Mellow Yellow: Transitioning to more sustainable sewage management by application of a systems thinking approach in Australia

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Abstract: This paper will explain how a framework derived from systems thinking, including soft systems methodology and the use of action research as a methodology, shaped a research project addressing an area of application (sustainable sanitation).

This Australia-first research project, was conducted by a multidisciplinary team of collaborators from academia, industry and government that included researchers, practitioners and students. It explored the use of innovative urine diverting toilets in an institutional setting. A UTS Challenge Grant was awarded to the project, enabling a pilot study of safe nutrient capture and reuse from urine diverting toilets installed on campus.

The paper is focussed on the initial stages of the project – the project design and early investigative phase, and demonstrates the systems thinking and a trans-disciplinary research approach that could be useful to address complex problems related to sustainability that infringe on social and cultural issues.

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INTRODUCTION

Excessive nutrient loading is one of the most important direct drivers of ecosystem change in terrestrial, freshwater, and marine ecosystems (Millennium Ecosystem Assessment, 2005). Urine contained in wastewater from sewerage systems is a major source of such nutrients. Wastewater treatment processes for removing nutrients before release or re-use are highly energy and chemical intensive.

At the same time, mineral phosphate rock deposits, from which phosphate fertiliser is derived, are approaching a peak not unlike peak oil, with known reserves estimated to run out within the next century (Cordell *et al*., 2009). Lack of availability of phosphorous could lead to insecurity of global food production resulting in hunger, social issues and conflict, for example.

Urine is a potential source of phosphorus, and diverting urine at source (the toilet) and capturing nutrients from it could partially replace mineral fertilisers in agricultural use, as well as reduce the cost of wastewater treatment and lessen negative environmental impacts. Therefore, concentrated populations in cities, in particular, offer a rich 'mine' for phosphorus. The effective exploitation of this resource however requires not only the technologies for diversion, transport, storage and land application, but the development of supporting regulations, institutional arrangements and markets, as well as changes in cultural norms (Geels, 2005). Effective exploitation also involves addressing underlying factors that influence attitudes (Ajzen, 1991) to support new toilet behaviours and overcoming social taboos towards the reuse of human waste.

This paper describes an innovative research project trialling urine diversion in a university setting in central Sydney, Australia; a project that sought to illuminate the above multiple aspects for mainstreaming urine reuse. While the two-year project ended in 2011, the aim of this paper is to demonstrate how systems thinking shaped the *design of the project*. The paper therefore focuses on the project launching stage only.

To reflect the systems aspects of the project design, the article is structured according to the four elements that Checkland (2000) identifies as generic to a soft systems approach for dealing with complex, real-world problems. They are:

- The perceived problem situation
- The process for tackling the situation
- The group of people involved in the process; and
- The combination of situation, process and people.

THE PERCEIVED PROBLEM SITUATION

Checkland (1999) identifies the starting point to SSM as a situation 'perceived as problematic' to a group of 'would-be problem solvers' who wish to take purposeful action to improve the situation. The poor performance of current models of urban sanitation in terms of sustainability is widely acknowledged (Pinkham *et al.*, 2004, Nelson 2007, Mitchell *et al.,* 2010) and was identified as the perceived problem situation the project team sought to improve.

The centralised piped sewerage model has provided enormous health benefits that have enabled economic development, and that model has, therefore, become the dominant paradigm for urban sanitation systems in developed countries (and aspired to by many countries that do not already have it (UNICEF, 2010). However, in the long term, the centralised piped sewerage model rates poorly from a sustainability standpoint. The model relies on large volumes of water, usually of a potable standard, being used to transport waste from cities for resource-intensive sewage treatment. The model involves the misplacement of potentially valuable nutrients as noted earlier, which lead to nutrient pollution in environments receiving sewage effluents, or the employment of costly processes for removing these pollutants.

The aim of the research project was to explore the range of interdependent factors that could support a transition from current established sanitation systems towards a more sustainable and resource efficient sanitation system, using urine diversion as a case study. To create such a shift requires mutually reinforcing institutional and socio-cultural transformations including new infrastructure planning processes; enabling regulatory and legal frameworks; and altered user practices (Geels, 2005). Facilitating this change, therefore, required partnership and collaboration from stakeholders with a range of disciplinary knowledge and a shared commitment to sustainability and transdisciplinary learning.

A competitive Challenge Grant from the UTS (a scheme to provide seed funding to support activities related to high-quality, collaborative cross-disciplinary research) was secured as funding for the two year project.

THE PROCESS FOR TACKLING THE SITUATION

The project was designed to take tangible steps towards closing the nutrient loop by retrofitting a men's and a women's toilet block on the UTS campus with a number of urine diverting toilets and waterless urinals. Figure 1 shows examples of some urine diverting toilets.

