Cape Town's problematic vacuum sewer: A reflection on the technical, social and institutional blockages that constrain municipal management

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ABSTRACT
South Africa's first vacuum sewerage system was completed in Kosovo, an informal settlement (shantytown or slum) in Cape Town in February 2009. Although hailed by project consultants and municipal officials as the ideal technology for the Cape Flat's level landscape, high groundwater table and sandy soils, the vacuum sewer has proved problematic, being continuously blocked since inception by gross solids in its collection chambers. Residents currently use the system's collection chambers as 40-litre conservancy tanks emptied three times a week. Kosovo's sanitation problem has become yet another example of how a technologically sound concept has failed disastrously in its implementation in a developing world context. The paper offers evidence of why the system was bound to fail as it was inherently a contextually inappropriate technology for Kosovo as implemented, and furthermore one that was poorly managed due to limited technical knowledge, institutional conflict and instability within the municipal structures of the City of Cape Town. It suggests that improving the functioning of the system requires the municipality to directly address the technical, social and institutional constraints that are jointly responsible for its failure.

KEYWORDS
Appropriate technology; informal settlements; municipal management; South Africa; urban drainage; vacuum sewerage

INTRODUCTION
The City of Cape Town (CoCT) faces monumental development challenges stemming largely from decades of colonial and racially segregated Apartheid rule which has resulted in inequitable wealth and service provision. Currently over 40% of Cape Town residents live below the poverty line (Smit, 2008) and approximately one third of its households reside in high density informal housing located in historically 'coloured' or 'black' townships with limited or no access to basic services (CoCT, 2008). The services backlog is expected to be compounded further by demands from the city's growing number of informal settlements and backyard dwellings (unregulated lodgers' homes in tenured homestead sites) because of rampant rural-urban migration, natural population growth and limited access to low-cost housing.

The South African national government has declared water and sanitation a basic human right and ordered local municipalities to provide free basic services to all indigent residents (DWAF, 2003). Municipal officials are under intense pressure to rapidly deliver safe, clean and accessible sanitation on a large scale to the country's informal settlements in a sustainable and equitable process, but with limited financial resources and capacity (Muller, 2008; Mjoli *et al.*, 2009). Further challenges arise because informal settlements are often regarded by planners as temporary, thus sanitation services installed are usually communal and not always of high quality. Consequently communal facilities are often vandalised by residents who desire security of tenure and see provision of a toilet per household as indicative of such security. CoCT currently aims to provide its informal settlements with one standpipe for every 25 households within a 100 meter radius and waterborne sanitation of one toilet for every five households (CoCT, 2010a).

Due to the limited sewerage infrastructure in Cape Town's townships, the majority of municipally-delivered sanitation options comprise of non-sewered chemical or container toilets (both are waterless latrines with seats positioned above 100 litre containers that are emptied regularly by private sector contractors). Such sanitation options do not adequately address urban municipalities' greywater problems: much household wastewater in informal settlements is emptied into stormwater drains thus polluting public water ways (CoCT, 2005; Holden, 2010). CoCT officials therefore prefer waterborne sewerage for the city's informal settlements to enable the transport of greywater to treatment works along with faecal matter. Conventional sewerage, however, is impractical for many of Cape Town's informal settlements because of the deep trenching and multiple pump stations required in the flat topography, sandy soils and high groundwater tables where they are situated. It is moreover difficult to implement in dense settlements where there is little space between structures and residents often resist being moved, even temporarily, while services are installed. After a review of alternative sanitation systems, a group comprising both municipal and consulting engineers assessed vacuum sewerage in 2005 to be an ideal technology for many of Cape Town's dense informal settlements because they require shallower trenching, fewer pump stations and require less residential relocation than gravity systems (CoCT, 2006a).

The municipal officials identified Kosovo in Phillipi to test the vacuum sewerage technology. Since its initial inhabitation in August 1999, this informal settlement had ballooned into one of Cape Town's largest with approximately 15,000 residents in 5,500 dwellings on 26.5 hectares of land (CoCT, 2006b; Goven, 2007). Trialling the vacuum system in Kosovo fitted neatly into the CoCT's plans for the settlement's in-situ urban drainage and access roads upgrade for which budget had been made available. There was also strong political support for something that would fulfil residents' demand for full-flush systems after they had widely rejected increasing the numbers of container toilets. Installation of Kosovo's vacuum system was eventually completed in February 2009 with 354 communal full-flush toilets in 43 blocks; each block with its own collection chamber. Concrete rings with lockable lids were added as a security feature to protect collection chambers from damage.

