-
				Walking with bicycle	0.44	0.84	0.4624	6.21	0.0034	-
	B	3 and 5	0.6 m 0.6 m	Bicycling	0.95	4.54	0.0452	10.07	0.0021	$t_{d=0.6\ m;\ submerged\ debris} \approx 1.44\ t_{d=0.6\ m}$
				Walking with bicycle	-0.33	-0.61	-	2.97	0.0412	-

Table O.12: Overview results.

Correlation
- r_{XY} = correlation coefficient. A large value for r_{XY} gives a low probability p and a strong linear correlation.
  - T = test statistic. A large value for T gives a low probability p.
- p = probability of finding no correlation between variable X and Y ($r_{XY} = 0$). If there is no correlation, variable X does not increase when variable Y increases and vice versa.

Difference
- T = test statistic. A large value for T gives a low probability p.
- p = probability of finding a zero mean difference between variable X and Y ($\mu_z = 0$). If the mean difference is zero, variable X and Y are equal and there is no difference the time measurements.

Relation
The relation of the least squares intersect free linear regression method is displayed in this table as this seems to be the most accurate method.

P. Experiment: bicycling – Influence of darkness

I) Data

Time measurements of walking during day and in the darkness										
	Part 1 (Basin 1)		Part 2		Part 3 (Basin 2)		Part 4		Part 5 (Basin 3)	
	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark
Round 1										
Person A	8.69	10.58	8.47	11.40	5.23	6.34	9.86	12.16	6.06	7.42
Person B	3.90	4.90	7.25	10.25	4.35	6.04	8.76	9.09	3.63	4.98
Round 2										
Person A	9.45	13.24	11.14	15.23	7.74	9.49	10.61	13.65	10.68	16.72
Person B	4.12	5.42	4.85	8.74	10.89	11.15	7.22	12.13	8.89	10.18
Round 3										
Person A	9.89	12.01	11.63	17.63	9.85	11.93	11.51	13.54	15.30	20.69
Person B	3.17	5.37	6.63	7.98	11.68	12.91	7.54	11.75	9.88	14.01
Round 5										
Person A	13.01	16.49	14.41	18.75	14.15	20.93	16.64	18.18	15.07	20.80
Person B	10.52	15.15	9.86	15.32	16.73	19.09	10.14	10.54	9.65	14.02

Table P.1: Data of bicycling during daylight and darkness.

Person A: Walking with the bicycle
Person B: Bicycling

II) Variables

Variables of walking during daylight and darkness	
X	Time during daylight [sec.]
Y	Time during darkness [sec.]

Table P.2: Variables X and Y.

III) Correlation

Hypothesis: $H_0: r_{XY} = 0$
$H_1: r_{XY} \neq 0$

Formula:
$$r_{XY} = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{n(\sum X^2) - (\sum X)^2}\sqrt{n(\sum Y^2) - (\sum Y)^2}}$$
$$T = \frac{r_{XY}\sqrt{df}}{\sqrt{1 - r_{XY}^2}} \text{ with } df = n - 2$$

Table of critical values for correlation coefficient r			
	α		
df	**10%**	**5%**	**1%**
23	0.337	0.396	0.505

Table P.3: Table of critical values for the correlation coefficient with n = 25.

For $df = 23$ with critical value $\alpha = 0.05$, there is a 95% probability of finding $-0.396 \leq r_{XY} \leq 0.396$ and 5% probability of finding a correlation outside this range.

Correlation of walking during daylight and darkness				
Person	r_{XY}	n	T	p
A	0.94	25	13.25	$3.0 * 10^{-12}$
B	0.91	25	10.22	$5.1 * 10^{-10}$

Table P.4: Correlation between time measurements from walking during daylight and darkness of persons 17 = person 20 and person 18 = person 21. r_{XY} = correlation coefficient, T = test statistic, p = probability. The null-hypothesis is rejected for large values of T, thus low values of p.

From table P.4 the $r_{XY} \approx 0.94 > 0.396$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a very strong positive linear correlation that is significant between walking during daylight and in the darkness.

From table P.4 the $r_{XY} \approx 0.91 > 0.396$. The null hypothesis of $r_{XY} = 0$ is rejected and the conclusion is that there is a very strong positive linear correlation that is significant between walking during daylight and in the darkness.

IV) Difference

Hypothesis: $H_0: \mu_z = 0$

$H_1: \mu_z \neq 0$

Formula: $T = \frac{\overline{Z}-\mu_z}{s}\sqrt{n}$

Table of critical values for test statistic T										
df	**α**									
2-tails	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.2%**	**0.1%**
23	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768

Table P.5: Table of critical values for test statistic T with n = 25.

See table P.5, for $df = 23$ with critical value $\alpha = 0.05$, the null hypothesis of $\mu_z = 0$ is rejected with a certainty of more than 95% if the p-value form the T-test is lower than the critical value $\alpha = 0.05$. In that case there is a relationship between the two paired variables.

Difference between walking during daylight and by darkness						
Person	T	$\overline{Z}$	μ_z	n	$s = \sigma_z$	p
A	9.48	3.39	0	25	1.788	$7.0 * 10^{-8}$
B	7.28	2.47	0	25	1.696	$3.1 * 10^{-6}$

Table P.6: Test statistic and probability for the difference between walking during daylight and by darkness.

The p-values ($p = 7.0 * 10^{-8}$ and $p = 3.1 * 10^{-6}$), see table P.6, are lower than the critical value ($\alpha = 0.05$). This means that the null hypothesis of $\mu_z = 0$ is rejected with a certainty of more than 95%. The difference between walking during daylight and darkness is significant.

V) Relation

Person	Correlation (Pearson T-test)			Difference (T-test)		Relation
	r_{XY}	T	p	T	p	
A	0.94	13.25	$3.0 * 10^{-12}$	9.48	$7.0 * 10^{-8}$	$t_{darkness} \approx 1.31\ t_{daylight}$
B	0.91	10.22	$5.1 * 10^{-10}$	7.28	$3.1 * 10^{-6}$	$t_{darkness} \approx 1.27\ t_{daylight}$

Table P.7: Relations.

VI) Graph

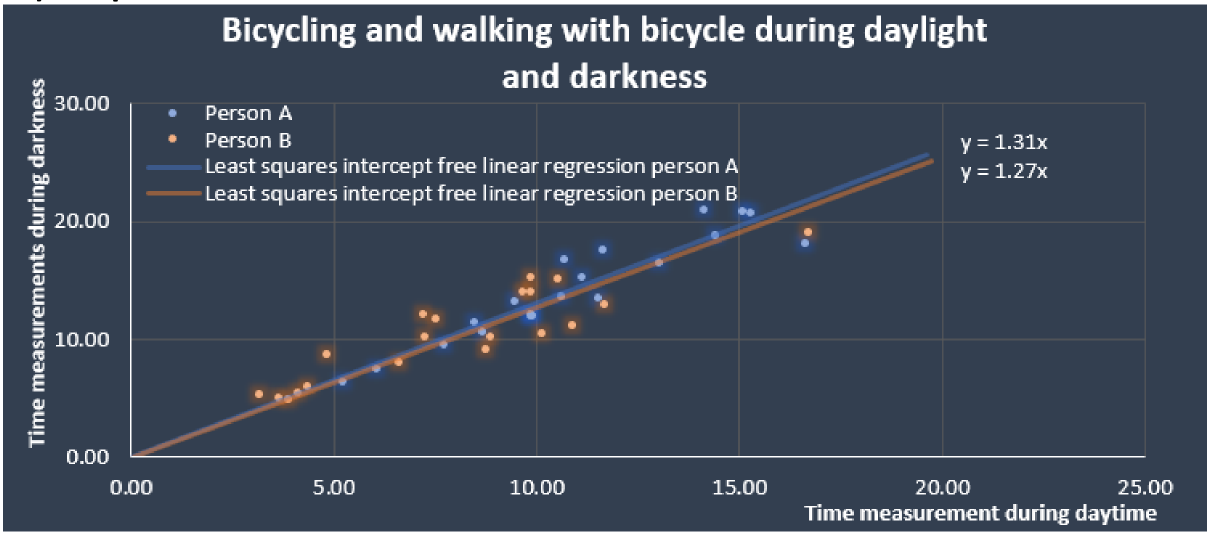


Figure P.1: Correlation between walking during daylight and darkness of person A (walking with bicycle) and B (bicycling) separately.

