Urine Collection Trolley for Informal Markets in Durban, South Africa

Student Paper

Author(s):
Colbach, Philippe

Publication date:
2023-06

Permanent link:
https://doi.org/10.3929/ethz-b-000619021

Urine Collection Trolley for Informal Markets in Durban, South Africa

Author: Philippe Colbach

Supervisor: Prof. Dr. Elizabeth Tilley

Advisors: Dr. Marc Kalina & Dr. Jakub Tkaczuk

Tutor: Prof. Dr. Mirko Meboldt

16 June 2023

Abstract

Asiye eTafuleni, a South African non-profit organization, has launched a program giving workers and customers at a popular market conglomeration in Durban, South Africa, access to public urinals. Since these urinals are not connected to a sewage system, they instead require a means to regularly empty the on-site urine storage and to transport the urine off to a centralized storage location.

The objective of this semester project was to find a solution to this problem by designing, building, and testing a urine collection trolley. If successful, the design was then to be replicated and deployed in Durban as part of the urinal program.

In order that Asiye eTafuleni could continue using their old cart, it was decided to use a barrow similar to the ones commonly found in South Africa as a basis for the prototype. Other key components included a 126-liter water tank, a cover, a pump, and a storage solution for the pump's hoses in the form of two plastic pipes. The entirety of the accessories could be removed from and reattached to the trolley with the help of two ratchet straps.

The system was tested the same way it would be used in its real working environment in Durban, except that the urine was exchanged for water. In other words, the testing stage consisted of repeatedly pumping water from a canister into the cart's tank, and then pulling the cart through the streets for 1.85 kilometers while loaded with 110 liters of water. Although a few design flaws manifested themselves over the course of the testing process, most of those are easy to fix and all in all both tests proved to be well feasible for the prototype.

As a result, the project can be viewed as a success, having produced a urine collection trolley capable of efficiently emptying the urinal drums and transporting the urine to a final storage location.

Table of Contents

1 Introduction

Asiye eTafuleni (AeT) is a non-profit organization based in Durban, South Africa, whose objective lies in improving the working conditions as well as the social standing of informal workers. To this end, AeT is not only lending them a voice and advocating for their rights on both a local and global level, but is also running several programs aimed at achieving immediate and tangible results (Asiye eTafuleni, 2020). This report is centered around one of those programs.

1.1 Project Background

Durban's Warwick Junction, apart from being a major transportation hub, is also home to a series of popular markets and stands at the core of AeT's efforts (Asiye eTafuleni, 2020). To improve the sanitary situation at the markets, AeT has launched a program providing the people working at or frequenting the junction with freely accessible urinals. These stand-alone urinals are not connected to a sewage system. Instead, the urine flows directly into a 50-liter drum that can be seen standing next to the urinal in Figure 1 on the left. Consequently, this drum must be emptied on a regular basis, which calls for an efficient, non-motorized way of transporting the urine away from the urinal station to a centralized storage point, where it can then be sold on as raw material.

Finding a suitable non-motorized transport (NMT) solution in the form of a hand-drawn trolley like the one on the right in Figure 1 was precisely the objective of this project.

Figure 1: Urinal station as placed at Warwick Junction (left), typical South African barrow (right). [Asiye eTafuleni]

1.2 Design Requirements

To ensure that the prototype would fulfill AeT's needs as best as possible, the design concept was developed in close collaboration with Mr. Richard Dobson, co-founder of AeT. With his help, the following design requirements were defined, laying the groundwork for what the prototype was going to look like. Some of the requirements were imposed by the cart's core purpose of transporting urine, others by external factors like Durban's urban environment.

a) Hygienic interface between the urinal drum, the cart, and the final storage tank

It should come as no surprise that handling urine constitutes a health hazard for the cart operator due to the risk of infections with various pathogens through both direct and indirect contact with urine (Bischel et al., 2019; Mnguni et al., 2008). While such infections can never be completely ruled out, the design should at least minimize the risk as much as possible.

b) Urine carrying capacity of 120 to 150 kilograms

A larger tank equals more flexibility and allows one to collect the urine from two or more urinal stations in a row instead of having to head back to the storage location in-between.

c) Ease of use

This requirement applies to two different aspects of the prototype.

First, the process of pumping urine into and out of the tank should be intuitive or at least easy to learn.

Second, during transport, the cart should not distract its operator in any way. Africa's urban spaces are not a friendly environment for NMTs (Kim, 2016; Njau, 2000). In addition to having to cope with many a pot hole (Golovcsenko & Mncube, 2011), cart operators are completely exposed to the surrounding traffic which oftentimes not only does not recognize NMTs as vulnerable road users necessitating a more careful driving behavior (Venter, 2017), but on the contrary even sees them purely as a hindrance on the road (Kim, 2016). Therefore, the cart should ideally have a slim, streamlined profile and all its components should be held securely in place. That way, the operator can pay full attention to the road and the people around him instead of having to worry about whether the cart behind him is going to clear an obstacle or collide with it.

d) Design based around materials available in South Africa

The idea behind the project was to develop a design that can be easily replicated in Durban by AeT. Every part that is used in the prototype should therefore have either an identical or at least a similar enough counterpart available in South Africa.

e) Urine-resistant materials

Materials in direct contact with urine must have a sufficiently high chemical resistance to it in order to prevent deterioration over time.

f) As few metal parts as possible

Since metals are a valuable material and hence a lucrative target for thieves, the use of metal parts ought to be kept to a minimum. Except for screws and the barrow itself, the design's components should preferably be made of plastic or similar.

g) Aesthetic appearance

Cart operators regularly find themselves confronted by a negative public opinion (Njau, 2000) as well as a systematic stigmatization as impoverished, lower-class citizens (Kim, 2016). Especially in the present case, where the operator will be moving a large quantity of urine through public spaces, it is of utmost importance to counteract these preconceptions and uphold the operator's dignity. The cart should therefore adhere to a certain aesthetic standard. More than anything, the fact that the cart is used to transport urine should not immediately be apparent to bystanders.