Figure 1. An example of a urine diverting toilet (a) and waterless urinal (b)

The aim of the project was to illuminate and learn about the various factors that come into play in the process of collecting and transporting urine from these toilets and reusing it as a substitute for phosphate and other fertilisers in a small-scale agricultural trial.

Figure 2. Systems and environment associated with the Pilot

Such a learning system was modelled by Checkland (1985) as consisting of an intellectual framework (F) and a methodology (M) for using F, on the area of application (A). The intellectual framework of ideas was grounded in systems thinking as explained below.

A systemic view of the multi-level project and its context (Figure 2) led the project to be designed as a set of four research strands conceived as interacting sub-systems:

- A *technology strand* to consider the 'hard systems', the physical aspects of the system, including the user interface (engineering and technical issues around designing, implementing and commissioning the toilet retrofit, and operating, maintaining and monitoring their technical performance), urine collection, sanitisation and transport, and implementing the agricultural trials.

- A *stakeholder engagement* strand, to track and shift attitudes of users of the toilets as well as maintenance and management staff, which was recognised as critical to the acceptability and ultimate success of the pilot.
- A *visual communications* strand, specifically focused on effective communication. While this is a subsystem of 'stakeholder engagement', the success of projects has repeatedly been shown to be dependent on effective communication (Jugdev & Müller 2005; Kappelman *et al.,* 2006). So a dedicated research 'sub system' or strand was set up.
- A *regulations/institutions* strand, to examine the regulatory and institutional context within which the pilot resource-efficient sanitation system exists, and which constrains or supports what is possible. Just as legal and regulatory frameworks and institutional arrangements enable and support conventional sewerage systems, it was recognised that they also play a role in enabling or impeding the kinds of paradigm change that the project sought to initiate.

To consider the system as an interacting whole and integrate emergent learnings from each research strand above, a fifth *integration* research strand was defined. The system in Figure 2 was thus designed as a research program of subsystems in a hierarchy shown in Figure 3, with other elements of Figure 2 acknowledged but left outside the scope of the project.

Figure 3. Hierarchy of research 'subsystems'

Action research

While urine diversion trials have been conducted previously (Larsen et al., 2001; Hood *et al.,* 2008; Blume & Winker 2011), this study was breaking new ground with its coverage of social and regulatory aspects and not merely technological ones. The combination of hard and 'soft' people-related systems under study drew on complex systems theory concepts as well as Soft Systems Methodology as discussed later. The project required design so that emergent learnings could by responded to within the timeframe of the project, and aligned with iterative learning within a 'learning system' (Checkland, 1999).

The systems- based intellectual framework (F) indicated Action Research as the overarching methodology (M) or a meta-methodology (Dick, 2004), for being particularly appropriate for supporting a learning system with a collaborating team of multidisciplinary researchers (discussed next section). Thus there was an opportunity to use essential elements of an action research cycle – plan, act, observe, reflect and plan for the next cycle – in this research project. According to the current edition of the *Handbook of Action Research* (Reason and Bradbury, 2008) action research is defined as:

"… a participatory process concerned with developing practical knowledge in the pursuit of worthwhile human purposes. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and their communities."

This research project aimed to use three action research cycles:

Cycle 1 would be an investigation cycle to facilitate the emergence of the 'thematic concern' for the project (Kemmis and McTaggart, 1988) in discussions with each of the research strands. The researchers planned to draw upon aspects of soft systems methodology to inform the detail of their actions. The aim of the project was confirmed to serve as the 'root definition' using the CATWOE mnemonic (Checkland, 1999)

Customers (C): The participating organisations ('victims or beneficiaries of the system')

Actors (A): The research project team ('those who would do T')

Transformation (T): Pilot urine diversion technology with the aim of illuminating a range of interdependent factors that determine successful uptake and potential scale-up of radical sustainable urban sanitation ('the conversion of input to output')

Weltanschauung (W): Sewage be viewed as a resource rather than waste product (‘the worldview that makes the T meaningful in the context’)

Owners (O): UTS, University of Western Sydney and University of New South Wales (‘those who could stop T’)

Environmental constraints (E): Constraints posed by institutions and regulations with regard to urine collection and use (‘elements outside the system which it takes as given’)

Cycle 2 would cover the design, contract and commissioning phase of the project where the technology strand oversaw the design of the retrofitting of the designated toilets, appointed contractors and supervised the installation and commissioning of the toilets. The stakeholder strand determined the attitude of end-users prior to installation in order to alleviate any concerns and the regulatory and institutions strand highlighted and advised on the regulatory enablers and impediments to the trial.

