Research Office
Legislative Council Secretariat

Fact Sheet

Application of innovation and technologies for improving environmental hygiene in selected places

FS04/18-19

1. Introduction

1.1 Public cleaning service is essential to every city. With society becoming more affluent, rising public expectations for a cleaner city have increased the demand for higher standards of public hygiene and better services delivery. Yet, the cleaning services industry has been supported by more elderly and less educated workers due to its work nature and lower wages offered.[1] In recent years, the industry has seen heightened competition for manpower resources as the workforce becomes increasingly higher educated. This, coupled with the advanced age of many cleaners, renders the need for use of innovation and technologies to empower a leaner way of working and make the cleaning jobs less physically demanding for older workers.

1.2 In **Hong Kong**, the Food and Environmental Hygiene Department has recently conducted technology trials for improving environmental hygiene. These include the installation of 360 degrees cameras to monitor accumulation of marine refuse in coastal sites, as well as using (a) pressure washer surface cleaners for street cleaning; (b) mini-mechanical sweepers to perform sweeping more efficiently; (c) leaf blowers to tackle fallen leaves; and (d) solar-powered compacting refuse bins to increase bins' storage capacity. The above technology trials are in response to the proposal of "exploring the introduction of automated cleaning machines or technology for trial use at suitable venues or after large-scale events" announced by the Chief Executive in her 2017 Policy Address.

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[1] The labour intensive cleaning services industry generally employs people with low levels of skills or education.

1.3 In recent years, many overseas cities have also made use of modern technologies for improving environmental hygiene. At its work plan meeting held on 1 November 2018, the Panel on Food Safety and Environmental Hygiene has requested the Research Office to study the use of innovation and technologies to improve environmental hygiene in overseas places. This fact sheet selects Australia, Barcelona[2] and Singapore for the study in view of their adoption of innovation and technologies on various fronts for public cleaning services. Singapore also leverages technologies to transform its environmental services industry[3] that still relies heavily on manual labour work processes.

2. Australia

2.1 In Australia, various states and territories have made use of automated cleaning equipment to reduce the amount of physical labour needed for cleaning jobs. They have also adopted innovative technology-based solutions to achieve efficiency in terms of manpower resources and costs required for waste management. Some examples of the equipment and solutions adopted are discussed in the paragraphs below.

Mechanical beach cleaners

2.2 In **Victoria**, the City of Port Phillip cleans the beaches by a combination of mechanical beach cleaners and manual litter pickers during summer time. The mechanical beach cleaner uses a combined sieving and raking action that improves the collection of small pieces of litter such as glass and cigarette butts (**Figure 1**).

[2] Barcelona is ranked among the top smart cities in the world. In addition, it could be the most aggressive of Spanish cities in utilizing innovation and technologies to help with street cleaning and waste management.

[3] Singapore's environmental services industry currently involves more than 78 000 professionals and 1 700 companies in the cleaning and waste management sectors.

Figure 1 – Mechanical beach cleaner

Source: City of Port Phillip (2018).

Electric bin-tugs

2.3 **Queensland** uses battery-powered machines – electric bin-tugs – to transport public place bins around the Central Business District ("CBD") for disposals of their contents and for deployment of new bins (**Figure 2**).

Figure 2 – Electric bin-tug

Source: Moreton Bay Regional Council (2016).

Other mechanical cleaning equipment

2.4 Queensland has also made use of other mechanical equipment to enhance the efficiency in cleaning the public areas. These include (a) mechanical street sweepers used in day and night shifts; (b) mechanical vacuum cleaners to suction micro-litter in gutters and on footpaths where mechanical street sweepers cannot reach; and (c) ride-on scrubbers to remove stubborn stains from the pavement.

Automatic public toilets

2.5 In **New South Wales**, automatic public toilets are installed in busy areas of the City of Sydney. Usage is limited to 20 minutes and is controlled by an alarm. The alarm is accompanied by a flashing light to let the user know that the door will be opening in a few seconds. The toilet bowl and floor are cleaned and disinfected automatically after each use.