1.3 Justification and Research Questions

The task consisted of designing, building, and testing a trolley prototype capable of efficiently transporting urine from the urinals to an arbitrary storage point, all the while adhering to the stated design guidelines. Testing the prototype should give answers to the questions of whether the overall system works as intended, which components – if any – do not work and which could be further improved.

The ulterior motive behind the project was to provide AeT with a fully functional design blueprint that they could either replicate as is, or take as a reference and further modify to their liking.

2 Prototype

2.1 Overview

The prototype, which can be seen in Figure 2 and Figure 3, is composed of two main component groups: the cart itself on one hand and all of its attachments, which are held in place by two straps, on the other.

Figure 2: Top, side, and bottom view of the prototype.

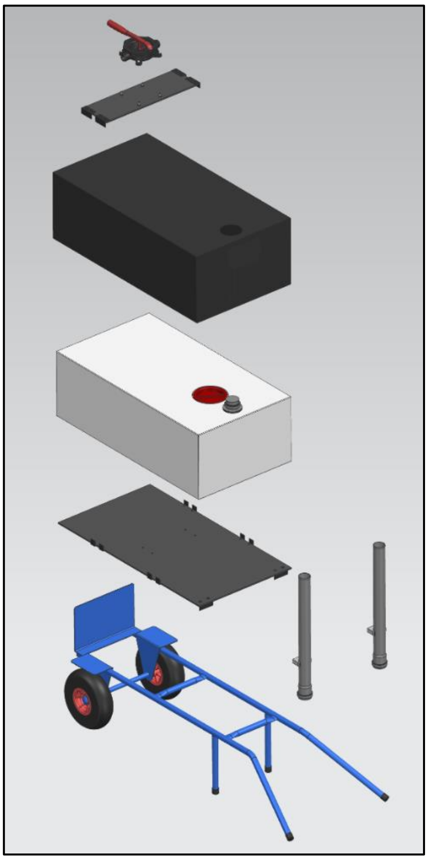

Figure 3: Exploded view of the prototype, showing its main components.

The prototype's cart imitates a type of barrow that is commonly found in South Africa, a picture of which can be seen in Figure 1 on the right. Indeed, the underlying idea of the project was to base the design around such a South African barrow so that AeT could continue using their old one.

The attachment group encompasses everything that transforms the regular cart into a urine collection and transportation system. As such, it is comprised of several key components: a water tank, a plate to hold the tank in place, a cover for the tank with an integrated glove pouch, a pump with two hose sections, a plate to hold the pump in place, two pipes that act as storage for the hoses and two straps that securely fasten the attachments to the cart. The advantage of having a quickly removable set of attachments that furthermore does not require any modifications to the cart, is that the cart retains its all-purpose character. By removing or reattaching the urine-related components, the cart can be used for either transporting urine or – like it did originally – any other goods, depending on what the current situation calls for.

Since the design configuration is highly adaptable and most of the components consist of either standardized or very basic parts (see Table 1), it should be possible to replicate the prototype in South Africa without running into difficulties concerning parts procurement. Furthermore, as demanded by the design requirements, the use of metal parts was kept to a minimum, meaning that apart from the cart itself as well as the fasteners, i.e. the screws, the two ratchet straps and two hose clamps, the prototype consists entirely of non-metal parts. Last but not least, the parts in direct contact with urine are all made of either polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC) or ethylene propylene diene monomer (EPDM), all of which are considered to be urine-resistant (IPEX, 2022; U.S. Plastic Corp., 2023).

To make sure that access to tools and manufacturing technologies would not play an impeding role in the prototype's replication, the system was almost entirely built with hand tools, namely a manual drill with a 3 mm, a 6 mm and a countersink drill bit, a saw, a file, sanding paper, a screwdriver, two wrenches of size 5.5 and 10, scissors and a sewing kit. Two notable exceptions are firstly the plates for the tank and the pump which were cut to size at the hardware store at the time of purchase, and secondly the modifications to the original sack barrow which should not need to be replicated anyway. Since some components, namely the tank and the original sack barrow, were not manufactured with a particularly high attention to dimensional accuracy and symmetry, it was easier to work directly with or on these components instead of relying on measurements that might fit on paper but not in reality. It may be helpful to proceed in the same manner when replicating the system.

The bill of materials in Table 1 lists all the items needed to create an identical copy of the prototype. Naturally, these materials are only suggestions and can be exchanged according to personal preference and parts availability.

Table 1: Bill of materials.