Q. Experiment: following the parcourse

Q.1. Walking

	Basin 1					Basin 2					Basin 3					
Round: Person	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**Round 4**
1																Bag (20 kg)
2																Bag (10 kg)
3																Dog
4																Bag (20 kg)
5																Air mattress
6																Bag (10 kg)
7								X								Dog
8																Air mattress
9															X	Bag (10 kg)
10																Dog
11																Air mattress
12																Bag (10 kg)
13																Air mattress
14																Dog
15																Bag (20 kg)
16 (darkness)																Air mattress
17 (darkness)																Bag (10 kg)
18 (darkness)																Dog
19 (darkness)																Bag (20 kg)
20																Bag (10 kg)
21																Dog
22																Air mattress
23																Dog
24																Air mattress
25																Dog
Total (excl. darkness)	0	0	0	2	1	0	0	1	1	1	0	0	5	8	2	
Participants (n, excl. darkness)	21	21	21	21	21	21	21	21	21	21	21	21	21	21	13	
Percentage (excl. darkness)	0.0	0.0	0.0	9.5	4.8	0.0	0.0	4.8	4.8	4.8	0.0	0.0	23.8	38.1	15.4	

Table Q.1: Walking next to the parcourse. A blue area means that a person went next to the parcourse and a light blue area means that a participant did not complete this round. 'X' means that a participants fell on the ground.

Q.2. Bicycling

	Basin 1				Basin 2				Basin 3				
Round: Person	**1**	**2**	**3**	**5**	**1**	**2**	**3**	**5**	**1**	**2**	**3**	**5**	**Method**
1													Other
2													Other
3													Walking with bicycle
4													Bicycling
5													Bicycling
6													Walking with bicycle
7													Walking with bicycle
8													Stepping
9													Walking with bicycle
10													Other
11													Other
12													Bicycling
13													Other
14													Bicycling
15													Bicycling
16 (darkness)													Bicycling
17 (darkness)													Walking with bicycle
18 (darkness)													Bicycling
19 (darkness)													Bicycling
20													Walking with bicycle
21													Bicycling
22													Walking with bicycle
23													Walking with bicycle
24													Walking with bicycle
25													Walking with bicycle
Total (excl. darkness)	1	1	0	1	0	2	3	1	4	6	13	9	
Participants (n, excl. darkness)	21	21	20	12	21	21	20	12	21	21	20	12	
Percentage (excl. darkness)	4.8	4.8	0.0	8.3	0.0	9.5	15.0	8.3	19.0	28.6	65.0	75.0	

Table Q.2: Walking next to the parcourse. A blue area means that a person went next to the parcourse and a light blue area means that a participant did not complete this round. 'Other' means that participants used different means of transport at each round, e.g. bicycling during one round, the other round walking with the bicycle or carrying the bicycle.

Q.3. Percentages per part

The data from the tables in paragraph Q1 and Q2 can be rewritten into percentages. This is done below in case of walking, bicycling and walking with a bicycle.

Walking

	Walking straight part (n = 21):			Walking over a bend (n = 21):	
Water depth	Walking	Walking with bag, dog or air mattress	Walking through debris	Walking	Walking with bag, dog or air mattress
d = 0.0 m	0.0 %	-	-	0.0 %	-
d = 0.2 m	0.0 %	9.5 %	4.8 %	0.0 %	-
d = 0.4 m	0.0 %	-	-	23.8 %	38.1 %
d = 0.6 m	4.8 %	4.8 %	4.8 %	-	-

Table Q.3: Walking next to the parcourse.

By darkness:

	Walking straight part (n = 4):			Walking over a bend (n = 4):	
Water depth	Walking	Walking with bag, dog or air mattress	Walking through debris	Walking	Walking with bag, dog or air mattress
d = 0.0 m	0.0 %	-	-	0.0 %	-
d = 0.2 m	0.0 %	0.0 %	0.0 %	25.0 %	-
d = 0.4 m	0.0 %	-	-	25.0 %	50.0 %
d = 0.6 m	25.0 %	25.0 %	0.0 %	-	-

Table Q.4: Walking next to the parcourse by darkness.

Bicycling

	Bicycling over a straight part				Bicycling over a bend	
Water depth (d)	Bicycling (n = 6)	Bicycling by darkness (n = 3)	Bicycling through debris (n = 4)	Bicycling through debris by darkness (n = 3)	Bicycling (n = 6)	Bicycling by darkness (n = 3)
d = 0.0 m	0.0 %	0.0 %	-	-	16.7 %	0.0 %
d = 0.2 m	0.0 %	0.0 %	25.0 %	66.7 %	16.7 %	66.7 %
d = 0.4 m	16.7 %	66.7 %	-	-	66.7 %	66.7 %
d = 0.6 m	0.0 %	66.7 %	25.0 %	100.0 %	-	-

Table Q.5: Bicycling next to the parcourse.

Walking with a bicycle

	Walking with bicycle over a straight part		Walking with bicycle over a bend
Water depth (d)	Walking with bicycle (n = 9)	Walking with bicycle through debris (n = 5)	Walking with bicycle (n = 9)
d = 0.0 m	0.0 %	-	11.1 %
d = 0.2 m	0.0 %	0.0 %	33.3 %
d = 0.4 m	0.0 %	-	87.5 % (n = 8)
d = 0.6 m	0.0 % (n = 8)	0.0 %	-

Table Q.6: Walking with a bicycle next to the parcourse.

R. Fleeing speed

In this section the fleeing velocity is calculated, see table R.1.

	Basin	Round	Water depth	Debris	Darkness	Fleeing velocity
Walking (n = 21)	1	2&3	0.2	No	No	t = 214.34/21 = 10.21 sec. v = x/t = (12/10.21)*3.6 = 4.23 km/h
	1	5	0.2	Yes	No	t = 295.81/21 = 14.09 sec. v = x/t = (12/14.09)*3.6 = 3.07 km/h
	2	2	0.4	No	No	t = 167.21/21 = 7.96 sec. v = x/t = (8.6/7.96)*3.6 = 3.89 km/h
	2	3	0.6	No	No	t = 192.70/21 = 9.18 sec. v = x/t = (8.6/9.18)*3.6 = 3.37 km/h
	2	5	0.6	Yes	No	t = 297.77/21 = 14.18 sec. v = x/t = (8.6/14.18)*3.6 = 2.18 km/h
Walking with bicycle (n = 9)	1	2&3	0.2	No	No	t = 105.66/9 = 11.74 sec. v = x/t = (12/11.74)*3.6 = 3.68 km/h
	2	2	0.4	No	No	t = 80.76/9 = 8.97 sec. v = x/t = (8.6/8.97)*3.6 = 3.45 km/h
	2	3	0.6	No	No	t = 87.19/8 = 10.90 sec. v = x/t = (8.6/10.90)*3.6 = 2.84 km/h (n= 8 instead of n = 9, because person 7 did not participated at this round with a bicycle.)

Table R.1: Fleeing velocity corresponding to the relations in the flow chart of figure 5.10 in paragraph 5.8.

From table R.1 the following is concluded:

- **Walking (daylight):** $v_{d=0.2} = 4.23$ km/h
  $v_{d=0.4} = 3.89$ km/h
  $v_{d=0.6} = 3.37$ km/h
  $v_{d=0.2,\ \text{floating debris}} = 3.07$ km/h
  $v_{d=0.6,\ \text{submerged debris}} = 2.18$ km/h

- **Walking with bicycle (daylight):** $v_{d=0.2} = 3.68$ km/h
  $v_{d=0.4} = 3.45$ km/h
  $v_{d=0.6} = 2.84$ km/h

S. Experiment: spread and check of normality of the variables

In this appendix the spread and a visualization of data, used in the flow chart in paragraph 5.8, is added to see whether it is normal distributed and thus met the requirement for using the Pearson moment correlation analysis and the paired sample t-test. This is done only for the relations which are used in the flow chart of paragraph 5.8, because it has no added value for this report to do this for every dataset from the experiment.