Smart bins

2.6 In **South Australia**, the City of Adelaide is piloting solar-powered "Clean Cube" bins in key areas of the city to optimize waste collection (**Figure 3**). The Clean Cube has a sensor that provides real-time data information about how full the bin is, so the bin can be emptied when required. It also contains a compactor which compacts the rubbish inside when it reaches a certain level.[4] Once the Clean Cube reaches a desired fill level and the rubbish cannot be compacted any further, the sensor will notify the cleaning team that the bin needs to be emptied. Such connected technology allows sensor bins to be emptied only as needed, thereby reducing unnecessary pick-ups of half empty bins while also preventing bins from overflowing and polluting the streets.

[4] This enables a 120-litre "Clean Cube" bin to hold up to 960 liters of rubbish, which is about eight times the amount a normal bin would hold.

Figure 3 – Clean Cube bin

Source: City of Adelaide (2018).

Underground bins

2.7 The City of Sydney has installed underground bins in some residential developments where residents empty their trash bins in one of several chutes on the pavement. These chutes are fed into large underground bins[5] embedded with sensors to alert the waste collection teams when they are full. Specialist trucks fitted with cranes are used to raise the bins stored underneath to street-level for emptying. Underground bins offer the advantage of having a large storage capacity that can be used to effectively manage the waste from many buildings, while only requiring a small above-ground footprint.

Automated waste collection system

2.8 In Queensland, the Sunshine Coast is building Australia's first automated waste collection system in its CBD. There will be separate waste inlets for organic, recyclable and general waste installed in buildings and public spaces throughout CBD. Waste dropped into each inlet will be stored in a sealed compartment below ground or in building basements. A vacuum pump will be activated, usually twice each day, to suck the waste at up to 70 km/h through a 6.5 km system of underground vacuum pipes to a central waste collection facility, where the waste is stored in sealed compactors for collection by the waste collection contractor.

[5] Underground bins are available in size up to 5 000 liters or more.

3. Barcelona

3.1 Barcelona has been one of the most advanced smart cities in the world. Back in 2013, the city government unveiled its smart city projects under the umbrella of "Barcelona Smart City", featuring the deployment of smart technologies across various urban systems including waste management, street lighting, public transit and parking. In waste management, A1A3 automated trolley, smart garbage collection system, and pneumatic waste collection system have been introduced to aid cleaning and waste collection operations.[6]

A1A3 automated trolley

3.2 The city council of Barcelona has divided the city into four sectors with a separate cleaning contractor for each. A cleaning contractor has recently developed a robotic system – A1A3 – to assist street cleaners with street sweeping. A1A3 is a cleaning trolley with an automated dustpan which a street cleaner can lower after pressing the button on the broom or on the trolley. After tipping the sweepings into the dustpan, the street cleaner can press the button again to lift up the dustpan and empty the sweepings into the trolley (**Figure 4**). The trolley is also designed with an autonomous tracking mode to follow cleaners so that they can focus on the street sweeping task at hand.

Figure 4 – A1A3 automated trolley

Source: Urban Clouds.

[6] Other equipment and technologies deployed include: (a) small mechanical sweepers with brushes and vacuum function for street cleaning; (b) machines for sieving of beach sand; (c) machines with pressurized hot water for cleaning gums and stains on the pavement; and (d) self-cleaning toilets.

3.3 In addition, A1A3 is fitted with a sensor to detect objects and slopes, so that it will stop when an obstacle is detected. It can also brake instantly, so it poses no danger to pedestrians. Furthermore, A1A3 can be operated manually if autonomous operation is not possible, e.g. when an obstruction gets in the way.

Smart garbage collection system

3.4 One of the initiatives developed under Barcelona's smart city strategy is the smart garbage collection system with garbage bins embedded with fill-up ultrasonic sensors. These sensors are capable of transmitting real-time signals when the bins are 80% full and should be emptied. Via the mobile communications network, the signals are sent to a web-based software application used by the cleaning services contractor. With real-time signals, the contractor can then plan the optimal route of collection services by sending waste-collection trucks only to those bins that actually need to be emptied.