Item	Part of which key component?	No. of units used	Notes
Sack barrow	Trolley	1	Irrelevant for replication.
Pipe for welding	Trolley	2	Irrelevant for replication.
Reinforcement pipe for welding	Trolley	1	Irrelevant for replication.
Foot caps Ø25 mm	Trolley	4	Irrelevant for replication.
35 L PE canister	Urinal drum	1	Irrelevant for replication.
Tank fitting Ø50 mm	Urine tank	1	Irrelevant for replication.
126 L PE tank 885 mm x 480 mm x 300 mm	Urine tank	1	
Resopal® panel 885 mm x 480 mm x 6 mm	Base plate (tank)	1	
Resopal® panel 150 mm x 480 mm x 6 mm	Base plate (pump)	1	
PVC corner profile 1.8 mm x 25 mm x 25 mm x 1000 mm	Base plates (tank & pump)	1	
Various screws, nuts, and washers	Base plate (tank & pump)	-	Type and amount are specified in section 2.2.2.
PVC pond liner 0.5 mm x 1505 mm x 1100 mm	Cover	1	The 1505 mm x 1100 mm cutout suffices for both the cover itself and the glove pouch.
Elastic cord Ø1.5 mm	Cover	1	A cord length of 500 mm is sufficient.
Thread	Cover	-	
Button	Cover	1	
Seaflo 720 GPH manual diaphragm pump	Pump	1	The exact same model is available in South Africa as well.
Hose clamp	Pump/ Hose	2	Needs to be large enough to fit over the hose.
PVC hose Ø 32 mm x 2700 mm	Hose	2	Needs to be flexible enough to fit onto the pump's input/output sockets with a max. diameter of 34.5 mm.
PVC rod Ø7.5 mm x 1000 mm	Hose	1	
Buckle strap	Hose	1	A strap length of 500 mm is sufficient.
Cable tie	Hose	10	
PP pipe Ø50 mm x 500 mm	Hose storage	2	
Pipe clip Ø50 mm	Hose storage/ base plate (tank)	2	
PP pipe plug Ø50 mm	Hose storage/ urine tank	3	Only 2 needed for replication, the other one serves as a plug for the tank fitting.
Ratchet strap 25 mm x 3000 mm	Fastening system	2	A strap length of 2000 mm is sufficient.
Pair of children's socks	Fastening system	1	

2.2 Main Components

The following sections contain a more in-depth description of each key component and reiterate the specific materials that are required to replicate them.

2.2.1 Trolley

The steps described in this section are mainly included for completion's sake. There should generally be no need to replicate them since the intention behind the design was for AeT to continue using their own South African trolleys.

For the prototype's cart (Figure 4), a regular sack barrow served as a starting point due to its fairly similar structural layout relative to the typical South African cart. However, since the manner such trolleys are operated in differs between Switzerland and South Africa, there were some key differences that had to be corrected. The first modification consisted of welding some extension pipes to the chassis to increase the cart's overall length and make the handles stand further apart. In a second step, two support legs were added so that the cart could be put down parallel to the ground.

Figure 4: Picture of the modified sack barrow.

2.2.2 Base Plates

The concept includes two solid core Resopal® panels that can be seen on Figure 5. The larger plate, which constitutes the main contact point between the trolley and the attachments, is primarily aimed at distributing the tank's weight and keeping it centered on the trolley. The smaller plate serves as a mounting platform for the pump.

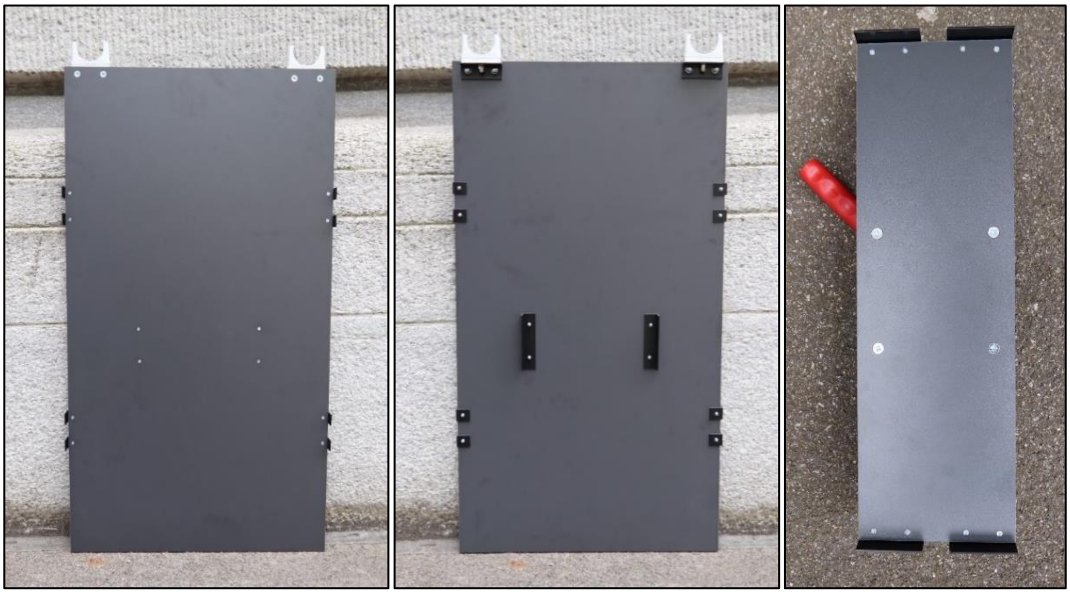

Figure 5: Top and bottom view of the tank's plate (left and middle), bottom view of the pump's plate (right).

The base plates are two of the more labor-intensive components. Their replication requires the following materials:

- Resopal® panel 6 mm x 480 mm x 885 mm
- Resopal® panel 6 mm x 480 mm x 150 mm
- PVC corner profile 1.8 mm x 25 mm x 25 mm x 1000 mm
- Two pipe clips Ø50 mm
- Twenty M3 flat head machine screws, washers, and nuts
  - Twelve for the brackets on the larger plate except for the two holding the pipe clips.
  - Eight for the brackets on the smaller plate.
- Eight M6 flat head machine screws
  - Four for the brackets holding the pipe clips on the larger plate.
  - Four for the pump on the smaller plate.
- Two M6 non-countersunk machine screws
  - One for each pipe clip on the larger plate.
- Fourteen M6 washers
  - One for every M6 screw on the larger plate.
  - Two for every M6 screw securing the pump on the smaller plate.
- Ten M6 nuts
  - One for every M6 screw on the larger plate.
  - One for every M6 screw on the smaller plate.