Since installation, however, Kosovo's vacuum sewer system has continuously been hampered by poor management from both the end users (Kosovo's residents) and the service providers (CoCT) (Ashipala, 2011). The disposal of items such as cutlery and bricks into the vacuum system by the residents quickly resulted in some interface valve diaphragms being pierced by sharp objects whilst some sumps were filled up with gross solids. These problems were exacerbated when some of sensor controllers malfunctioned due to fats and dirt clogging the pilot tubes, or rendered completely useless from water-logging after the chambers over-filled

as a consequence of the failure of the valves to open. This has resulted in sewage regularly flooding the concrete ring, inundating the collection chambers and spilling out onto the ground around the toilet blocks (Figure 1). Meanwhile, the vacuum pumps have been overworked due to air leakages.

Figure 1. Clockwise from left to right: Typical conditions of a vacuum system toilet; raw sewage being pumped out of a clogged sump and flooded concrete ring; a brick in a sump; and a spoon piercing an interface valve diaphragm.

The persistent vacuum system problems quickly revealed CoCT's limited technical knowledge and the lack of an operation and maintenance (O&M) plan. By early 2011, the ZAR17 million (USD$2.4 million) installation was functioning as 40-litre conservancy tanks that were being emptied three times a week at an annual cost of ZAR500,000 (USD$70,000); 25 times more expensive than container toilets and 5.5 times more expensive than the "expensive" chemical toilets on a per litre basis.

Kosovo's unresolved vacuum sewerage problem has become yet another example of how a seemingly technologically sound concept has failed disastrously when implemented in a developing world context. This paper reviews and discusses how Kosovo's vacuum system was bound to fail due to a number of technical, social and institutional constraints – including inconsistent lines of accountability by CoCT officials at various levels – factors which continue to plague attempts to rehabilitate the now dysfunctional vacuum system.

METHODS

The primary research method employed was participant observation (O'reilly, 2005) that aimed to understand and represent the perspectives of CoCT officials providing basic services to informal settlements. Insight into the complex challenges municipal officials face was obtained by first interviewing and then observing officials' behaviours and interactions in their daily routines, and also participating as management support in municipal projects. This was supplemented by interviews and site visits with officials involved in service delivery from the South African municipalities of CoCT, eThekwini and Overstrand, private contractors, non-governmental organisations (NGOs) and academic researchers; meetings with community and elected leadership; and data supplemented by municipal officials.

RESULTS AND DISCUSSION

In retrospect, it is evident that Kosovo's vacuum system was bound to fail due to a number of technical, social and institutional constraints that have paralyzed effective municipal management. All municipal officials familiar with Kosovo's vacuum sewer, including the project leadership, now acknowledge that regular blockages of the system by foreign objects and the municipality's lack of knowledge about how to manage vacuum systems suggest that it was an inappropriate technology for informal settlements as implemented. This paper argues further that insufficient attention was given to the social context in informal settlements, whilst O&M has been compromised by conflict and lack of capacity in the municipality. High staff turnover, municipal restructuring and a lack of conflict resolution skills have resulted in inconsistent lines of project accountability that have made it difficult to hold any one person or department accountable for the system's failures or take responsibility for resolving the problems.

Technically constraints: The "blockage" problem

CoCT officials struggle with sewerage blockages in their conventional sewerage installations with some 90,000 blockages reportedly occur annually city-wide in part because people use sanitation facilities for other than its intended purpose of conveying human waste and toilet paper (CoCT, 2010b). Technically, any sewerage system is susceptible to blockage by bulky objects and by the build-up of grease and fats. What distinguishes a vacuum system in this regard is that, as usually implemented, blockages tend to occur locally at collection chambers and result in the discharge of sewage on site, whereas blockages in gravity systems tend to occur further downstream – away from the users. Officials regularly complain that informal settlement residents misuse toilets by flushing foreign objects (rags, newspaper, stones and sharp objects), a practice they attributed to residents' incomprehension about, and unfamiliarity with, sewerage rather than to circumstance (Beauclair, 2010). Yet observational data suggest that it is more logically attributed to a lack of household greywater disposal points and insufficient provision for solid waste disposal – including food waste. All municipal officials interviewed now believe that the vacuum system is more suitable for affluent areas that enjoy good solid waste disposal services and regularly use soft, biodegradable anal cleansers such as toilet paper, which many informal settlement residents cannot afford or refuse to purchase.