Pneumatic waste collection system

3.5 Barcelona installed its first automated vacuum (pneumatic) waste collection system in the Olympic Village District in 1992, as part of the city's renovation for the 1992 Olympic Games. Since then, Barcelona has expanded the system to various areas of the city as it provides an attractive alternative to conventional vehicle-operated waste collection.

3.6 Pneumatic waste collection system is a system that transports waste from a number of waste points or bins to a suction point (mobile system) or a central collection centre (stationary system) by a network of underground pipes. Mobile system uses a truck to suction waste from several suction points and then compacts the waste and transports it for treatment or disposal. In a stationary system, waste is transported to a central collection centre where the waste is compacted and transported to a processing or disposal facility. Pneumatic waste collection system allows the collection of waste at any time during the day, as it is devoid of negative visual and other annoying effects (e.g. bad smell and noise) associated with surface collection.

4. Singapore

4.1 Singapore prides itself on being a clean city. The Singaporean government has been cultivating a clean and healthy living environment to improve the quality of life of its people. Specifically, the National Environment Agency ("NEA"), a statutory board under the Ministry of the Environment and Water Resources, is responsible for overseeing the cleaning of all public areas in Singapore, except for the public housing estates that are under the purview of town councils.

4.2 NEA started to use automated cleaning machines for street cleaning back in the late 1980s, when the difficulties in hiring cleaning workers precipitated the use of mechanical sweepers and mobile vacuum cleaners to enhance the efficiency of street cleaning.[7] Different types of mechanical sweepers have now been used to clean streets and kerbs of main roads (**Figure 5**). Some are trucks mounted with large round bristles on the kerb side of the vehicles, while some others hold tanks for collecting and retaining debris and dried leaves. In addition, one-man-operated mobile vacuum cleaners have been used for cleaning areas not accessible to mechanical sweepers. These cleaners are equipped with long flexible vacuum hoses for cleaning nooks and crannies along walkways and around roadside kerbs (**Figure 6**).

Figure 5 – Mechanical sweeper

Source: Chye Thiam Maintenance Pte Ltd.

[7] According to the Centre for Livable Cities (2016), Singapore had a public cleaning workforce of over 7 000 workmen in the 1960s. By the late 1980s, most of the street-cleaning workforce was approaching retirement age and the prospect of recruiting younger cleaners was daunting. The cleaning workforce had dwindled to 2 100 at that time, while demand for environmental services continued to rise amid urbanization and population growth.

Figure 6 – Mobile vacuum cleaner

Source: Ministry of Manpower (2012).

4.3 At present, NEA has outsourced most of the cleaning work to four cleaning services contractors. Nevertheless, it has been proactively working with these contractors to source and put to test suitable new equipment for cleaning public areas the contractors are responsible for. Other public authorities, such as the Housing and Development Board ("HDB[8]"), have also made efforts in exploring the use of technologies to aid cleaning and waste management operations. Some of the key initiatives trialled and implemented in recent years are detailed in the paragraphs below.