The PVC corner profile is used to create various types of brackets, each of which serves a different purpose. The first type is found on both the larger and the smaller plate and is mounted in pairs, as depicted on the upper right and lower right of Figure 6. These brackets act as guide rails for the ratchet straps in addition to tightly hugging the tank, thus ensuring a secure fit for the latter and the pump. The second type is used to hold the two pipe clips on the larger plate and can be seen on the lower left of Figure 6. The third and final bracket type shown on the upper left of Figure 6 prevents in-plane movement of the tank's plate relative to the trolley. The exact placement of the various brackets on the larger plate depends on the layout of the cart's tubing, which is certainly going to differ between the prototype and its South African counterpart.

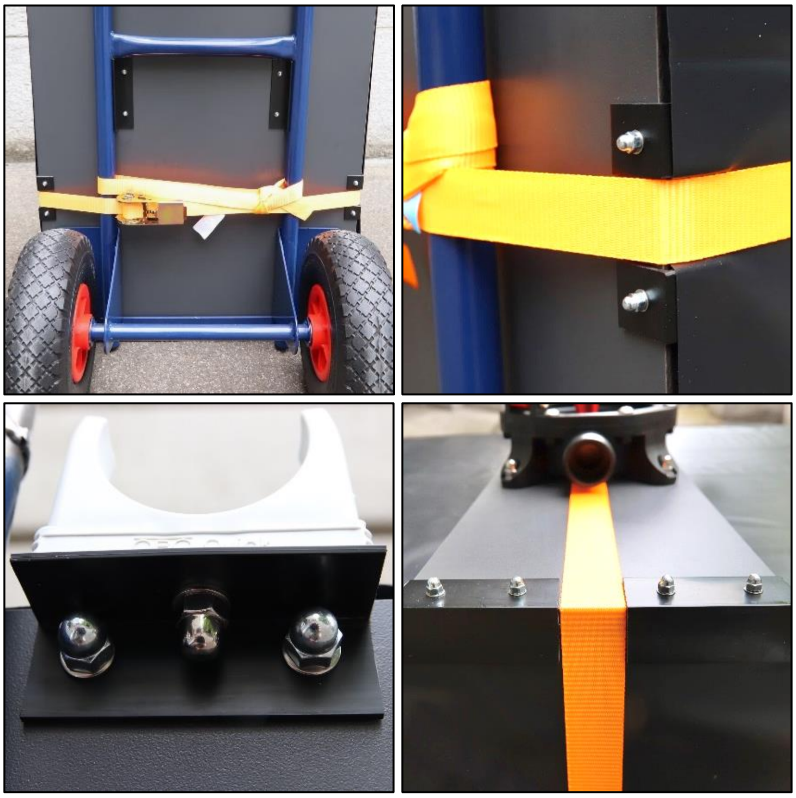

Figure 6: Pictures of the different types of brackets.

The prototype relies on M6 screws for fastening the pump as well as the pipe clips and their respective bracket, and uses M3 screws for all remaining connections. Countersinking the bores on the plates' tank-facing side allows the flat head screw heads to lie flush with the plates and thus prevent damage to the tank.

The prototype uses plates made from Resopal®, which is a material that strictly speaking does not classify as plastic, but its relatively high resin content does grant it similar benefits like good weather resistance and cleanability (Resopal®, 2020). A plate made from genuine plastic ought to work just as well and might be easier to come by in Durban.

2.2.3 Urine Tank

The prototype's centerpiece is a rectangular 885 mm x 480 mm x 300 mm PE water tank with a 126-liter capacity (Figure 7). Its footprint efficiently utilizes the space allocated by the trolley while also keeping a low profile, which in theory results in a more controlled and stable handling.

Figure 7: Side view of the tank sitting on the trolley.

The prototype's tank originally came with a 150 mm tank opening only, which is why a smaller one was added using a 50 mm tank fitting with a plug for closure. Assuming the respective South African tank comes with a pre-installed 50 mm to 60 mm opening, there is no need to replicate this step. However, if the tank were to require a second opening, it is advisable to install a fitting with a screw cap instead of a plug, as it offers a more secure fit.

In the event that the pump were to break while the tank is still carrying considerable amounts of urine, emptying the tank would become a challenging – and not to mention messy – feat. Therefore, it is advisable to have a second pump at hand as a backup solution. Alternatively, one could also fit a tap to one of the tank's sidewalls, although one must keep in mind that a tap constitutes a weak point in the system as it is at constant risk of collisions and might suddenly start leaking.

2.2.4 Cover

A replication of the cover as shown in Figure 8 requires the following materials:

- PVC pond liner 0.5 mm x 1505 mm x 1100 mm
- Thread
- Elastic cord Ø1.5 mm
- Button

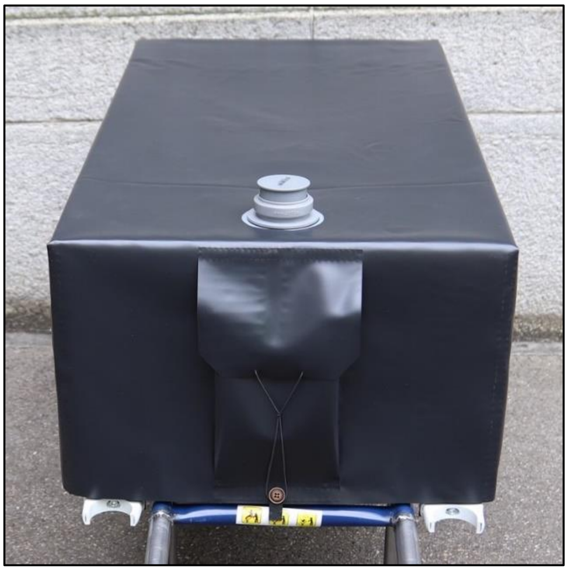

Figure 8: Picture of the tank's cover.