	Walking					Walking with bicycle		
Water depth (d) [m]	0.2	0.4	0.6	0.2, floating debris	0.6, submerged debris	0.2	0.4	0.6
Participants (n)	21	21	21	21	21	9	9	8
Factor	1.58	1.93	2.20	1.34	1.54	1.29	1.87	2.19
Mean (μ)	1.62	1.98	2.30	1.45	1.55	1.39	2.11	2.46
Standard deviation (σ)	0.356	0.469	0.442	0.544	0.228	0.296	0.679	0.586
5% Boundary	1.11	1.39	1.64	1.02	1.22	1.12	1.53	1.85
95% Boundary	2.09	2.68	2.89	2.49	1.86	1.81	3.22	3.29

Table S.1: Properties of the data.

	Darkness		
Water depth (d) [m]	Walking	Bicycling	Walking with bicycle
Participants	2	1	1
Data points (nd)	25	25	25
Factor	1.53	1.31	1.27
Mean (μ)	1.57	2.11	1.35
Standard deviation (σ)	0.189	0.679	0.232
5% Boundary	1.30	1.18	1.04
95% Boundary	1.84	1.52	1.70

Table S.2: Properties of the data.

Notes:

- For walking in the darkness, there are 25 mean factors. The next section describes what is done to obtain these main factors. Two participants completed the whole experiment in the dark, resulting in 25 time measurements per person at basin 1, 2 and 3. These two participants also completed the experiment during daylight. The time measurements during daylight and darkness are comped at each part, resulting in 25 factors per person. After this, the mean of each factor is calculated, resulting in 25 factors (= 25 data points).
- The factors in the relations used in the flow chart will not be lower than zero and are far enough away from the zero point. Because of this, a lognormal distribution might be a better fit than the normal distribution. However, to use the Pearson moment correlation analysis and the paired sample t-test, the data should be checked if it follows a normal distribution.

S.1. Walking

Walking through water depths of d = 0.0 and d = 0.2 meter

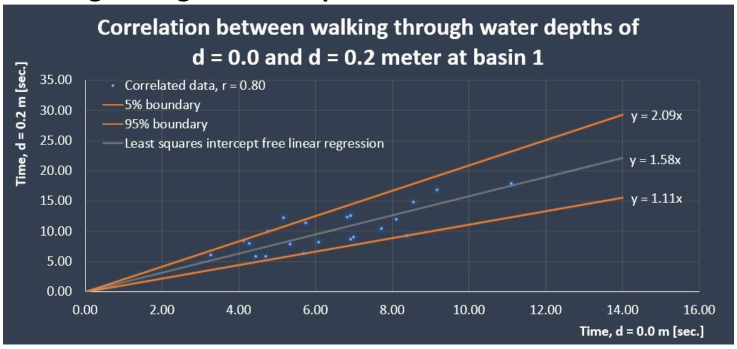
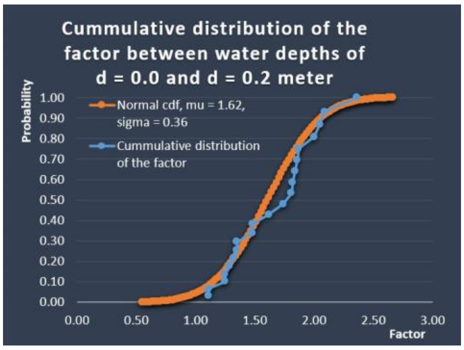


Figure S1: Relation between walking through water depths of d = 0.0 and d = 0.2 meter, and the 5% and 95% boundaries.



Data points (n) = 21
Mean (μ) = 1.62
Standard deviation (σ) = 0.356

5% boundary normal distribution:
$1.62 - 1.645 * 0.356 \approx 1.03$

95% boundary normal distribution:
$1.62 + 1.645 * 0.356 \approx 2.21$

Figure S2: Cummulative distribution if the data is normal distibuted [orange] and the cummulative distribution of the factor [blue].

Walking through water depths of d = 0.0 and d = 0.4 meter

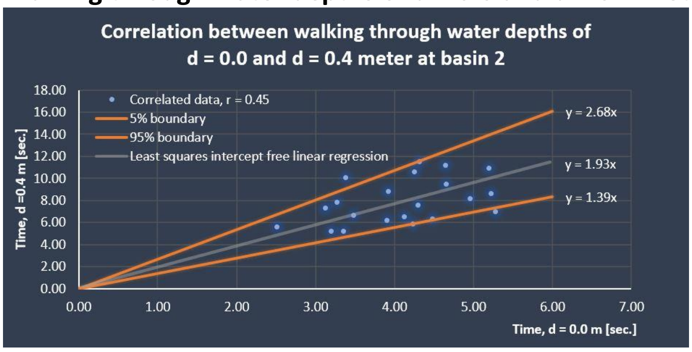
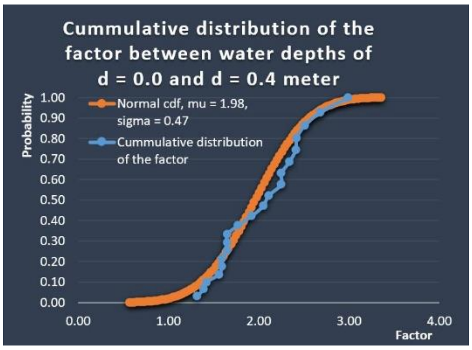


Figure S3: Relation between walking through water depths of d = 0.0 and d = 0.4 meter, and the 5% and 95% boundaries.



Data points (n) = 21
Mean (μ) = 1.98
Standard deviation (σ) = 0.469

5% boundary normal distribution:
$1.98 - 1.645 * 0.469 \approx 1.21$

95% boundary normal distribution:
$1.98 + 1.645 * 0.469 \approx 2.75$

Figure S4: Cummulative distribution if the data is normal distibuted [orange] and the cummulative distribution of the factor [blue].

Walking through water depths of d = 0.0 and d = 0.6 meter

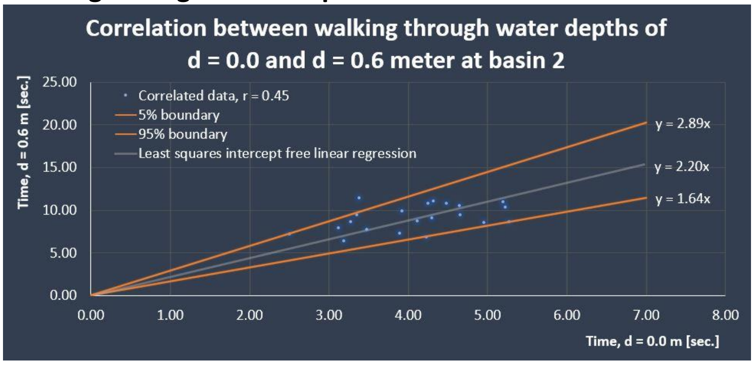
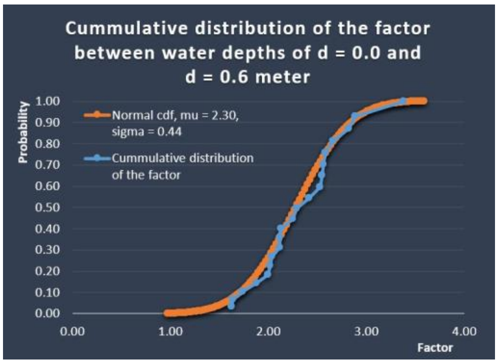


Figure S5: Relation between walking through water depths of d = 0.0 and d = 0.6 meter, and the 5% and 95% boundaries.