Integrated Public Cleanliness Management System

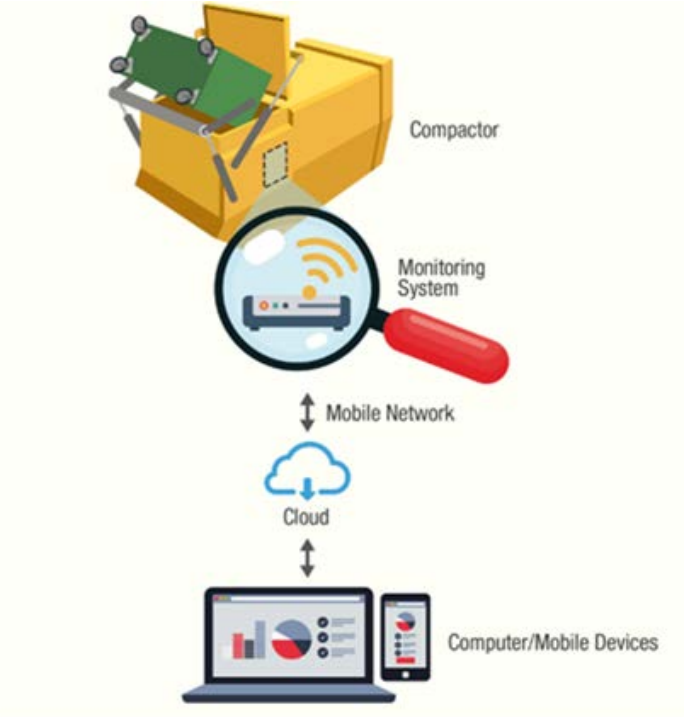
4.4 NEA has made use of the Integrated Public Cleanliness Management System to track and audit the performance of the four cleaning contractors. The system is made up of several sub-systems, of which the Remote Cleanliness Monitoring System makes use of self-powered video camera units to monitor Singapore's cleanliness hotspots. Another sub-system is the Cleaning Performance Monitoring System with features of the installation of Global Positioning System ("GPS") trackers, video cameras and sensors on the mechanical road sweepers operated by the cleaning contractors. The above two sub-systems function on mobile devices, whereby NEA's officers can monitor the cleanliness of public areas through the footage and information captured on their tablets and other mobile devices remotely. They can then alert the cleaning services contractors to rectify any cleaning lapses found.

[8] HDB is the public housing authority in Singapore and operates as a statutory board under the Ministry of National Development.

Refuse monitoring system

4.5 In July 2018, NEA started a pilot project in two new towns where 78 refuse bin centres are installed with the refuse monitoring system (**Figure 7**). The system features the installation of sensors in trash compactors to detect the waste level and send out alert when the trash compactor is nearly full. The alert is sent via mobile network to a controlling centre, which can track the location of trash compactors through a GPS system and implement needs-based waste collection. The refuse monitoring system reduces the number of refuse collection trips, which in turn increases the productivity of waste removal team and eliminate overflowing trash compactors.[9] It was reported that NEA would roll out the system progressively island-wide and would call new tenders between 2019 and 2021.[10]

Figure 7 – Refuse monitoring system



Source: National Environment Agency.

[9] Earlier on, NEA piloted similar technology in 2015 with the installation of position sensors and fullness-level sensors on about 10 000 NEA-managed litter bins for implementing the needs-based waste collection. NEA also in 2015 tested the use of smart bins, which are equipped with trash compactors and sensors to enable storage up to eight times a normal bin of the same size as well as detection of trash level. As at the publication of this fact sheet, NEA has not responded to the request by the Research Office for providing information on the outcomes of these two pilot projects.

[10] See Lim, V. of Channel News Asia (2018).

Side-loader recycling trucks

4.6 Currently, recyclables within the HDB estates are collected using rear-end-loader ("REL") trucks. Each REL truck is manned by one driver and two workers whose task is to push the 660-litre blue recycling bins into the REL trucks for emptying.

4.7 In April 2018, NEA commenced a one-year trial of using side-loader trucks for recyclables collection.[11] The new side-loader truck is more efficient in requiring only one worker, namely the driver. To collect recyclables, the driver activates the vehicle's self-mounted lifting mechanism to automatically lift up the compatible recycling bin and offload the recyclables into the truck's storage compartment (**Figure 8**).[12]

Figure 8 – Side-loader recycling truck

Source: Waste Management & Recycling Association of Singapore.