The cover's purpose is twofold. First, it hides the fact that the cart is transporting urine and second, it protects the tank from dirt and damage. It is sewn from a PVC tarp according to the templates in Figure 9. Thanks to its waterproof properties, the cover is also easy to clean in case of spillage.

On the front, a pocket intended as storage space for a pair of gloves has been incorporated into the cover. The material for the pocket stems from two of the four leftover squares that resulted from cutting out the cover's contour. The pocket's flap is a few centimeters wider than its body to prevent rainwater from accumulating inside. Figure 10 shows the pocket as well as the stitching along the cover's edges in more detail.

During the testing phase, the glove pouch was perceived as slightly too small. It might be worth considering increasing the width of the body and the flap by 30 mm, resulting in a new width of 170 mm and 200 mm, respectively. Additionally, a lighter color might be preferrable for the cover as it would stay cooler on sunny days.

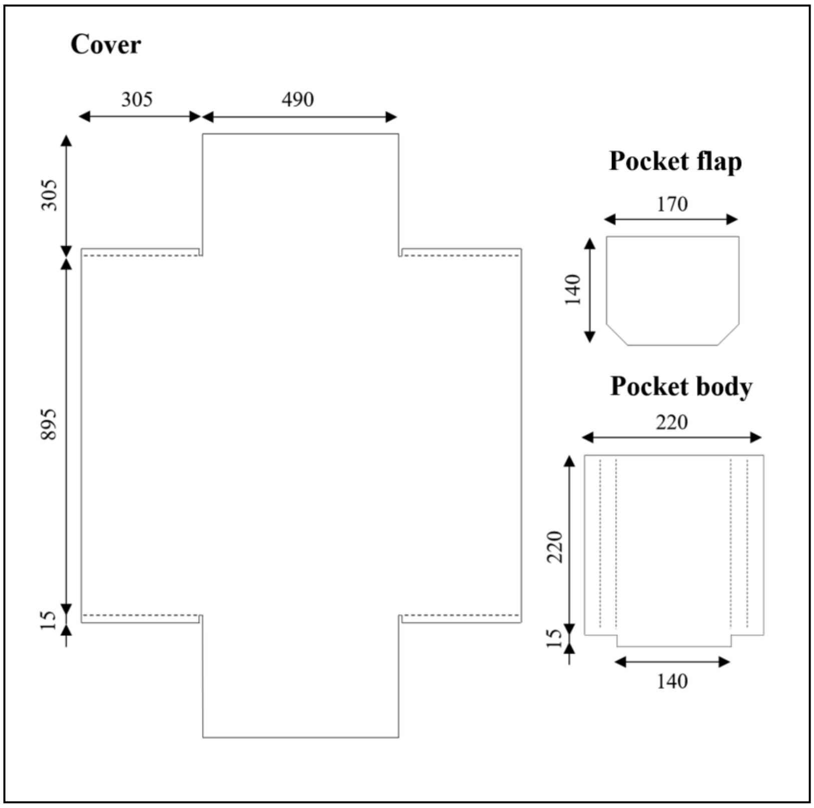

Figure 9: Templates for the cover and the glove pocket. Unit: [mm].

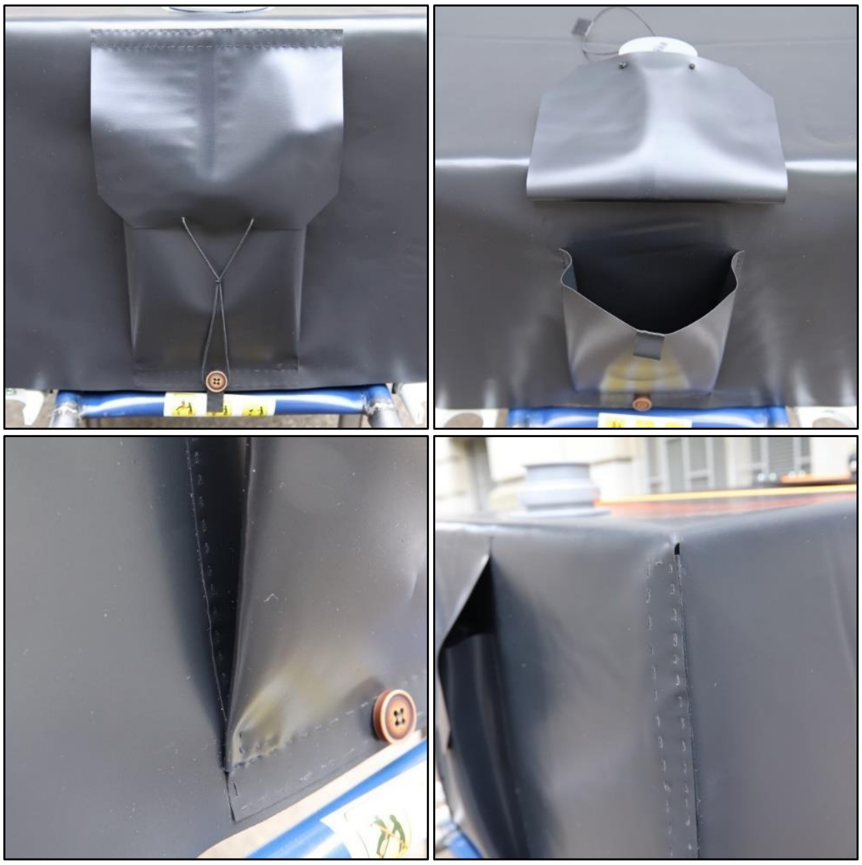

Figure 10: Pictures of the glove pouch and one of the cover's corners.