Cycle 3 would cover operation, monitoring, evaluation and closure of the project. The performance of the toilets, storage and agricultural trials would be monitored and evaluated. End-users’ responses to the use of the toilets would be gathered and analysed. The visual communications strand would evaluate the effectiveness of their messages and the regulations/institutions strand would focus on the barriers to closing the loop on nutrient recovery and use while balancing competing interests such as health and safety, particularly relating to transport and storage of waste and land application. The integration strand would carry out an overall evaluation, decide on new projects extending from this project as well as put together a final report to the stakeholders.

The problem being addressed in this project was a complex real-world problem that could be looked upon as a ‘wicked problem’ (Rittel and Webber, 1973). Soft systems methodology (SSM) was developed by Checkland and colleagues (Checkland, 1999) as a way of addressing wicked or ill-structured, complex, real-world problems faced in management situations, when they found that ‘hard’ systems approaches, based on systems engineering, were not effective while addressing such problems at an ICI factory in the UK.

This project therefore adopted many concepts, ideas and tools of SSM that were useful and relevant in the design of the project to deal with complexities arising in a real-world situation.

A recent book by Checkland and Poulter (2006) presents a basic version of SSM which includes the following activities:

1. Perception of a problematical real-world situation demanding action to improve it;
2. Creation of models of purposeful activity *relevant* to the situation from different worldviews;
3. A process to explore the models as devices to explore the situation;
4. A structured debate about desirable and feasible changes including a discussion on power issues and considering social norms and values; and
5. Taking action to improve the situation.

A basic version of SSM is shown in the authors 'latest book (reproduced here as Figure 4). The actual process of analysis includes the components described in the earlier versions such as drawing 'rich pictures' to clarify the problems as perceived by the stakeholders and developing a 'root definition' based on what the agreed purpose of the system would be.

Figure 4. Basic SSM process (Adapted from Checkland and Poulter, 2006)

Some components of soft systems methodology were been applied during the initial meetings of the research team. Among these was a conceptualisation of the desired project outcomes in terms of an articulation of individual visions – an acknowledgement of the range of worldviews present.

THE GROUP OF PEOPLE INVOLVED IN THE PROCESS

For the sake of clarity, in this paper we interpreted this group to mean the research team: that is, the group of people seeking to take purposeful action to improve the problematic situation, as distinct from the ‘stakeholders’ who were the subject of our social research noted in the previous section.

The project was led by researchers at the ISF at UTS with skills, expertise and a passion for transitioning to sustainable futures in line with the Institute’s mission “to create change towards sustainable futures”, of which sustainable sanitation and phosphorus futures are a part. In line with the ‘plurality of perspectives’ that are important to consider within complex systems (Gallopin, 2001), they systematically identified the key perspectives that would be relevant to the system of interest (as in Figure 2), and potential research partners representing these perspectives. As observed by Checkland (1999), the researchers acknowledged that research outcomes would be uniquely shaped by the particular collaborators and their perceptions, at the particular time, of the project, and therefore, not ‘reproducible’. However, by careful inclusion of representative, key, professional and institutional perspectives of importance, it was expected that the learning outcomes would be useful in improving the problematic situation of conventional urban sanitation. This led to the inclusion of research partners with relevant disciplinary perspectives, knowledge and similar commitments to sustainability from within UTS, other local universities, industry and government, as well as an international expert to play the role of a strategic advisor.

Partnerships with the UTS Faculties of Engineering and Information Technology (FEIT) and Design, Architecture and Building (DAB), brought a combination of experience in technical engineering, project management, stakeholder engagement and visual communications. . An academic from the University of Western Sydney (UWS) was collaborating closely with UTS visual communications experts to bring a design focus to the visual communication strand, and collaborate on student research projects. A specialist in water law, as it relates to urban wastewater systems, from the University of New South Wales (UNSW), was leading the research strand on regulatory and institutional issues.

An academic expert in agriculture and farming systems from UWS provided the facilities and carried out the testing and trialling of urine as a phosphorus source. A soils and nutrients specialist from the Australian Nursery and Garden Industry Australia (NGIA) collaborated closely in these trials.

Sydney Water, the local retailer of water and provider of wastewater services, took a keen interest in the research and committed funds and personnel to the project. Caroma Dorf, the leading manufacturer of Australian toilet hardware, contributed its significant experience in the end-user interface to advise on design, installation and monitoring, as well as providing waterless urinal hardware.

Partners from government included a health regulator and a representative from the local government authority, the City of Sydney.

UTS's Facilities Management Unit was also an active participant that committed time and funds towards the installation of capital works.