Data points (n) = 21
Mean (μ) = 2.30
Standard deviation (σ) = 0.442

5% boundary normal distribution:
$2.30 - 1.645 * 0.442 \approx 1.57$

95% boundary normal distribution:
$2.30 + 1.645 * 0.442 \approx 3.03$

Figure S6: Cummulative distribution if the data is normal distibuted [orange] and the cummulative distribution of the factor [blue].

Walking through water depth of d = 0.2 meter with and without floating debris

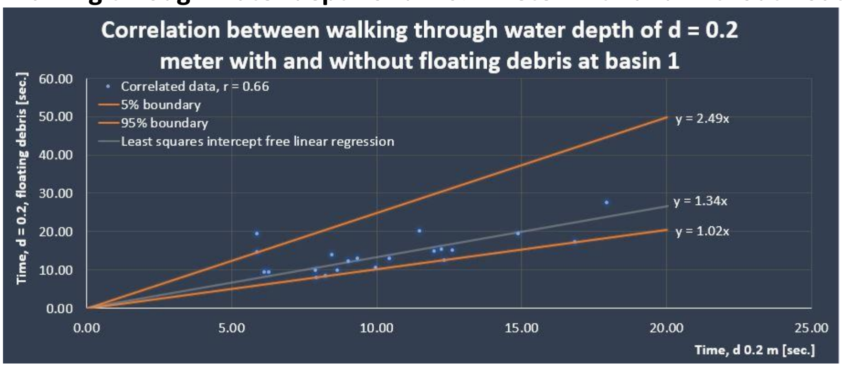
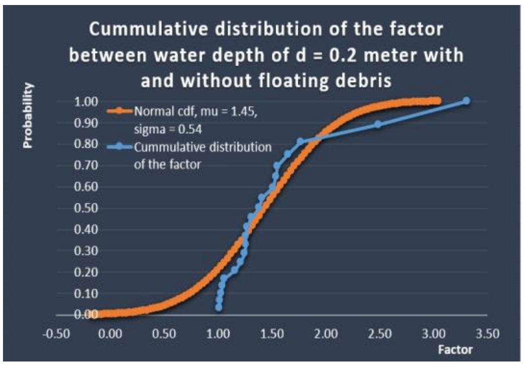


Figure S7: Relation between walking through water depth of d = 0.2 meter with and without floating debris, and the 5% and 95% boundaries.



Data points (n) = 21
Mean (μ) = 1.45
Standard deviation (σ) = 0.544

5% boundary normal distribution:
$1.45 - 1.645 * 0.544 \approx 0.56$

95% boundary normal distribution:
$1.45 + 1.645 * 0.544 \approx 2.34$

Figure S8: Cumulative distribution if the data is normal distributed [orange] and the cumulative distribution of the factor [blue].

Walking through water depth of d = 0.6 meter with and without submerged debris

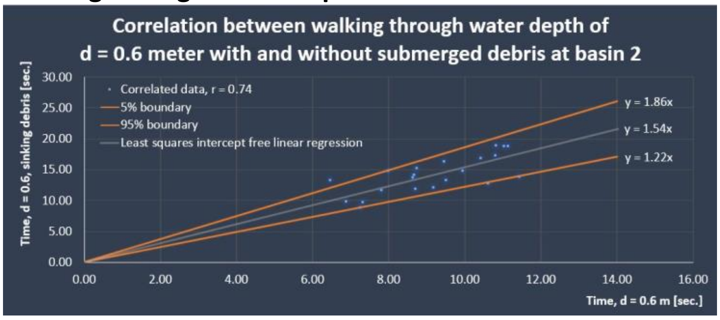
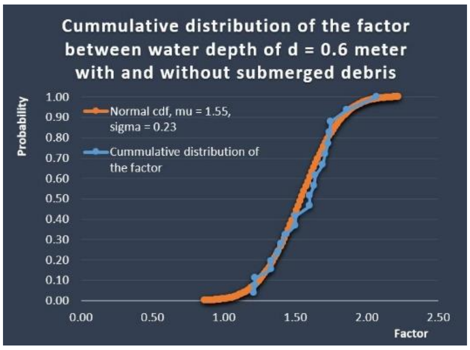


Figure S9: Relation between walking through water depth of d = 0.6 meter with and without submerged debris, and the 5% and 95% boundaries.



Data points (n) = 21
Mean (μ) = 1.55
Standard deviation (σ) = 0.228

5% boundary normal distribution:
$1.55 - 1.645 * 0.228 \approx 1.17$

95% boundary normal distribution:
$1.55 + 1.645 * 0.228 \approx 1.93$

Figure S10: Cummulative distribution if the data is normal distibuted [orange] and the cummulative distribution of the factor [blue].

S.2. Walking with bicycle

Walking with bicycle through water depths of d = 0.0 and d = 0.2 meter

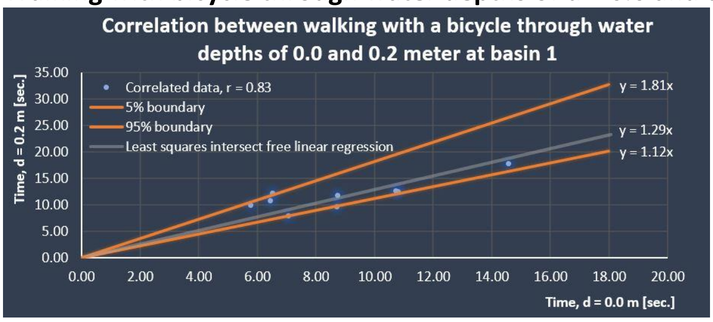
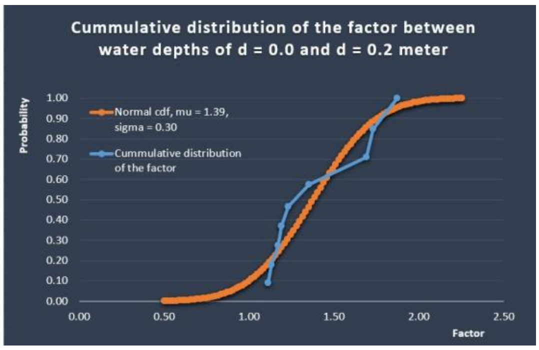


Figure S11: Relation between walking with bicycle through water depths of d = 0.0 and d = 0.2 meter, and the 5% and 95% boundaries.



Data points (n) = 9
Mean (μ) = 1.39
Standard deviation (σ) = 0.296

5% boundary normal distribution:
$1.39 - 1.645 * 0.296 \approx 0.90$

95% boundary normal distribution:
$1.39 + 1.645 * 0.296 \approx 1.88$

Figure S12: Cummulative distribution if the data is normal distibuted [orange] and the cummulative distribution of the factor [blue].

Walking with bicycle through water depths of d = 0.0 and d = 0.4 meter

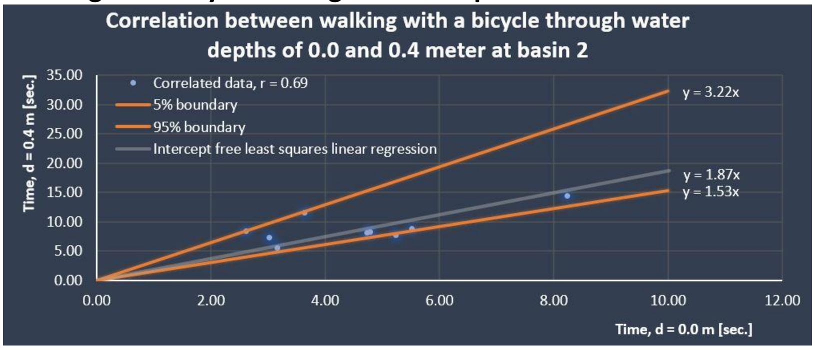
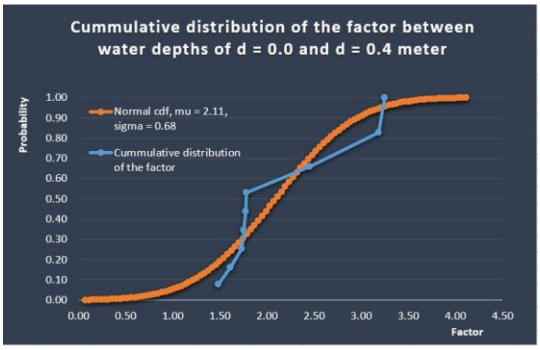


Figure S13: Relation between walking with bicycle through water depths of d = 0.0 and d = 0.4 meter, and the 5% and 95% boundaries.