2.2.5 Pump

To transfer urine into and out of the tank, a manual diaphragm pump with a PP body and EPDM membrane was deemed to be the best solution in terms of both hygiene and convenience. Compared to a system relying on a funnel or trough to pour the urine into, the cart operator does not have to worry about the funnel overflowing, the urinal drum slipping out of his hands, or urine running down the drum's side.

The pump is mounted on the 150 mm x 480 mm plate described in section 2.2.2 that is now lying across the tank's cover (Figure 11, left). Adding one layer of washers in between the pump's feet and the plate frees up just enough space for the ratchet strap to run through (Figure 11, right).

The pump's handle can be repositioned with regard to the input and output sockets by removing the lock ring that is securing the diaphragm. While up to personal preference, a configuration where the handle is pointed away from the operator and then pulled up towards him while pumping is advisable, as it results in a more natural movement than the other way around.

Figure 11: Pictures of the pump mounted on the cart.

The pump setup further requires the following items:

- Two PVC hoses Ø32 mm x 2700 mm
- Two fitting hose clamps
- PVC rod Ø7.5 mm x 1000 mm
- Ten cable ties

The 2.7 m long ribbed PVC hoses are attached to either side of the pump and secured with a hose clamp. On their free end, a PVC rod of 500 mm in length and 7.5 mm in diameter is fastened with five cable ties, as shown in Figure 12. The purpose of these rods is to stiffen the hose ends, enabling the operator to grasp the hoses at the upper end of the rods with only minimal sway at the hose ends. As a result, the hoses can be handled without touching the section that was in direct contact with urine during the pumping process.

Figure 12: Pictures of the PVC rod attached to the hose end.

One could also use a smooth hose instead of a ribbed one, which would have the benefit of not retaining as much residual urine on its walls that could then fall off while moving the hose into or out of its storage pipe. Similarly, if desired or required, the round reinforcement rods could be exchanged for differently shaped ones, as long as the hose ultimately still fits into the storage pipe, the urine tank and the urinal drum.

2.2.6 Hose Storage

The storage system is comprised of the following parts:

- Two PP pipes Ø50 mm x 500 mm
- Two PP pipe plugs Ø50 mm
- Buckle strap

The pump's hoses are wrapped around the pump once and then inserted into two PP pipes for storage. The latter are half a meter in length and sealed with a pipe plug at the bottom. They are mounted to a pair of pipe clips at the front of the cart that allow them to be quickly removed for drip-free handling of the hoses (Figure 13). While mounted, the pipes are resting directly against the tank, which relieves the clips from some of the forces and – more importantly – the torques exerted by the hoses during transport. Hence a single clamp per pipe is sufficient to ensure a secure hold.

Figure 13: Side and front view of the pipes used for storing the hose ends.

Despite the hose ends already being stored in their respective pipes, the hoses are additionally secured to the upper ratchet strap using a short buckle strap (Figure 14) to further restrict their movement and thereby once again reduce the exerted forces. Provided that the cart can be placed close enough to the urinal drum, the buckle strap can even remain closed for the entirety of the pumping process.

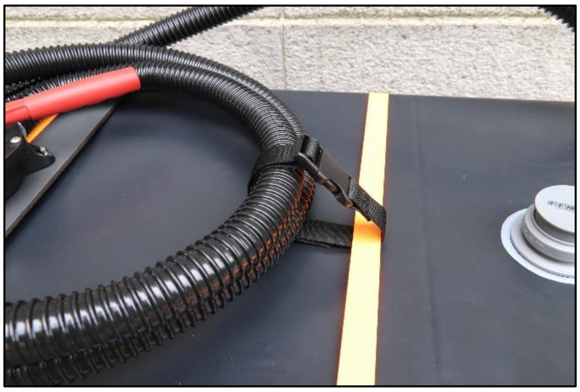

Figure 14: Buckle strap securing the hoses to the upper ratchet strap.

2.2.7 Fastening System

As a final step, the attachments are secured to the cart by two ratchet straps that follow the path dictated by the plates' brackets. To hide their metallic nature and thus reduce the risk of theft, each ratchet is additionally covered by a sleeve made from half a children's sock, one side of which has been sewn shut except for a slit to let the strap pass through, as shown on the left of Figure 15. As an alternative to socks, any kind of sleeve that fits over the ratchet without being too loose ought to work.

Once all the components have been fastened to the cart, the system's total weight amounts to around 24 kilograms.

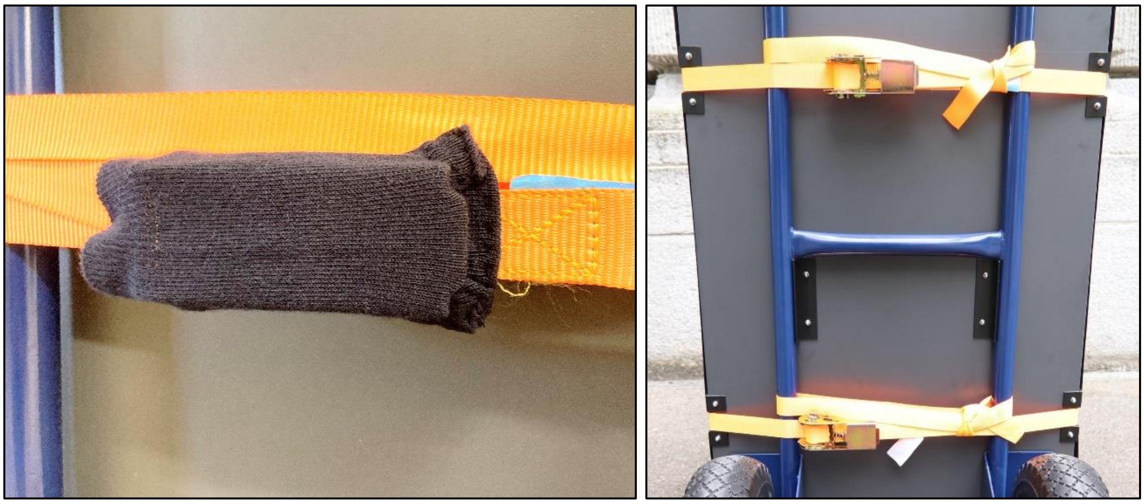

Figure 15: Ratchet straps with and without their sleeve.