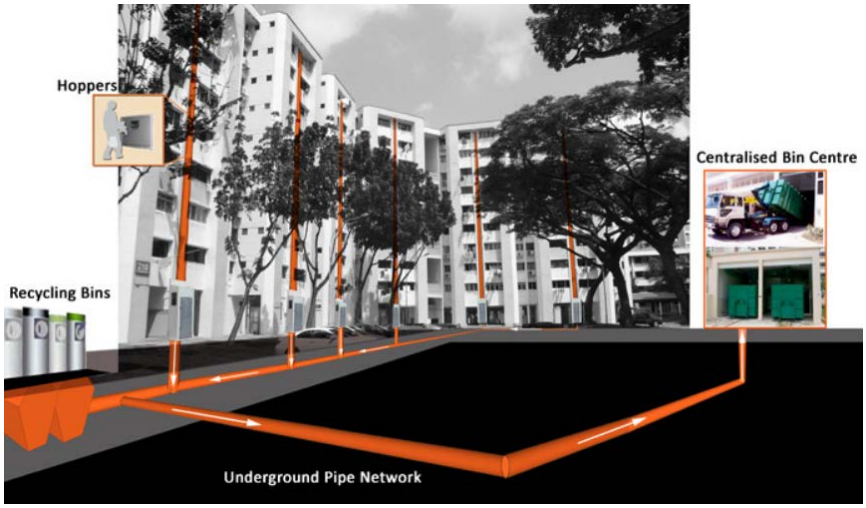
[11] See Loh, J. of Channel News Asia (2018).

[12] The side-loader truck trial also entails the use of new compatible blue recycling bins, which are approximately three times the capacity of the current 660-litre blue recycling bins.

Pneumatic Waste Conveyance System

4.8 As part of HDB Greenprint[13] to create sustainable public housing, HDB pioneered the installation of the first Pneumatic Waste Conveyance System ("PWCS") at Yuhua estate in Jurong in 2015, where 38 retrofitted blocks of flats were installed with PWCS (**Figure 9**). PWCS is an automated waste collection system that uses a vacuum-type underground pipe network to collect household waste, which is then transported from throw-points through underground pipes to a refuse bin centre. Trucks then periodically collect the waste for disposal.

Figure 9 – Pneumatic Waste Conveyance System



Source: Housing and Development Board.

[13] The HDB Green print is a comprehensive and integrated framework of goals and strategies to bring sustainable living into existing public housing estates, through sustainability initiatives in areas such as waste management and energy and water conservation.

4.9 HDB has since 2015 implemented PWCS in selected new HDB developments where feasible, including Tampines North, Punggol, Bidadari and Sengkang.[14] More recently, Singapore has increased its commitment to PWCS by requiring all new non-landed private residential developments[15] with at least 500 dwelling units to install PWCS effective from April 2018. Added to this, Parliament amended the Environmental Public Health Act in October 2018 to roll out the technology district-wide.[16]

Transformation of environmental services industry

4.10 In addition to the adoption of innovation and technologies for improving public cleanliness in Singapore, NEA has also committed to transforming the environmental services industry with the launch of the Environmental Services Industry Transformation Map ("ES ITM") in December 2017. ES ITM sets out the strategies and initiatives that will help the industry strive towards greater vibrancy, sustainability and professionalism.

4.11 Thirty-three initiatives across 12 strategies have been spelt out in ES ITM, which aim to: (a) drive innovation and widespread technology adoption; (b) upskill workforce to take on better jobs; (c) improve productivity; and (d) capture value overseas (**Figure 10**). It is expected that by 2025, about 30 000 workers in the environmental services industry can benefit from higher value-added jobs through upskilling and technology adoption by the industry.