Data points (n) = 9
Mean (μ) = 2.11
Standard deviation (σ) = 0.679

5% boundary normal distribution:
$2.11 - 1.645 * 0.679 \approx 0.99$

95% boundary normal distribution:
$2.11 + 1.645 * 0.679 \approx 3.23$

Figure S14: Cummulative distribution if the data is normal distibuted [orange] and the cummulative distribution of the factor [blue].

Walking with bicycle through water depths of d = 0.0 and d = 0.6 meter

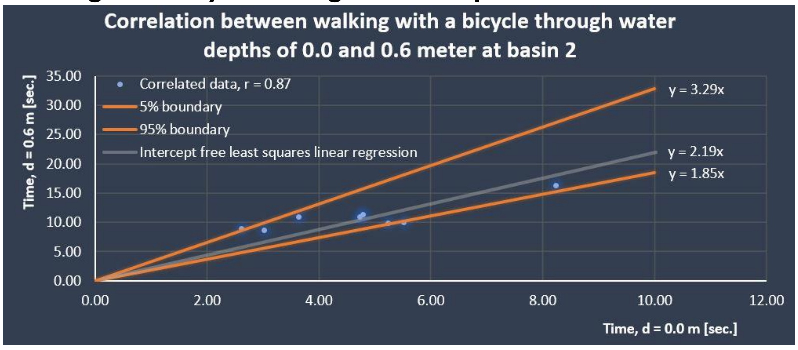
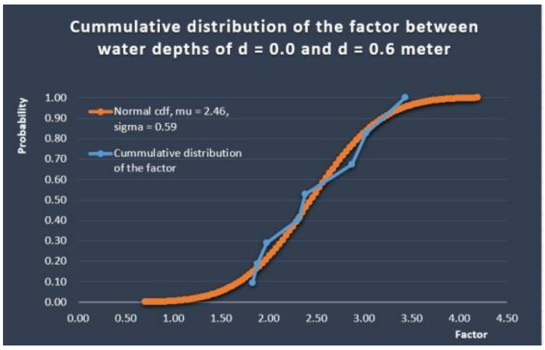


Figure S15: Relation between walking with bicycle through water depths of d = 0.0 and d = 0.6 meter, and the 5% and 95% boundaries.



Data points (n) = 8
Mean (μ) = 2.46
Standard deviation (σ) = 0.586

5% boundary normal distribution:
$2.46 - 1.645 * 0.586 \approx 1.50$

95% boundary normal distribution:
$2.46 + 1.645 * 0.586 \approx 3.42$

Figure S16: Cummulative distribution if the data is normal distibuted [orange] and the cummulative distribution of the factor [blue].

S.3. Darkness

Walking

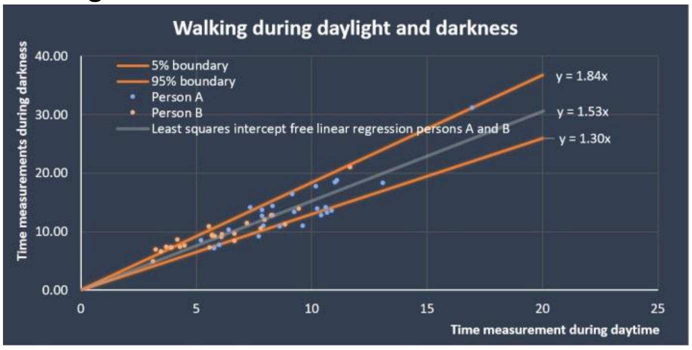
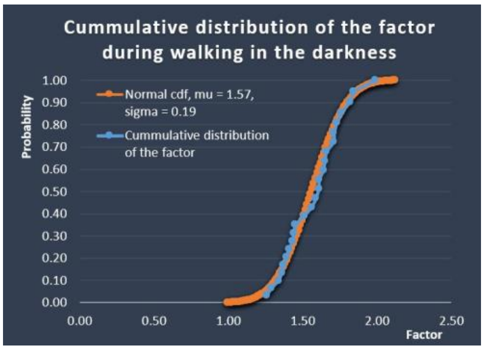


Figure S17: Relation between walking during daylight and darkness, and the 5% and 95% boundaries.



Data points (nd): 25 (mean of 2 participants)
Mean (μ) = 1.57
Standard deviation (σ) = 0.189

5% boundary normal distribution:
$1.57 - 1.645 * 0.189 \approx 1.26$

95% boundary normal distribution:
$1.57 + 1.645 * 0.189 \approx 1.88$

Figure S18: Cummulative distribution if the data is normal distibuted [orange] and the cummulative distribution of the factor [blue].

Walking with bicycle

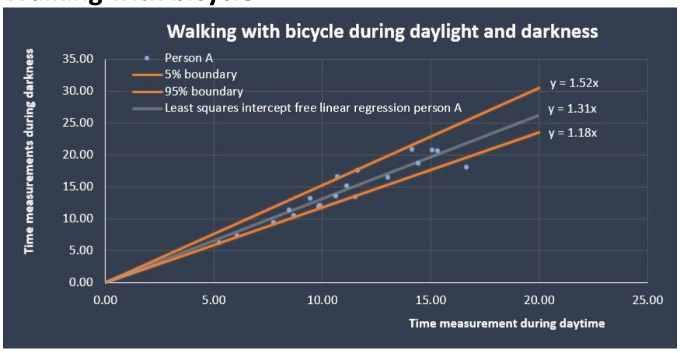
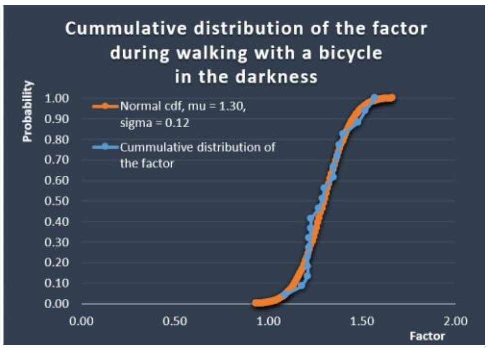


Figure S19: Relation between walking with a bicycle during daylight and darkness, and the 5% and 95% boundaries.



Data points (nd) = 20 (1 participant)
Mean (μ) = 2.11
Standard deviation (σ) = 0.121

5% boundary normal distribution:
$1.30 - 1.645 * 0.121 \approx 1.10$

95% boundary normal distribution:
$1.30 + 1.645 * 0.121 \approx 1.50$

Figure S20: Cummulative distribution if the data is normal distibuted [orange] and the cummulative distribution of the factor [blue].

Bicycling

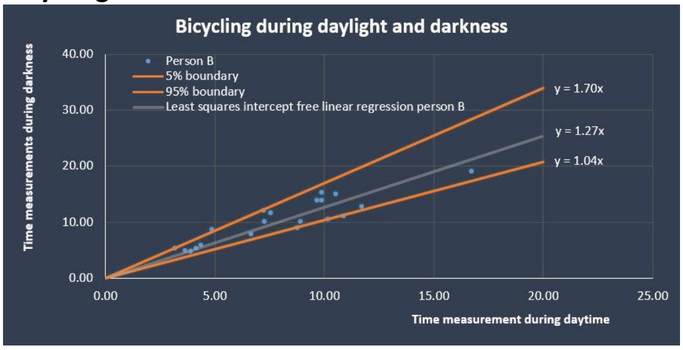
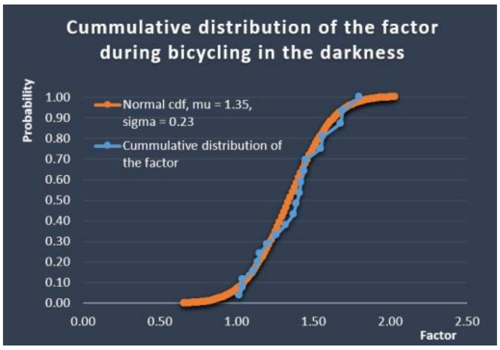


Figure S21: Relation between bicycling during daylight and darkness, and the 5% and 95% boundaries.