3 Testing Method

The validation procedure of the cart was split into two main parts. The first part was focused on the pumping system that is used to fill up or empty the cart's tank, while the second one consisted of completing a predefined track with a full tank on the cart. The goal was to verify whether the prototype's design fulfils the requirements and would theoretically be ready to be deployed as is in its target destination of Durban, South Africa.

3.1 Technical Test

The technical check covered the entire sequence of events from the moment the cart operator arrives at the urinal drum, which in the present case was a 35-liter canister, until the moment he leaves again.

As illustrated by Figure 16, the first step consisted of filling up the canister with water. The first time, it was filled with roughly 30 liters whereas during the five subsequent run-throughs the water quantity was reduced to circa 14 to 18 liters due to the combined challenges of weight, distance to carry, and slipperiness when wet. After putting on gloves, the storage pipes were then successively removed from the cart while still carrying the hose ends inside them. Only once the pipe was positioned as close to the tank or the canister's opening as possible was the hose extracted and immediately inserted into the target container, thereby lowering the risk of dripping urine along the way. On completion of the pumping process, the same procedure was repeated in reverse.

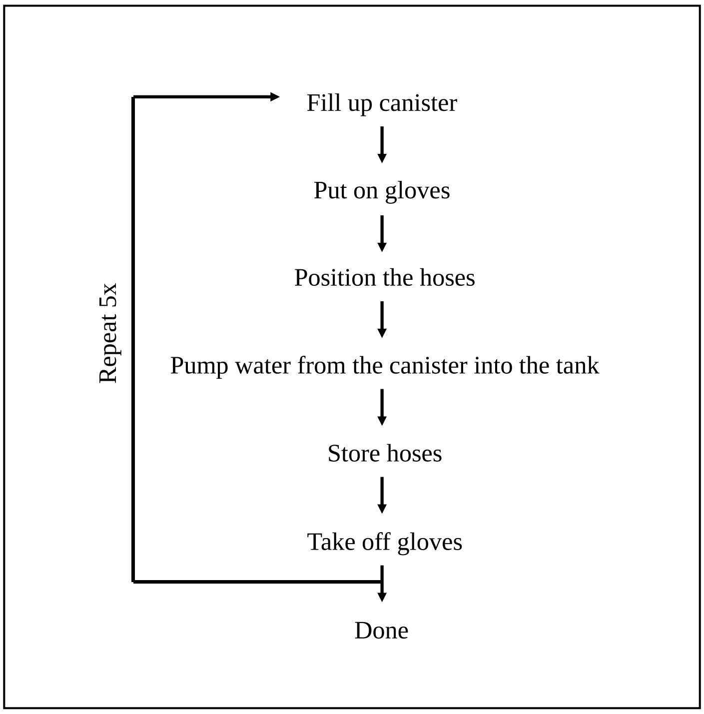

Figure 16: Illustration of the technical test procedure.

In total, the technical test was carried out six times back-to-back, hence there was enough time to get familiar with the system and determine any weak points. After the final iteration, the cart was carrying approximately 110 liters of water.

3.2 Test Run

After the technical part of the test, the cart was subsequently taken on a test run while still loaded with 110 liters of water. Its objective was twofold. First, it allowed one to verify that the tank and the rest of the attachments do not budge under load even when subjected to shocks and vibrations. Second, one could gain an impression of the cart's handling and determine whether the tank's current capacity is too high or, on the contrary, could even be further increased.

The route was approximately 1.85 km long with maximum uphill and downhill gradients of +7 % and -6 %, respectively. The test route's distance was chosen based on the distance the cart would later have to cover during the collection trips in Durban. To account for different deployment scenarios, it also included a 500 m long section that ran almost continuously uphill. The road surface was mostly smooth asphalt, except for a 135 m long cobblestone section and the occasional low-profile curb.

During the test run, the weather was sunny with temperatures around 24 °C.

4 Results and Discussion

4.1 Technical Test

Without rushing, it took 3 minutes and 50 seconds to complete an entire test iteration starting from the arrival at the canister, which was filled with approximately 16 liters of water, until the moment of departure. Furthermore, based on two timed executions of the pumping process alone, one can roughly assume a pump rate of 21.2 L/min at a pace of 68 strokes/min, meaning that the displacement of 1 liter of water requires 3.2 strokes. It should be noted that these two measurements can only be taken as rough approximations, since the estimation of the canister's water level that the calculations are based on may have been off by a couple of liters. Additionally, the last few strokes were not able to draw in meaningful amounts of liquid anymore and are thus distorting the results as well.

The first run-through was intended as an opportunity to get familiar with the system. As such, its execution was quite poor, having chosen the rather inefficient approach of primarily relying on arm muscles to pump, as well as spilling several drops of water while removing the hoses from their respective containers. During the subsequent repetitions, the pumping was done using the entire upper body, resulting in a rowing-like motion that rendered the process much less exhausting. The hoses were also removed more carefully from their container and thoroughly shaken on their way out to lose as many of the residual water droplets as possible, which proved to be an effective approach. An example of what the prototype looked like once set up for the pumping process is given by Figure 17.