THE COMBINATION OF SITUATION, PROCESS AND PEOPLE

The interaction of the problematic situation, process and people led to a series of research questions of interest to each research team member from the perspective of his or her particular affiliation and role. For example, team members with teaching commitments integrated student research projects into the program while some other team members without relevant teaching commitments at the time, supervised student interns from outside their home institutions. Both activities, helped open up the research space by identifying, and in some cases, addressing, knowledge gaps.

This is discussed below in relation to stakeholders who were identified through: (a) brainstorming during several meetings organised for the project; (b) dialogue with specialists from outside the project team who were invited to attend these meetings; (c) extended peer networks; (d) and by studying and analysing the instructions provided by the manufacturers of the toilets.

The key stakeholders in the project included: staff and students of, and visitors to, UTS; cleaners; building managers; toilet and plumbing manufacturers; engineers; plumbers; scientists; institutions which engaged in sewage management, such as Sydney Water; the agricultural and horticultural industries; interior designers and architects; bathroom product companies, e.g. manufacturers of odourisers; and the central management of UTS.
The following description takes each stakeholder and highlights how the research team anticipated that he/she/it would potentially engage with the pilot, pointing out where it was possible/likely that different stakeholders could have conflicting or aligning interests.

Staff, students and visitors as users: The staff, students and visitors were key stakeholders because they were the people who actually used the urine diverting toilets. Hence, it was considered necessary to provide sufficient encouragement for them to use the alternative toilets rather than the traditional ones. It was also considered to be important to monitor that use. One key factor, alluded to in the literature, was that men needed to sit to urinate, rather than stand (Lienert and Larsen, 2010), if they were to use the alternative toilet properly. If saving water by not flushing the toilet was also an objective, then women needed to place their toilet paper in a separate receptacle after urination rather than in the toilet bowl itself. It was also anticipated that disabled users' and children's experiences needed to be monitored and analysed. The impact of use on parties such as cleaners was also considered necessary to monitor. Further, it was envisaged that interior designers and architects would be concerned to make the space in which the toilets were housed both functional and aesthetically pleasing. Hence they would also be interested in user-stakeholders' experiences and interests.

Students as educators and facilitators: Several student-based projects were planned to support the pilot program. Engineering students at UTS would investigate detailed site assessments and identify technological specifications for the installations. UTS and UWS students working on visual communication methods and contemporary design practices would create resources aimed at informing other user stakeholders and the community more generally about the aims and objectives of the pilot. Student-based projects were also aimed at specifically raising consciousness about phosphorous collection and use along with the importance of urine diversion as an alternative phosphorous source, hopefully assisting to avert a phosphorous crisis.

A student-based internship program supervised through UNSW would involve the examination of relevant legal and regulatory frameworks in order to identify examples of the legal and regulatory barriers to installing and maintaining urine diverting toilets, as well the barriers to transporting and storing waste in the form of urine.

The student-based projects were intended to build on the technical capacity and values of the industry partners involved with the research. It was hoped that the research synergy would make a positive contribution towards the education of tomorrow's industry professionals and bureaucrats and provide them with direct exposure to involvement with real issues facing industry.

Cleaning staff: We anticipated that the effectiveness of both the pilot itself and its wider application in the community would be linked to the experience of the staff who were responsible for cleaning the urine diverting toilets. Special biodegradable cleaning chemicals were needed, to avoid contamination of urine that might, in turn, prevent the urine's application in agriculture. Because cleaning staff were required to use special cleaning chemicals and employ different cleaning procedures for urine diverting toilets compared with traditional toilets, engagement with this stakeholder group was seen as critically important. This group, if successfully engaged, could provide valuable observations, monitoring and feedback. This point was brought to the attention of the project team by the Facilities Management Unit at UTS who hired the cleaning contractors.

The interests of cleaning staff as stakeholders also involved questions of risk management and industrial, health and safety issues. For example, it was anticipated that cleaners may have perceived a greater risk in cleaning an alternative toilet because it was unfamiliar. The time it took to clean the alternative toilet may also have involved an increased workload, leading to a range of associated industrial and employment issues which needed to be canvassed and addressed.

Building managers: The manager of the building(s) in which the urine diverting toilets were installed was another stakeholder. It was anticipated that the building manager may be very significant in helping monitor and prevent vandalism of the alternative toilets.

To explain, many novel installations are the subject of both use and/or abuse. For example, curious experimentation or enthusiastic uptake may reflect use, while abuse may play out in different types of vandalism- such as acquisitive, tactical, ideological, vindictive and malicious (Cohen, 1972), the latter being motivated by 'the pursuit of illegal fame or recognition, adrenaline rush, emotional or artistic expression and [the desire to cause] malicious damage' (NSW Department of Justice and the Attorney General, 2009; Brown *et al.,* 2011).