Data points (n) = 20 (1 participant)
Mean (μ) = 1.35
Standard deviation (σ) = 0.232

5% boundary normal distribution:
$1.35 - 1.645 * 0.232 \approx 0.97$

95% boundary normal distribution:
$1.35 + 1.645 * 0.232 \approx 1.73$

Figure S22: Cummulative distribution if the data is normal distibuted [orange] and the cummulative distribution of the factor [blue].

T. Experiment: cross correlations

Table T.1 is added which shows the cross correlations for the relations used in the flow chart for fleeing in paragraph 5.8.

		Walking							Walking with bicycle						
							Debris							Debris	
		B1		B2			B1	B2	B1		B2			B1	B2
		d = 0.0	d = 0.2	d = 0.0	d = 0.4	d = 0.6	d = 0.2	d = 0.6	d = 0.0	d = 0.2	d = 0.0	d = 0.4	d = 0.6	d = 0.2	d = 0.6
Walking	Basin 1, d = 0.0		0.80	0.84	0.58	0.61	0.56	0.62	0.72	0.84	0.78	0.85	0.89	0.58	-0.71
	Basin 1, d = 0.2			0.48	0.80	0.83	0.66	0.67	0.57	0.87	0.58	0.90	0.80	0.93	-0.13
	Basin 2, d = 0.0				0.45	0.45	0.31	0.44	0.69	0.61	0.79	0.58	0.66	-0.73	-0.57
	Basin 2, d = 0.4					0.78	0.42	0.45	0.29	0.63	0.45	0.77	0.44	-0.07	0.53
	Basin 2, d = 0.6						0.61	0.74	0.60	0.63	0.57	0.66	0.51	0.70	0.17
	Basin 1, d = 0.2, floating debris							0.71	0.55	0.61	0.44	0.60	0.79	0.81	-0.56
	Basin 2, d = 0.6, submerged debris								0.57	0.49	0.51	0.51	0.52	0.73	-0.05
Walking with bicycle	Basin 1, d = 0.0									0.83	0.95	0.62	0.83	0.01	0.36
	Basin 1, d = 0.2										0.82	0.91	0.94	0.74	0.48
	Basin 2, d = 0.0											0.69	0.87	-0.60	0.44
	Basin 2, d = 0.4												0.88	0.57	0.11
	Basin 2, d = 0.6													0.40	-0.33
	Basin 1, d = 0.2, floating debris														-0.03
	Basin 2, d = 0.6, submerged debris														

Table T.1: Cross correlations for the relations used in the flow chart for fleeing.

From this table it can be seen that the correlation for debris shows some low values. This indicates that a person is slower at this part than the mean. It is possible that this has to do with de limited amount of data points for walking with a bicycle through debris, see table T.2.

Means of transport	Number of data points (or participants)
Walking	21
Walking with bicycle	9
Walking with bicycle through debris	4

Table T.2: Number of data points.

U. Questionnaire: answers on experiences on boat rescues

Notes:

- 6 out of 12 experts responded with answers on the questionnaire.
- The response of expert 4 is in Dutch and translated before adding it into the next section.

U.1. Introduction

		Expert			
		1	2	3	4
Experience [year]		40	> 30	12	24
Experience with life boat rescues on:	**Rivers**	Yes	Yes	Yes	Yes
	North Sea	Yes	Yes	Yes	Yes
	Lake	Yes	No	Yes	Yes
Reddingsbrigade		40 years Member CLG	40 years Former PC, 10 years leader of alarm squad CLG	12 years Sr. Lifeguard, skipper/kader CLG Raalte	33 years Chairman and examinator Deventer RSG
KNRM		28 years Skipper CLG	> 10 years Deputy skipper CLG	-	-
Participation 1953, 1993, 1995		1993	1995	-	-

Table U.1: Introduction experts 1 till 4.

Notes:
CLG = Callantsoog
PC = 'Post commandant'

		Expert	
		5	6
Experience [year]		30	10
Experience with life boat rescues on:	**Rivers**	Yes	Yes
	North Sea	Yes	Yes
	Lake	Yes	Yes
Reddingsbrigade		30 years Sr. Lifeguard, coordinator, Liaison CLG, Security reg. Utrecht (VRU)	> 8 years Sr. Lifeguard, skipper and PC Wierden, Raalte, Deventer, Sluis
KNRM		-	-
Participation 1953, 1993, 1995		1995 Dike breach 2003 Wilnis	-

Table U.2: Introduction experts 5 and 6.

U.2. Navigation speed

2a) What is your estimation about the navigation speed and what is the navigation speed in a flooded area for a lifeboat [knots]? Please fill in the table below.

1.) Vlet							
		Expert					
		1	2	3	4	5	6
Estimation of navigation speed non flooded area [knots]		10	8	5	-	8	7
	Water depth:						
Estimation of navigation speed in flooded area for different water depths [knots]	I.) 0.0 – 0.5 m	2	< 3	3	4	< 2	1
	II.) 0.5 – 1.0 m	7	< 5	3	6	3-5	3
	III.) 1.0+ m	9	< 5	?	max.	<8	3

Table U.3: Navigation speed Vlet.

2.) Tinn Silver							
		Expert					
		1	2	3	4	5	6
Estimation of navigation speed non flooded area [knots]		22	25	25	-	30	33+ with (75hp) new engine
	Water depth:						
Estimation of navigation speed in flooded area for different water depths [knots]	I.) 0.0 – 0.5 m	2	< 3	3	-	< 2	1
	II.) 0.5 – 1.0 m	10	< 5	3	-	3-5	1
	III.) 1.0+ m	12	< 10	?	-	15	1

Table U.4: Navigation speed Tinn Silver.

3.) Rescue 3							
		Expert					
		1	2	3	4	5	6
Estimation of navigation speed non flooded area [knots]		26	30	25	-	28	30+
	Water depth:						
Estimation of navigation speed in flooded area for different water depths [knots]	I.) 0.0 – 0.5 m	2	< 3	1	-	< 2	1
	II.) 0.5 – 1.0 m	9	< 5	2	-	3-5	1
	III.) 1.0+ m	16	< 10	-	-	15	1

Table U.5: Navigation speed Rescue 3.

Comment expert 3: Speed is reduced significantly. I think it is difficult to estimate by how much. Rescue 3 boats are more sensitive to under water obstacles. Navigating through floodplains / river banks in high water situations have shown barbed wire and land posts are invisible but can cause serious damage. Maximum velocity is limited by how fast you can check / clear your path.

Comment expert 6:

Inflatable rescue boat (IRB)		
Estimation of navigation speed non flooded area [knots]		22
	Water depth:	
Estimation of navigation speed in flooded area for different water depths [knots]	I.) 0.0 – 0.5 m	3-5
	II.) 0.5 – 1.0 m	5+
	III.) 1.0+ m	10+

Table U.6: Comment of expert 6 about an inflatable rescue boat.

2b) What is the influence of debris on the navigation speed compared to the navigation speed in a normal waterway? If relevant, distinguish between different situations.

Expert	Answer
1	- Floating debris will (dramatically) reduce navigation speed and may cause damage to boat and/or engine. Floating debris however, can often be seen and collision can be avoided. - Underwater debris/structures will also reduce speed, it can often not be seen, so the chances on damage are bigger.
2	Debris is dangerous. You can't take the risk to damage your equipment/boat. No boat is no rescue. Hitting floating debris on high speed with an outboard engine can result in a broken engine.
3	This depends very much on the kind of debris. These lifeboats are fairly resistant to light floating debris. In a flood situation obstacles are less predictable and therefore more dangerous.
4	In a flooded area you have to adjust your speed anyway. You are not familiar with obstacles. It is important to avoid damage to the equipment and crew. If you sail to a flooded area via a waterway you can keep the speed high, but be careful because of more debris in the water.