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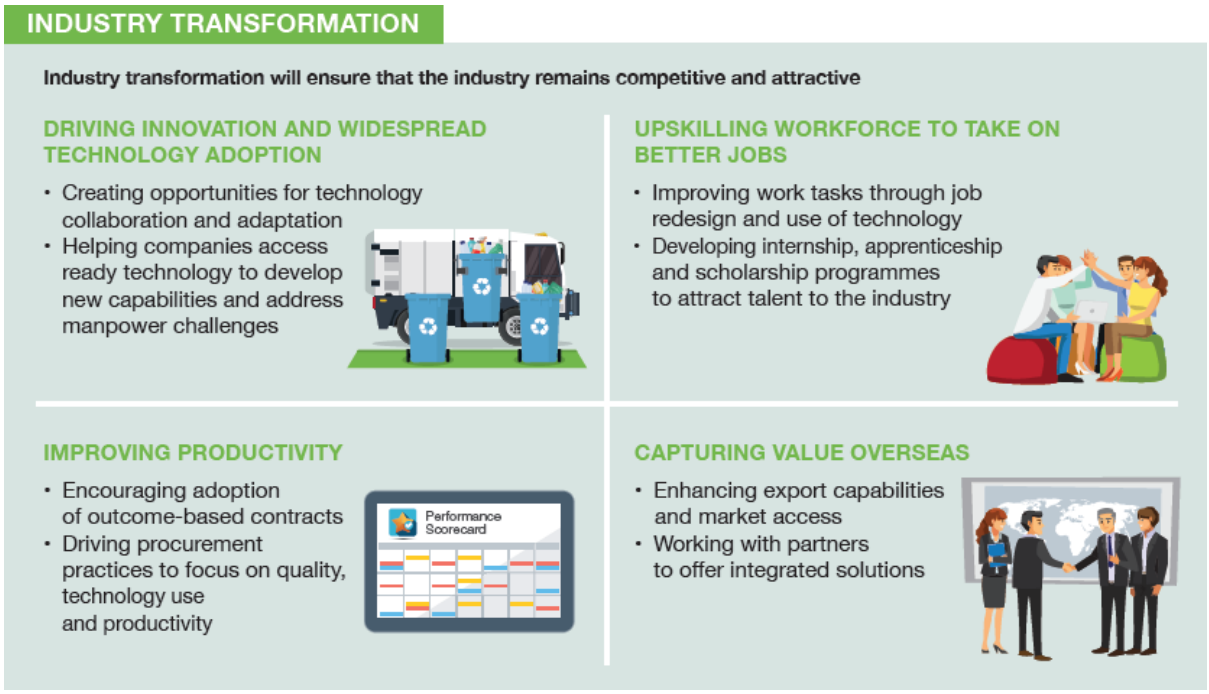
[14] See Ministry of National Development (2016).

[15] In Singapore, private residential properties are generally divided into two types, namely non-landed properties (i.e. private condominiums and apartments) and landed properties (e.g. terrace houses, detached house and bungalows).

[16] Under the amended Act, the Singaporean government is empowered to designate a "District Pneumatic Waste Conveyance System zone" and require owners and occupiers located within the zone to use the system. At the district level, premises owners/occupiers should enjoy cost savings due to economies of scale through a central collection station and shared air and ventilation equipment and pipe networks. See Ministry of the Environment and Water Resources (2018).

Figure 10 – Four pillars of ES ITM



Source: National Environment Agency.

4.12 On driving innovation and widespread technology adoption, NEA has brought together the public and private sectors to prototype, pilot and profile environmental services solutions through the INCUBATE[17] initiative. For upskilling workforce, NEA has collaborated with Workforce Singapore[18] to launch the Environmental Services (Cleaning) Job Redesign Initiative featuring the implementation of various job redesign projects to help the cleaning workers to take on better jobs.

INCUBATE

4.13 Under INCUBATE, NEA has partnered with various organizations to collectively innovate and curate better technologies, solutions and innovations for the environmental services industry. NEA signed Letters of Intent with seven INCUBATE partners in December 2017 and another 11 in July 2018 to kick-start trials of innovative environmental services solutions at the partners' premises. These INCUBATE partners include Changi Airport Group, Changi General Hospital, City Developments Limited (a property and hotel

[17] INCUBATE stands for Innovating and Curating Better Automation and Technologies for Environmental Services.

[18] Workforce Singapore is a statutory board under the Ministry of Manpower overseeing the transformation of the local workforce and industry to meet ongoing economic challenges.

conglomerate), the Sports Hub, Ngee Ann Polytechnic and Republic Polytechnic, and some of the technology trials conducted by them are highlighted in the ensuing paragraphs.