Socially constraints: Failure to address the social context

The CoCT repeatedly emphasises the need for behaviour change through education and awareness programmes to enable successful new technology uptake. Despite municipal officials' claims that such behavioural education and awareness is critical, no education and awareness programmes were however ever initiated in Kosovo, whilst the posters indicating what can be disposed into a vacuum system were stored in the vacuum pump station and neither distributed nor displayed. On the other hand, the posters may have made little difference owing to the problem of inadequate waste disposal services and lack of toilet paper already described. Meanwhile, residents have came to view the malfunctioning vacuum system as an inferior technology to conventional systems (Beauclair, 2010) and by 2011 were demanding alternative connections to gravity sewers or the system's complete replacement with the – generally detested – container toilets.

Institutional constraints: Poor O&M

The lack of municipal knowledge to manage vacuum systems, departmental tension between CoCT sanitation providers and the lack of capacity to ensure new technologies reliably operate are further reasons why the vacuum system was an inappropriate technology choice.

The Water and Sanitation Informal Settlements Unit (WSISU) personnel and pump station operators responsible for the vacuum system's O&M did not receive adequate training for the "pilot" system and were not even given the O&M manual that the contractor had provided. Things started a poor footing when the system was handed over by the Kosovo Project Manager after it had already started malfunctioning. In the absence of the O&M manual, the technical personnel were forced to learn how to operate the system by trial and error. The situation was aggravated by the fact that there were insufficient spare parts available to replace damaged sensors and valves. These critical and expensive units had to be sourced directly from the German manufacturers because parts were not locally available. Furthermore, the lack of coordinated approach to O&M between CoCT Water and Sanitation (W&S) Department's network and mechanical personnel was a major contributor to the vacuum system's continuing malfunctioning. Municipal O&M officials explained that W&S "Pipes" and "Pumps" units disagreed over who was responsible for the vacuum system's collection chambers – a major constraint as a vacuum system cannot be managed as a collection of 'components' by a series of uncoordinated O&M agents. With hindsight, the Kosovo Project Manager conceded that it might have been better to appoint a private service provider to carry out the O&M for the vacuum system (CoCT, 2009) given the unfamiliarity of the technology to the WSISU.

The events that led to this unfortunate situation are as follows. The Kosovo Vacuum Sewerage Project was initiated by the Development Service (DS). DS strongly believed in the coordinated development of roads, stormwater, water, sanitation and solid waste services in informal settlements. A small group of project managers oversaw the planning and construction of settlement-wide infrastructure provision – which was generally outsourced. They expected the Department of Water and Sanitation (W&S) to take responsibility for maintaining infrastructure in informal settlements contract completion and handover. Such a split approach to sanitation provision was commonly accepted by officials in both Departments. For example, when DS first consulted a W&S official in June 2005 about the proposed vacuum system, the W&S official unquestioningly assumed W&S would be responsible for its maintenance (CoCT, 2006c).

During interviews conducted in 2010/11, however, junior officials reported that W&S senior management had become increasingly agitated by DS implementation of new water and sanitation services without adequate consultation with W&S. In an e-mail sent in late 2006, a W&S senior official suggested that DS should play a coordinating function between the city's decentralised technical departments rather than simply initiate and provide new services (CoCT, 2006d). Further tension between the two Departments was revealed in W&S senior management's opposition to and lack of support for the vacuum system. In February 2006, two of the W&S O&M officials submitted departmental applications to visit Botswana together with the DS Kosovo Project Manager and the vacuum system supplier in order to prepare for future O&M. Yet, W&S senior officials rejected the request, reportedly because they felt other available technologies were more suitable for informal settlements (CoCT, 2006e). Moreover, a senior W&S official had noted on the case study application that the request had come earlier than expected, a factor that may be interpreted as reflecting some political pressure to install the technology. In addition, two O&M officials reported during interviews that that W&S leadership had advised them in 2006-7 that no special measures should be taken by O&M personnel to learn how to operate the infrastructure until such time the system was commissioned.

Ultimately, the WSISU found itself financially and logistically burdened with an O&M "problem" that previous leadership appeared to have chosen not to address. Whereas, when neighbouring Overstrand municipality had to cope with three months of sewage overflows during its wide-scale settled sewerage implementation in 1995, that municipality immediately investigated the problems and systematically adapted procedures to resolve them (Van Vuuren, 2010), observational data showed that the majority of CoCT's pilot sanitation projects do not receive such rigorous troubleshooting. This is primarily due to WSISU's lack of technical capacity. It is, however, normal to encounter technical difficulties when implementing new technologies (Van Vuuren, 2010).