(Table proceeds on the next page).

5	Depending on quantity and type of debris. For example you will find debris from local farms, industrial activities and/or residential areas. In the case of debris the general action is to decrease speed as a safety measure. The chosen speed depends on the visibility of the debris and a good overview of the situation by the crew.
6	Near loss of all speed due to loss of familiarization on the location.

Table U.7: Influence of debris on navigation speed.

2c) Does the hinder that waves from lifeboats cause to the environment reduce the navigation speed during a flood? If relevant, distinguish between different situations.

Expert	Answer
1	Waves caused by lifeboats may cause hinder to other lifeboats operating in the same area. Usually, lifeboats operate at low speeds in shallow flooded areas, so speed will not be reduced too much. Possibly, the waves could hinder rescued people in (crowded) lifeboats and even create instability of affected lifeboats.
2	Lifeboats on low speed don't make big waves. There will not be an issue for the navigation speed.
3	Speed should already be reduced significantly because of the unpredictable situation under water, therefore you should not make big waves. The waves that are produced are not a big problem in open areas but could be a large hinder to your own lifeboat when navigating narrow streets with houses / walls on both sides.
4	For example, if you sail through streets, the waves bounce off the houses and the boats sailing behind you can suffer from this. On open water you can certainly suffer from waves from other boats. Because boats are loaded, the boats sometimes come into plane badly, so you get a decent fence wave. Which is annoying and dangerous for other boats. E.g. low water enters water, causing victims to become wet and may become hypothermic.
5	Certainly
6	Yes, it could cause unnecessary damage due to wakes overtopping dry spots or barriers.

Table U.8: Influence of environment on navigation speed.

U.3. Transferring people into a lifeboat

3a) How can one person be saved from a higher floor above the water and be brought into a life boat?

Expert	Answer
1	- Descent into the water (ideally wearing a life jacket) and be rescued by lifeboat crew - Be hoisted from the roof (and lowered into lifeboat) by helicopter - Climb down to a lower level where lifeboat rescue is possible - Lifeboats could utilize a ladder to enable people to descent safely into lifeboat
2	For saving people from height we need special equipment. Firefighters and medics can join the lifeboats and need to bring at least ladders. In case we have to open the house we do need tools to do so. Injured, elderly and handicapped humans need more attention. In my point of view our lifeboats are not capable to rescue those people easy. Boats are too small and not a stable platform to work from.

(Table proceeds on the next page).

3	The Vlet and Tinn Silver type lifeboats all have a flat surface on the bow. You would typically just steer the boat straight in to the building / platform and leave the engine of the boat running, pressing the boat against the building. This way the boat is secured and people can easily step on. A little climbing could be involved depending on the situation. If someone is not capable of climbing for whatever reason they could be transported on a stretcher. This is not very comfortable for the patient and it does take multiple lifeguards therefore it is not preferred but if necessary the stretcher could even be lowered in to the lifeboat by rope.
4	Depending on the boat type: - Vlet: max. 7 persons (incl. crew) - Tinn Silver: max. 7 persons (incl. crew) - Rescue 3: max. 6 persons (incl. crew)
5	Bring the boat to the window frame and the evacuees can enter the boat via the bow.
6	By use of a brancard if necessary, otherwise a rope ladder if the stairs are not assessable.

Table U.9: Saving people from a higher floor.

3b) How can a person be saved from a collapsed building in a flooded area and brought into a lifeboat? If necessary, distinguish between different situations. Furthermore, indicate if you think it is not safe or possible to rescue this person.

Expert	Answer
1	- First of all, safety is no.1 priority, this is situation depending and also depends on the skills and judgement of the lifeboat crew - If a person is on a collapsed building, the person should be approached with great care
2	Collapsed buildings give different risks. It is possible unsafe to enter the building. Who will decide it is safe? For these rescues we do again need fire fighters, medics and possible engineers to see if the situation is safe enough to enter.
3	The crew of a lifeboat should always asses if a situation is safe (enough) for them to go. If not, or when in doubt they could contact specialists from the fire department.
4	Evacuation from a collapsed house is possible. Reddingsbrigade people are not allowed to enter the collapsed building, because of the danger of collapse. You have the facility USAR for that.
5	The reddingsbrigade is not equipped for rescuing a person from a collapsed building. We only facilitate the transport from place of accident to the landing site. Getting out the victim from a collapsed building is a task for the fire department or USAR.
6	Department to invest if the structure is save to enter.

Table U.10: Saving people from a collapsed building.

3c) In which ways can a person be taken out of the water into a lifeboat?

Expert	Answer
1	- Pulled on board vertically by lifeboat crew - Pulled on board horizontally by lifeboat crew - Simply climb on board lifeboat on their own (possibly using a climbing/scramble net, ladder or rope) - By lifeboat crew using of a “Jason’s cradle” - Climb on board with assistance of lifeboat crew - By the use of a MOB recovery system (e.g. “Reelsling” or “C-Hero”)

(Table proceeds on the next page).

2	Depends on the injuries of the victim. If hypothermic then we have to lift the victim horizontally out of the water. With the current lifeboats, especially the Vlet and Tinn Silver it is not possible to do so. All other type of injuries needs to be assessed.
3	If a person is unable to climb / step on the lifeboat by himself they will be assisted by the crew. In a straight forward situation this means they would be lifted by one or more lifeguards. If a person is injured they could be lifted on a stretcher. The type of stretcher used by these lifeboats does float but is easily pushed under the victim and has large openings for the water to flow out of when lifted above the water level.
4	Depending on the type of boat. - Tinn Silver: via hatch - Vlet: backwards - Rescue 3: backwards Horizontal is difficult due to the weight of the person and the number of rescuers you have in a boat.
5	It depends of the type of lifeboat. If the person is into the water for a while hypothermia is the greatest danger. Horizontal rescuing is key is this situation. The Tinn Silver has an opening on starboard side to make this possible. Other boat do not have this option. Specific rescue equipment such as a Jason's cradle rescue net or a salvage stretcher can be for added value. There are also some manual technics to take a person horizontal into a lifeboat.
6	By use of a brancard if necessary, otherwise a rope ladder or by lifting.

Table U.11: Saving people from a collapsed building.

3d) How much time do you estimate it takes to transfer one person from the hiding place into a lifeboat? This is the time between making contact with the person till the moment that a person is in the lifeboat. Please distinguish the scenarios of question 3a, 3b and 3c and mention the time unit (seconds, minutes, hours).

		Expert					
		1	2	3	4	5	6
Time estimation [min.]	**Higher floor/attic**	4	> 10	3	10	10-15	5
	Collapsed building	10	> 60	3	30	Various	15 min. till hours
	Water	1	1	5	5	0.5-1	Till 10 min.

Table U.12: Time estimations of boarding of people.

Comment expert 3:
Note: This depends very much on space available to navigate the boat and the accessibility for the victims. For example, if you can manoeuvre the boat straight under a normal first floor window it would be very straight forward to climb out of the window on to the lifeboat. But if the only way out of an attic is a narrow skylight it would be a lot harder and therefor more time consuming for a group of people to climb out. People that are completely wet after being rescued from the water need more care to prevent hypothermia and would therefor take more time.

Comment expert 6:

- Collapsed building: 15 min. to hours, depending on safety.
- Water: Depending on the state of the person mere seconds to 10min if with brancard.

3e) What equipment is needed during a flood, in addition to the regular equipment in a boat regarding transportation of people into a lifeboat?