In order to reduce the risk of the urine-diverting toilets being abused through vandalism, misuse or graffiti, building managers were co-opted and encouraged to be vigilant in their monitoring of relevant buildings and rooms. It was envisaged that an on-going dialogue would take place with the building manager. The building manager would also be important as part of the use-monitoring process and he or she could be relied on to report breakdowns and problems. His or her on-going engagement was, therefore, seen as crucial.

Toilet and plumbing manufacturers: Toilet and plumbing manufacturers (such as research collaborator Caroma Dorf) were other key stakeholders at the user interface of the technology that lay at the heart of the pilot. While urine diverting toilets are not currently manufactured locally, the research can influence whether they will be in the future. Of particular interest to these stakeholders will be the question of (a) user attitudes and (b) institutional (e.g. central university management) attitudes, because both will impact on the viability of manufacturing urine diverting toilets. Put simply, even if urine diverting toilets prove technically effective in the capture of phosphorous, they are unlikely to be manufactured if people find them distasteful or difficult to use. The market for them will be too uncertain. This proposition is supported by the theoretical work on competitive strategy by Michael Porter where he considers the interplay of cost leadership (no frills), differentiation (the creation of uniquely desirable products and services) and focus (the offering of a specialised service in a niche market) emphasising the importance of claiming a premium price in a focused market. (Porter 1985; Porter, 1991).

Engineers, scientists and plumbers: It was envisaged that technical experts such as engineers, scientists and plumbers would play a significant stakeholder role because they were responsible for the installation and maintenance of the alternative toilets, piping, and collection and testing tanks. It was also anticipated that Struvite (a phosphorus compound) precipitation would be a significant issue because it was known to lead to blockages of urine pipes (GTZ, 2009) and therefore, both the toilets and the relevant piping would need to be monitored and managed.

Sydney Water: Sydney Water – an agent of change in water use and a wastewater service provider – was both a collaborator and a stakeholder in this pilot. It brought with it a wealth of experience in encouraging the uptake of new technologies such as dual flush toilets and reduced water consumption showerheads. It was anticipated that there would be a sharing of uptake-encouragement knowledge, particularly with student educator stakeholders, who were working on visual communication methods and contemporary design practices. As a water service supplier Sydney Water was also interested to understand the water saving potential of urine diverting toilets. If these toilets represented the next wave of sanitation development, it was likely that Sydney Water would be very keen to observe how that impacted on its operation in terms of the implications for its existing sewerage infrastructure, and other regulatory obligations.

A further point of intersection existed between Sydney Water, in its capacity as a sewerage/wastewater service provider, and other stakeholders, such as UTS's central management. To explain, if the pilots were successful, organisations and institutions (such as UTS or the owners of large office/residential blocks, for example) might choose to separate urine onsite and then send it to collection points where it would be treated for its phosphorous content. Presumably logistics and economics help determine how such decisions are made and whether the owners of the sites where the urine is collected undertake such processes themselves or employ the expertise of third party companies. In either event, such approaches may largely by-pass the services of Sydney Water, a fact which may, in turn, have fiscal implications for that institution because of erosion to its customer base. A similar issue has been the subject of discussion in the context of recycled water which has been manufactured from sewage. There a related question has been who, if anyone, owns the sewage in the first place? Or put another way, is there property in sewage? (Gray and Gardner, 2008; Gray, 2008) Such a question appeared to be equally applicable in relation to urine itself.

The agricultural and horticultural industries: These stakeholders were considered imperative to the research as they are the recipients of the diverted urine. It was necessary to identify research institutions willing to investigate the influence and interactions of diverted urine on farming systems. World food and fibre demand, crop production and fertiliser use is driven by global population and economic growth. Global population, projected to surpass 9 billion in 2050, will place considerable pressure on agricultural and horticultural production systems (United Nations, 2009). In order to meet the food and fibre needs to sustain this growth, farming systems will need to become more efficient in what they do while enhancing productivity in a sustainable business environment. Environmental pressures including drought, climate change and variability and natural resource management will also play a pivotal role in sustaining the growth of these industries.