(A) Smart bins

4.14 In August 2018, Changi Airport Group replaced the litter bins in Terminal 4 with smart bins after months of trial. These bins are equipped with sensors to alert cleaners when they are full (**Figure 11**). Cleaners are equipped with mobile devices allowing them to receive the alerts from the bin sensors and identify the locations of the bins that need to be cleared. Instead of checking each bin at a scheduled time, cleaners can implement needs-based trash collection. According to Changi Airport Group, smart bins are expected to be implemented in the other terminals progressively.

Figure 11 – Smart bin

Source: Changi Airport Group.

(B) Autonomous floor cleaners/scrubbers

4.15 Changi Airport Group has also piloted the use of autonomous floor cleaners/scrubbers at Terminal 4, which helps to improve the cleaners' productivity and efficiency. These autonomous floor cleaners/scrubbers can avoid obstacles and clean floor areas quickly at up to 1 600 sq m/h. They are also equipped with real-time monitoring and round-the-clock remote manning service to ensure safety and security during cleaning operations.

(C) Power-assisted janitor cart

4.16 Power-assisted janitor cart is also being tested by Changi Airport Group. It is a battery-operated housekeeping cart with a speed of less than 5 km/h, designed to replace the conventional manual one. The cart reduces cleaners' fatigue and enhances their performance and productivity.

(D) Exoskeletons

4.17 The Centre for Healthcare Assistive and Robotics Technology at Changi General Hospital is testing the use of exoskeletons to give senior healthcare workers extra support as they perform their duties, particularly lifting heavy loads. Exoskeletons are powered brace-like wearables that enable limbs to move with increased strength and endurance.

(E) Smart and easy-to-clean toilets

4.18 City Developments Limited has been testing anti-smell tiles around the urinals of male toilets in one of its shopping malls. When urine or other foul-smelling substances land on the tiles, the coating will neutralise the odour. The shopping mall has also tested the use of traffic and ammonia sensor systems that will alert cleaners if many people use the toilet at the same time or when the odour level exceeds a pre-defined threshold.

(F) Rodent control

4.19 The Sports Hub, an integrated sports and community hub in Singapore, is going to deploy sensors to enable targeted and effective control of rodent population through data analytics.[19]

[19] A private company has also developed an Internet-of-Things solution for rodent control, which replaces manual checks with sensors to monitor rodent activity, detect travel routes taken by rats and how often they are used. According to 8 頻道新聞及時事節目 (2018), the above rodent control solution was part of the trial with NEA.

(G) Robotics technology

4.20 Ngee Ann Polytechnic is exploring the use of robotics technology for the cleaning and maintenance of building facades. Meanwhile, Republic Polytechnic is exploring the use of trackable robots for cleaning of common areas such as lift lobbies.

Environmental Services (Cleaning) Job Redesign Initiative

4.21 The Environmental Services (Cleaning) Job Redesign Initiative, as part of the efforts under ES ITM, aims to help cleaning services providers and buyers transform and grow through leveraging easy-to-adopt job redesign solutions[20] that can benefit their older workers, optimize manpower resources and raise productivity.

4.22 The Initiative is open to cleaning services providers and buyers who are keen to become manpower-lean and/or develop an age-friendly workplace through job redesign to improve work processes for their cleaning workforce. They can access advisory and funding support of up to S$300,000 (approximately HK$1.7 million) per company under the Job Redesign Grant to implement relevant job redesign solutions for older workers aged 50 or above.

[20] Cleaning services providers and buyers are provided with (a) a suggested list of easy-to-adopt solutions identified to improve effectiveness and efficiency of their businesses; and (b) contact information of vendors offering job redesign solutions. The suggested solutions include autonomous robotic scrubbers, mini compact scrubber dryers, light-weight high pressure water jets, blowers/battery-operated weed trimmers, battery-operated carts and mechanical suction sweepers.

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