Expert	Answer
1	- Scramble net - Ladder - Swim-ladder - Ideally, lifeboats involved in flood should have a bow- or stern visor - Possibly, some kind of "breeches buoy" system
2	Ladders, tools to open up the house like crowbars and big hammers. Floating and hypothermic stretchers and lots of ropes is good to have. Lightning the area is needed especially for night-time operations. Crews need to bring at least flashlights.
3	Typical flood rescue crafts are equipped with a "peilstok", "bergingsbrancard", ropes, communication equipment and the crew are equipped with a survival suit and lifejacket.
4	Crowbar, bolt cutter, sledgehammer, knife, mat stretcher.
5	In general the NRV boats are sufficiently equipped for there task. More attention for personal protective equipment of the crew. For example GPS trackers, helmets and more lifelines.
6	Brancard and life vests.

Table U.13: Saving people from a collapsed building.

U.4. Employability of rescue equipment and people

4a) In what way and by what can a boat be damaged during navigating in a flooded area? Arrange this from largest to lowest risk of occurrence and indicate if a lifeboat can proceed to rescue people during the flood.

Expert	Answer
1	- Propellor damage due to debris-replace prop - Cooling water issues due to debris-clean/repair - Structural damage due to debris-out of order
2	There is a big risk of damaging lifeboats. We don't know where we move, and can't look down the water. The water depth is possible low, what means you can hit a lot. When moving too fast through the area the risk is getting higher. Debris is everywhere, not only floating on top of the water.
3	Lifeboats like the Vlet and Tinn Silver are selected for their though hull. It would take a significant event to damage them in a manner that would render them useless. The engine is the most sensitive part. It could be damaged by obstacles under water, by a collision with another boat or for example by taking in the wrong or contaminated fuel. If the engine stops working it would obviously render the boat useless.
4	-
5	Underwater obstacles (stones, rocks, e.g.) Chemicals into the water
6	1. Floating debris 2. Unfamiliar area with obstacles 3. Undepts

Table U.14: Damage during navigating in a flooded area.

4b) Is it likely that a lifeboat is damaged due to navigating in a flooded area and cannot proceed to rescue people during the flood?

Expert	Answer
1	Yes, depending on the amount of debris, skills of crew, visibility of debris and operating speed
2	I would say the risk is high, but when taking down the speed the risk will be lower. The lifeboat can proceed longer. Note; Lifeboats got only 1 engine, when dead in the water, the lifeboat crew needs to be rescued.
3	Yes
4	If danger is thought of and navigation speed reduced, the risk of damage can be avoided. In this case, the boat can continue to sail to the incident. Low speed is having reaction time, having reaction time is likely to avoid damage.
5	This is not unthinkable; in practice and at exercises damage occurs.
6	No, dual hull prevents sinking, Vlet is indestructible. Most likely loss of propulsion

Table U.15: Likeliness of damaging a lifeboat.

4c) How many times can a lifeboat be deployed during the total rescue operation, until it is unsafe to deploy and must be repaired? If necessary, indicate different situations and indicate if there is a difference for boat types.

Expert	Answer
1	If handled properly, a lifeboat can be used numerous times, depending on the situations described in question 4b
2	All depends on the amount of crew available. Crews need to have food and water, but I would say, with four crewmembers a shift, a lifeboat can operate for 24 hrs.
3	Lifeboats should have multiple crews each and therefor be able to operate 24/7. As long as there is a fresh crew, and there is no damage, the lifeboat can safely be deployed.
4	In the event of collision with an object, check the hull after deployment. Check the engine (tailpiece check as soon as possible). Propeller may be out of balance or suspension rubber, backed may have been damaged.
5	Depends on the type of damage. If there is damage of vital elements it is not safe for the boat and its crew, the boat must be repaired immediately.
6	Puncture on rib causes it to be out of action. Other significant damage is caused by the person navigating and therefore not safe to deploy again.

Table U.16: Deployments during the whole flood.

4d) What material(s) or specifications are useful to prevent damage to a lifeboat?

Expert	Answer
1	- Engine type - Propellor protection - Cooling system - Shape of hull
2	At least a propellor guard housing will save the propellor. A depth indicator is useful.
3	A “peilstok” or “bootshaak” is used to check for obstacles in front of the boat.
4	Do not use Ribs, Tinn Silver and Vlet are best suited due to the aluminum or polyester hull.

(Table proceeds on the next page).

5	-
6	Prop protector and a metal strip from bow to stern on the lowest part.

Table U.17: Materials to prevent damage.

4e) How many people do you think are necessary to have one boat operational for 24 hours during a flood? If necessary, differentiate between different scenarios.

Expert	Answer
1	3-crew boat, 24 hours, 10-12 persons
2	I would say a four men crew, 2 rescuers, 1 firefighter and 1 medic per shift. 12 hour shifts is possible for a few days. This means for 24 hours, 2 rescue crews.
3	A boat needs a minimum of 2 crewmembers, 3 is preferred. 3 crews are needed for 24 hours after that the first crew could be called again. So 9 crewmembers for 1 lifeboat. In addition a crew is needed to attend to the victims once they get of the lifeboat. In addition a command post is needed to oversee the entire operation.
4	Max shifts of 8 hours times number of people as crew of the boat. E.g. Tinn Silver: 3x3 = 9 crew members. In addition, driver to pick up the members and take them away due to fatigue.
5	The lifeboat has a crew of 3 persons and a maximum shift of 8 hours, so in total 9 persons for a 24 hour duty.
6	3 a boat, 6h max, so 12 under normal actions, in case of CPR or death at own crews notice.

Table U.18: Crew needed during 24 hours.

U.5. Reaching people

5a) Can you think of a way to systematically search the flooded area for survivors?

Expert	Answer
1	Yes, by use of search patterns
2	Give every lifeboat an responsible area. Move slow through the area, Knock on every house and make notes of where people are located. Evaluate the area and assess the first victims to be rescued on a later stage.
3	This depends completely on the environment. For example in an urban area you could go door by door, in a less populated area search patterns could be used. Communications with a central command post should be used to record which areas have been searched and which areas still need to be searched.
4	-
5	In residential areas we will do a house to house check. For open areas the assist of a helicopter is required.
6	Street by street based on both type controlled by a central point and map

Table U.19: Systematically searching the area.

5b) Do you think it is realistic to find every person that needs to be rescued during a flood? If necessary, describe different situations and make a distinction between the Vlet, Tinn Silver, Rescue 3 and other lifeboats.

Expert	Answer
1	No, people will be missing after a serious flood.
2	I would say that not everybody will show up. Entering every house is not realistic and possible not allowed. If people drowned then these people are hard to find in the area. All boats got weak and strong points, but in my opinion all these boats are not very strong for efficient evacuations.
3	Depends on the situation. In case of a river flood in an urban area most victims should be found but in case of a large coastal disaster this might not be the case.
4	The Vlet and Tinn Silver has a good chance of getting to all victims which can be found. The Rescue 3 is more intended for quick reconnaissance or casualty transport that needs to be transported quickly.
5	At the end I think we can find 95% of the population in a flooded area. The success depends on the past time, area size and number of boats. The type of boat is less decisive for success.
6	No it is not realistic, depending on the time between action and flood people could have died. This means you would have to search all homes instead of helping people presenting themselves. All areas should be assessable so that is not a problem.

Table U.20: Finding people.

U.6. Experience

6a) Can you describe your own experience with boat rescues?

Expert	Answer
1	Approx. 40 years of experience and training…too much to describe
2	I was active in 1995 for a week in the village of Broekhuizen. We did not do rescues of people in the area, but assisted the firefighters with transporting and installing pumps in dangerous area's. With doing this we prevented the area for chemical spills. We did help to increase the strength of dikes by throwing sandbags from the boats against the weak spots in the dike.
3	+/- 12 years of lifeguarding at Callantsoog. Preventive surveillance and rescue operations at the beach. +/- 8 years of lifeguarding at Deventer / Wierden. Annual floods exercises and preventive surveillance for large events.
4	20 years experience at sea with different vessels 24 years of experience with the Vlet on different waters 8 years of experience with the Tinn Silver on various inland waters
5	-
6	Rescues people of all ages on sea, rivers and lakes. All where consciousness but some came very close to drowning

Table U.21: Experiences of experts with boat rescues.