To satisfy food and fibre demands in Australian production systems, on-farm best management practices such as Nursery Industry Accreditation Scheme Australia (NIASA) Best Management Practice guidelines, EcoHort Environmental Management System for Production Nurseries or the Enviroveg Program for vegetable growers are desirable. A key element of these guidelines will be improving nutrient use efficiency rather than relying on fertiliser inputs. Urine diversion is of significant interest to these industries due to its characteristics and its potential to minimise fertiliser inputs and improve the fertility of soils and growing medium used in crop production. These characteristics include the high concentration of readily available nitrogen, phosphorous and potassium. The fertilising effect is also reported to be similar to that of nitrogen-rich inorganic fertiliser (Kirchman and Pettersson, 1995). Several studies have determined the capacity of urine as a fertiliser, notably to the similar growth response in plants fertilised with urine and manufactured fertilisers (Pradhan *et al.* ,2009; Guadarrama *et al.,* 2002). Owing to the diversity of cropping systems, a number of species and growing conditions were investigated as part of this study at the University of Western Sydney. NGIA was involved in this aspect of the research through the provision of technical as well as academic support.

Interior designers and architects: These stakeholders are also crucial to transitioning alternative toilet technologies into the commercial and domestic sectors. They are likely to play a role in technology uptake (through recommendations) and accordingly will be instrumental in the development of new sociologies of the bathrooms, in general. In that regard we have already witnessed a shift from bathrooms as utility spaces devoted to cleanliness (and which after the 1920s included inside toilets), to spaces of pampering and luxury (Davison, 2008). It is possible that there may be a shift to incorporate a moral and ethical element in the next iteration of the sociology of the bathroom: an element which may involve 'greening the bathroom'.

Bathroom consumer product companies e.g. manufacturers of odourisers: The interests of this stakeholder group were considered likely to align with many of the interests of the interior designer and architect stakeholders. It was anticipated that both groups would be concerned with the aesthetics and social aspects of the operation of the urine diverting toilets in the context of the bathroom, the building as a whole and the wider environment. It was also anticipated that there would be a nexus between the interests of this group and user stakeholders as well cleaner stakeholders.

The Central Management of UTS: One aspect of the relationship of this stakeholder to the pilot was discussed above, in the context of alternative waste (water) service provision. However, the UTS Central Management's interests extend beyond that issue. UTS is implementing a new campus masterplan which is underpinned by sustainability principles. It was anticipated that the research would create valuable information that could be applied to other innovations being considered in the masterplan. For example, UTS will be concerned with issues including service provision, cost effectiveness and uptake rates. It will also be concerned with satisfying any legal obligations that fall to it in terms of health related compliance issues and approval/consent issues for the operation of a sewage management facility, including backup service arrangements.

CONCLUDING REMARKS

The project launching phase, the focus of this paper, incorporated the investigation phase, the first action research loop. Several student projects, especially in engineering and visual communications were undertaken. Meetings were held with all the strands to ascertain their key concerns. After the project kick-off meeting held with key stakeholders took place their vision for the end of project was captured so as to ascertain what success would mean to each one of them. This part of the process resulted in very interesting discussions. A STEEP (Social Technical Environmental Ethical and Political) analysis was carried out. A collaborative platform and repository on a website was set up for the researchers to work together as they are geographically dispersed. A task analysis of how people use toilets was undertaken so as to understand issues that could come up before the new toilets were installed.

This project's commitment to a soft systems approach meant that it amounted to an investigation of the feasibility and desirability of urine diversion as a potential way of improving the sustainability of urban sanitation systems by closing the nutrient loop. While it may be argued that urine diversion makes good sense from a thermodynamic standpoint, the experimentation with an actual installation from a whole of system and lifecycle perspective was thought possibly to reveal trade-offs (for example, costs). This may show that it was not feasible in practice – or that this socio-technical innovation was not desirable within the current socio-cultural or institutional context. The team planned that it would secure additional funds when the tenure of the initial funding expired so allowing it to move to further phases of the research. However, in case further funding did not eventuate or in case learning outcomes from the initial project suggested it was necessary, the plan included setting aside funds for decommissioning of the project.

A transdisciplinary approach is often required to address complex problems in relation to sustainability issues that infringe on social and cultural issues as there is no clear-cut and ready-made acceptable solution. The problem that this project sought to address was socio-culturally complex and, therefore, the effectiveness of approaches and methodologies used during the project has implications beyond sustainable sanitation. In particular, the effectiveness of systems thinking approaches and action research as a meta-methodology to find viable solutions was tested during this project. At the initial stage everyone involved in the project seemed very enthusiastic about their contribution even though some aspects of this research could be looked upon as engaging with taboo topics. The real test for this project came in the second phase when people actually started using the urine diverting toilets and judged whether the toilets offered a feasible and desirable way to adopt a change in their attitudes and practices in order to contribute to a more sustainable world.