Figure 17: Urine collection trolley during the pumping process.

The first design flaw that stood out was that the glove pouch is slightly too narrow at 140 mm in width. The way the gloves were intended to be put back into the pocket was by holding them by their sleeve and slowly lowering them fingers first towards the pouch before finally letting them glide into it by themselves. This approach has the advantage that the operator's hand does not come into direct contact with the presumedly contaminated pocket interior. And while it is possible to do so at the current width, it involves quite a bit more patience compared to just shoving them in, since the gloves' fingers are prone to getting caught on the pocket's edge. Widening the pocket by 30 mm ought to resolve the issue.

The button to keep the pocket flap closed is somewhat hard to access due to the cart's uppermost crossbar, although this issue is highly dependent on the tank's dimensions as well as the position of the crossbar.

The two hose storage pipes must be emptied after every trip since there is always some residual liquid in and on the hoses after pumping which ultimately accumulates at the bottom of the pipes.

4.2 Test Run

The 1.85 km long test route was completed in 28 minutes with an average speed 4 km/h.

Although it is difficult to properly assess and objectively describe the cart's handling without prior experience in cart pulling and thus without a reference for comparison, the following paragraphs nonetheless strive to reflect the observations made during the test as genuinely as possible.

The first thing to be noticed was that the cart swung back and forth from one wheel to the other for a couple of seconds when pulling it up or down a curb at an angle instead of perfectly perpendicular. Yet, apart from interrupting the smoothness of the ride, there were no noticeable downsides to this.

Taking left and right turns as well as bringing the cart to a full stop worked well on all surfaces, be they flat, uphill or downhill. Setting the cart in motion on flat and downhill sections did not pose much of a problem either.

On the steeper uphill sections, however, putting the cart in motion and pulling it up the hill proved to be incredibly exhausting for the arms and legs. The arms in particular did not fully recover from the exertion until after the end of the trip. This circumstance in combination with a steadily growing exhaustion in the lower back made the second half of the route quite a challenge. Yet, it is conceivable that for an experienced cart operator with a strong physique, the test route would have posed much less of a challenge. Therefore, upgrading to a 150-liter tank – as suggested by the design requirements – may well be a worthwhile investment, all the more so considering that the roads in the immediate vicinity of the markets in Durban are rather flat.

Finally, the physical exertion in combination with the warm weather resulted in sweaty palms, rendering the handles quite slippery. While unpleasant, at no point did it feel like the handles were about to slip out of one’s hand, largely thanks to the end caps mounted on them. However, if slippery handles were to pose a problem, one could try to counteract it by wrapping them either in bicycle handlebar tape, which is available in a variety of different colors, materials and textures, or any other kind of tape that has similar properties. A light-colored tape with a texture that offers a good amount of grip could for example be an effective remedy when out in the sun.

5 Conclusions and Recommendations

In summary, the urine collection trolley prototype works as intended and is able to successfully overcome the challenge of efficiently emptying the urinal drum and subsequently transporting the urine to a centralized storage location, all the while adhering to the given design requirements.

Although there are a few flaws, most of those can be fixed fairly easily. In particular, it is first and foremost recommended to widen the glove pouch. Then, based on personal preference, it could make for a worthwhile improvement to use a more lightly colored tarp for the cover, go for a higher tank capacity, and wrap the trolley's handles in a non-slip tape.

Finally, as mentioned before, the design can easily be modified or upgraded at any time, should the need for it arise.

6 References

Asiye eTafuleni. (2020). *Where We Work – Asiye eTafuleni*. Retrieved June 4, 2023, from https://aet.org.za/about-asiye-etafuleni/warwick-junction/

Bischel, H. N., Caduff, L., Schindelholz, S., Kohn, T., & Julian, T. R. (2019). Health Risks for Sanitation Service Workers along a Container-Based Urine Collection System and Resource Recovery Value Chain. *Environmental Science & Technology*, *53*(12), 7055–7067. https://doi.org/10.1021/acs.est.9b01092

Golovcsenko, A., & Mncube, P. (2011). *Hidden Warwick: A photo essay of the barrow operators and their role in Durban's informal economy*. SIT South Africa: Social and Political Transformation.

IPEX. (2022, August 25). *EPDM & FKM Chemical Resistance Guide – IPEX* [Chemical resistance chart]. Retrieved June 7, 2023, from https://ipexna.com/resources/document-repository/epdm-fkm-chemical-resistance-guide/

Kim, T.-E. (2016). *Pedestrians, Handcarts, Minibuses and the Vitality of Urban Mobility* [Doctoral Thesis]. Arizona State University.

Mnguni, M., Ndlovu, S., Gounden, T., Pfaff, W., Rodda, N., & Buckley, C. (2008, May 19). *Health Risk Assessment of the Operation and Maintenance of a Urine Diversion Toilet*. WISA 2008 Conference, Sun City, South Africa.

Njau, E. K. (2000). *Factors That Generate And Sustain Handcart Transport Activities: A Case Study Of Nairobi* [Master's thesis]. University of Nairobi.

Resopal®. (2020, January 23). *Decorative High Pressure Laminates – Resopal®* [Product data sheet]. Retrieved June 9, 2023, from https://www.resopal.de/sites/resopal/files/docs/resources/product_data_sheet_resopal_hpl_01.pdf

U.S. Plastic Corp. (2023, January 17). *General Chemical Resistance Chart – U.S. Plastic Corp.* [Chemical resistance chart]. Retrieved June 7, 2023, from https://www.usplastic.com/knowledgebase/article.aspx?contentkey=825

Venter, K. (2017, July). *Driver Perception of Non-Motorised Transport Users: A Risk in Traffic?* Southern African Transport Conference, Pretoria, South Africa.