Inconsistent lines of accountability

Problems with Kosovo's vacuum sewer persist after two years in part because no one official or department has taken consistent responsibility for managing it. This has been caused by changing project leadership because of staff turnover, municipal restructuring and officials' hesitance to accept responsibility for a failed and contentious project. Even before the system was fully installed and commissioned, the project leadership was impaired by the project champions' departure: the original Kosovo Project Manager joined another CoCT department and the consultant Social Facilitator's contract came to an end. General CoCT practice requires that the project 'champions' (i.e. personnel committed to the successful implementation of a project) stay with the project as they are critical components to ensure project success. The Kosovo in-situ upgrade project was further hindered when DS, the department originally responsible for the project, was closed down in 2007 with its personnel being dispersed and its responsibilities handed over piecemeal to four CoCT departments: Housing, W&S, Electricity, and Roads and Stormwater. Kosovo's vacuum system planning was subsequently inherited by the Housing Informal Settlements Engineering Services (HISES) department while its O&M went to WSISU in 2009.

In addition to hesitancy for accepting a failed project, municipal officials are wary to accept responsibility for the vacuum system because high levels of politicisation amongst Kosovo's residents require people with astute conflict resolution skills. Bipartisan conflicts amongst Kosovo's residents undermined the implementation of the upgrade from the beginning and caused massive project delays (Beauclair, 2010). Yet the majority of infrastructural projects are managed by technical staff that are not equipped with these sorts of social skills.

What the above all points to is the importance for municipal officials involved in service delivery to understand how the combination of technical, social and institutional constraints can together contribute to the potential malfunction of any service. This might enable them to identify management gaps and proactively develop the types of procedures that are more likely to facilitate successful projects.

CONCLUSIONS AND RECOMMENDATIONS

Considered in retrospect, it is evident that Kosovo's vacuum system was bound to fail as implemented because it did not adequately address the technological challenge of managing blockages, it failed to adequately consider the social context, the CoCT lacked O&M knowledge and an enabling environment to effectively plan and manage new technology, and inconsistent project leadership left no one immediately accountable to manage the infrastructure. W&S is presently (2011) left to handle expensive rehabilitation costs and find a way to sustainably manage a discredited system. Given their past experiences, WSISU officials have adopted a constraints-based approach to identify the way forward. The first step,

taken some 25 months after the system was commissioned, was to arrange a five-day skills training course for the WSISU technical staff and the pump operators to learn how to manage the system. Simultaneously, consulting engineers have provided new O&M manuals detailing short- and long-term maintenance requirements.

The municipality is still struggling with how to best address the social and institutional constraints that plague effective management of the system. Some CoCT officials advocate contracting a service provider for a year to further build municipal O&M capacity; others promote custodial services to reduce system vandalism. No matter what course of action is taken, it is clear that the indisputable assignment of various O&M responsibilities is necessary to enable municipal officials and residents to hold each other accountable for the vacuum system's functioning and failures. Improved social management of sanitation assets in a service-driven informal settlement environment may require adequately resourced custodial services – such as the provision of janitors for shared sanitation facilities – and in Kosovo this has been recommended as part of a system rehabilitation programme that requires holistic O&M. The value of such custodial services has been demonstrated in both the Overstrand and eThekwini (Durban) municipalities which began providing janitorial services for shared sanitation facilities in informal settlements during 2009-2010. Overstrand and eThekwini officials report having reduced vandalism and consequent rehabilitation expenses through the employment of local residents as janitors (Gounden, 2010; van Vuuren, 2010). CoCT has had similar experiences with community-managed facilities at Pooke se Bos where residents have come to recognize a complementary social and economic benefit to what, on the surface, is purely an infrastructural upgrade. The University of Cape Town's Urban Water Management Group is currently drafting guidelines specific to the implementation and management of alternative sewerage technologies in informal settlements, which will include successful South African municipal applications of custodial services.

The most significant lessons learned from the Kosovo vacuum sewerage case are:

- Sanitation technologies cannot be simple infrastructural installations as their success is contextually bound to how they are planned, managed and locally adopted;
- Infrastructural pilot project plans need an extensive period for monitoring, evaluating and adaptive troubleshooting; and
- A constraints-based approach can be used to proactively identify management gaps in order to find effective resolutions that counter these problems, but only if project management and M&E extend over an adequate amount of time and are sensitive to the dynamic nature of relationships between municipal departments, officials, and residents.

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