Postscript:

While this article was being revised for submission, the actual project was successfully completed. The project ultimately differed somewhat from the one planned serving to demonstrate the attractiveness of employing a systems thinking approach and action research methodology. That approach supported adaptation and change along the way in response to emergent learning. Despite some changes to the project, discussion of which is beyond the scope of this article, it remains valuable to articulate how systems thinking, including the SSM concepts, shaped the design of the project.

The project won recognition for its industry collaboration and contribution to transforming industry perceptions of sustainable sanitation with respect to urine diversion, through a NSW Government 'Green Globe' award for Excellence in Leadership and Innovation (environmental innovation category) in Australia (OEH, 2012). Industry transformation includes a decision by UTS to incorporate pipework for urine diversion in its new Faculty of Engineering and Information Technology building currently under construction; and on-going discussions in the development sector about including the pipework at the time of construction as a means of 'future proofing' commercial buildings for a resource constrained future.

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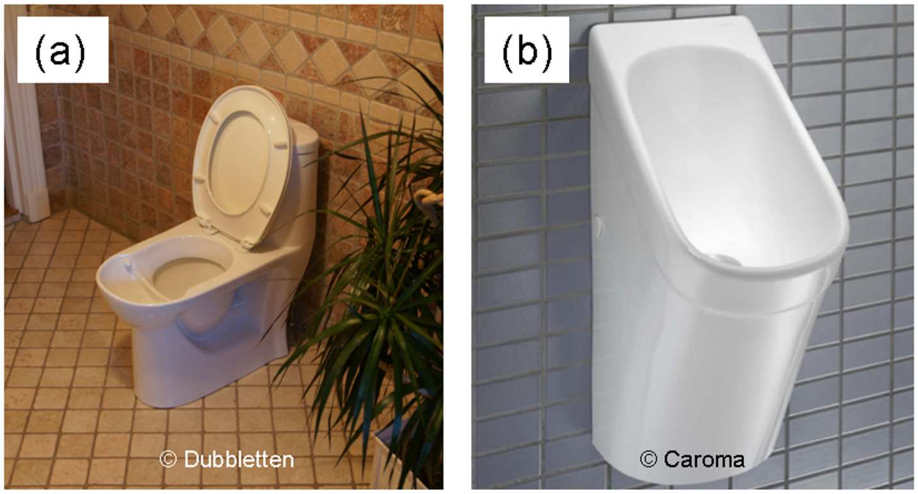
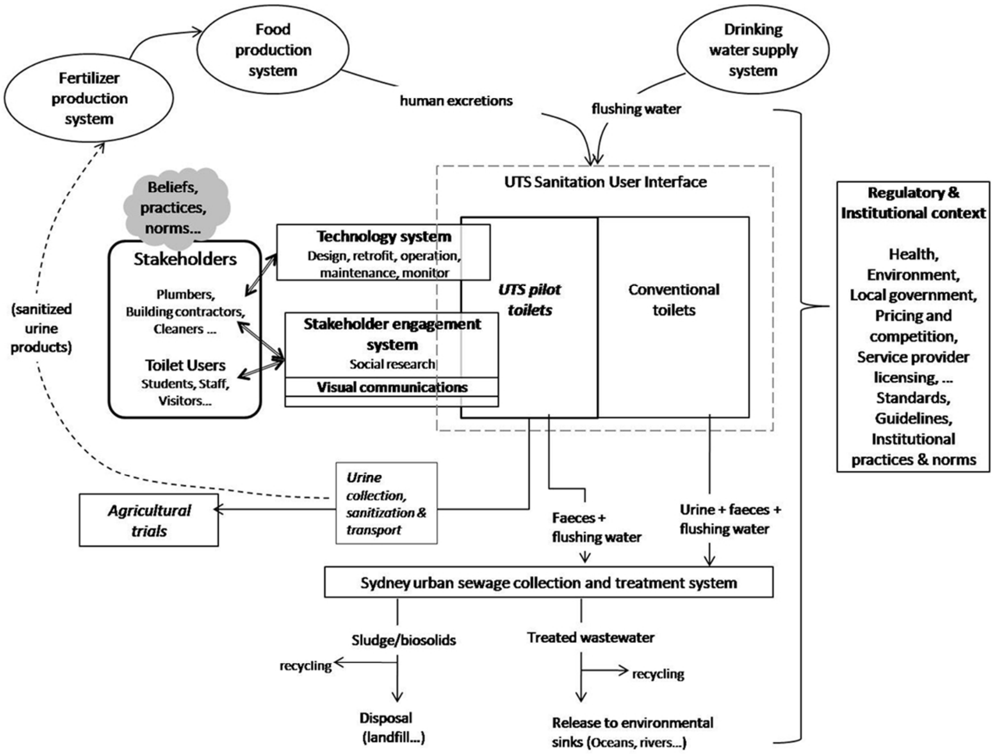
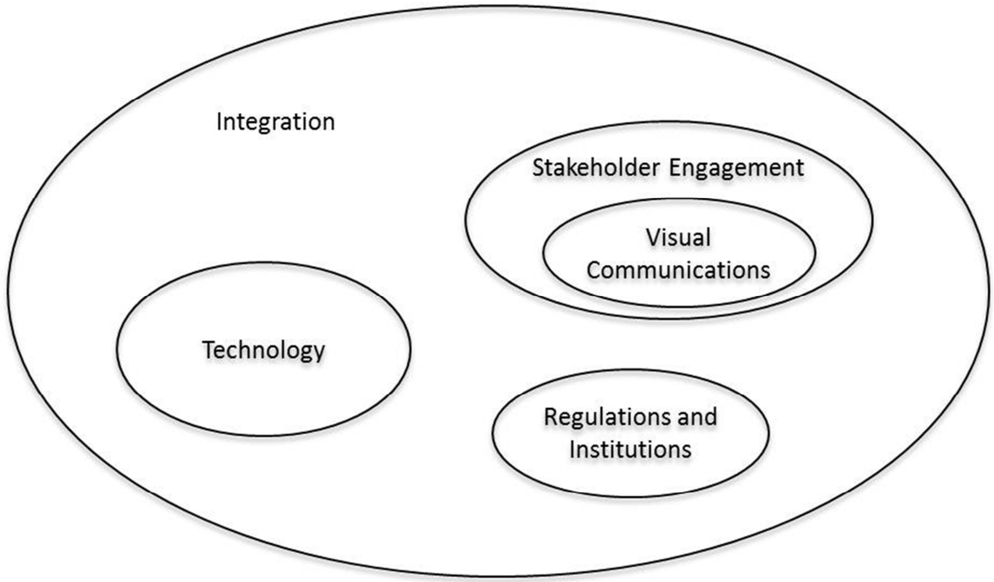


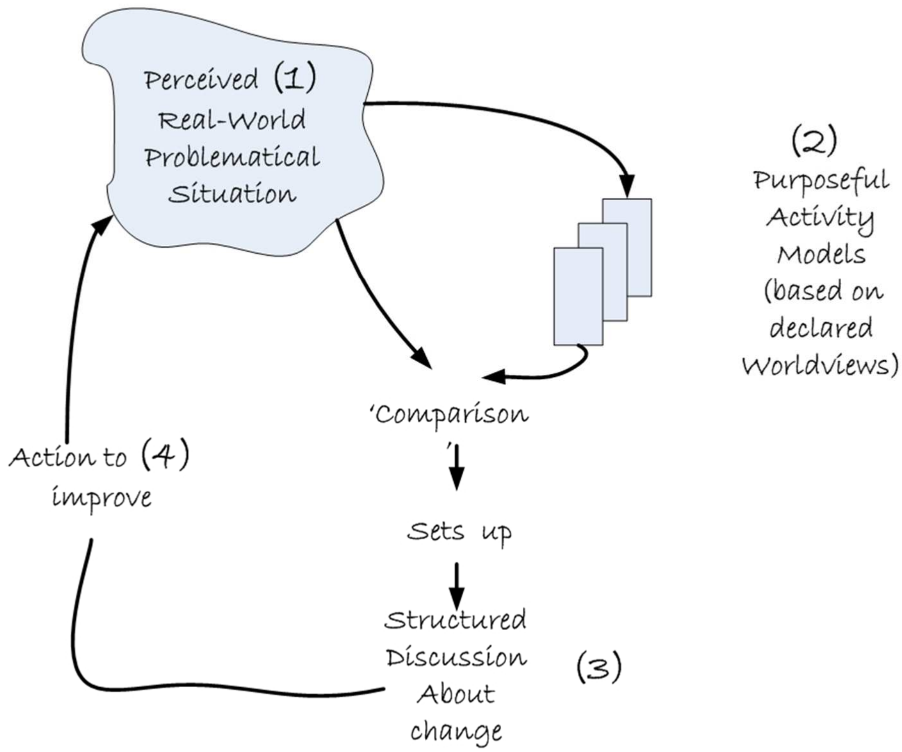
An example of a urine diverting toilet (a) and waterless urinal (b)
152x84mm (150 x 150 DPI)



Systems and environment associated with the Pilot
199x150mm (150 x 150 DPI)



Hierarchy of research 'subsystems'
156x92mm (150 x 150 DPI)



Basic SSM process (Adapted from Checkland and Poulter, 2006)
165x141mm (150 x 150 DPI)