Case study of sustainable sanitation projects

Urban urine diversion & greywater treatment system Linz, Austria

Fig. 1: Project location

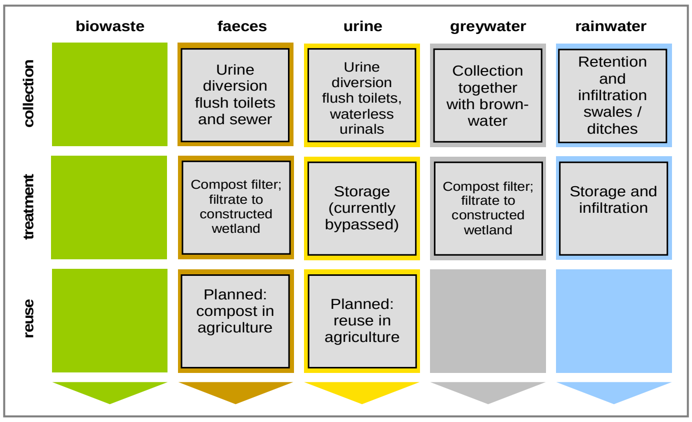

Fig. 2: Applied sanitation components in this project

1 General data

Type of project:
Medium-scale ecosan pilot project in new urban area

Project period:
Start of planning: 1998
Start of construction: 2004
Start of operation: 2006 (and ongoing)

Project scale:
Approx. 250 inhabitants in 88 flats and 270 pupils in a primary school with a childcare facility (in total 460 population equivalents).
Total costs: EUR 2.3 million up to 2008

Address of project location:
solarCity Pichling
Linz, Austria

Planning institution:
OtterWasser GmbH, Lübeck, Germany

Executing institution:
LINZ AG, Linz, Austria
Technisches Büro Steinmüller, Linz, Austria

Supporting agency:
None

2 Objective and motivation of the project

Worldwide, many ecosan projects have already been implemented on a small scale. However, there is still a lack of practical experiences with medium to large scale urban ecosan projects. Ecological sanitation systems can be an approach to address future water and phosphorus scarcity. Being the 2nd largest public service company in Austria, the LINZ AG[1] sees this project as part of its responsibility towards society.

Fig. 3: Buildings of the ecosan project in solarCity (source: Hochedlinger, LINZ AG, August 2009)

General objectives:

- Creation of a sustainable settlement in a new city district (high demand for residential buildings).
- Establishment of ecological buildings and low energy construction concepts.

Specific objectives:

- Implementation of innovative solutions for water supply and wastewater treatment with a reduction of the infrastructure costs for municipal wastewater treatment.
- Establishment of a holistic sanitation approach enabling the use of nutrients contained in excreta or wastewater in agriculture.
- Research into the treatment of micropollutants in urine[2].

[1] Public service company for energy, telecommunication, transportation and communal services (including wastewater collection and treatment).
[2] By PhD research of Winker (2009).

3 Location and conditions

Linz-Pichling is located in the southern part of Linz, a city of approx. 200,000 inhabitants. The project area is characterised by different types of houses (single houses and flats), small lakes, a creek, and the neighbouring Traun-Donau meadows and forest, the biggest joint biotope structure in Upper Austria. The ecosan pilot project is part of an innovative town planning project with many ecological features. It was developed with participation of the municipal authorities, 12 housing companies and READ (Renewable Energies in Architecture and Design) as the main architectural initiator.

4 Project history

In 1992 a master plan was developed for a new city district called solarCity. It envisioned up to 6,000 flats in Linz-Pichling and the associated infrastructure. Based on a study investigating sustainable energy concepts for such a settlement, in 1994 the town authorities declared their willingness to plan and finance a first model ecological settlement of 630 flats in a low-energy building standard together with four non-profit residential building cooperatives and world-renowned architects. This project was supported by the EU with EUR 600,000.
From 1995 to 1998 several architectural and landscape design competitions were carried out. Eight further non-profit housing companies and several architects and engineers joined the project, which led to the planning of 1,300 flats on an area of approx. 60 hectares.
From 1999 to 2005 this building project was implemented, and the construction phase of the ecosan project started in 2004. The construction of all parts (separation toilets, urine collection pipes, etc.) and the information for the users were carried out by the non-profit residential cooperatives. The contract between the LINZ AG and the cooperatives includes total cost coverage by the LINZ AG for retrofits to a conventional sanitation system in the case the ecosan system would fail.
In mid 2006 the ecosan system was taken into operation. The new inhabitants of the flats were informed before moving in by a small brochure containing information on the new sanitary installations and the separation concept. Public relation work was first done by the residential cooperatives, which was not successful. Later it was taken over by the LINZ AG and the city of Linz.
In 2008, the ecosan project solarCity Linz received the Project Innovation Award as regional winner for Europe in the category „Small Projects“ by the International Water Association (http://www.iwahq.org/uploads/pia/PIA%20A.pdf).

5 Technologies applied

This project manages the wastewater of approx. 460 population equivalents by means of urine separation, compost filters and constructed wetlands (design details are given in Section 6).
A primary school and childcare facility for 270 pupils and personnel (system 1), as well as 88 flats of three housing companies with approx. 250 inhabitants in 7 buildings (system 2) are equipped with the following ecosan components:

System 1 (primary school and childcare)

- 12 urine-diversion flush toilets
- 20 waterless urinals
- 2 separate pipe networks for urine and other wastewater
- 2 fibreglass tanks for urine collection and storage (total volume: 3 m³)
- 2 compost filters for pretreatment of the mixed brownwater[2] and greywater (solids removal)
- 1 constructed wetland for the treatment of the filtrate from the compost filters

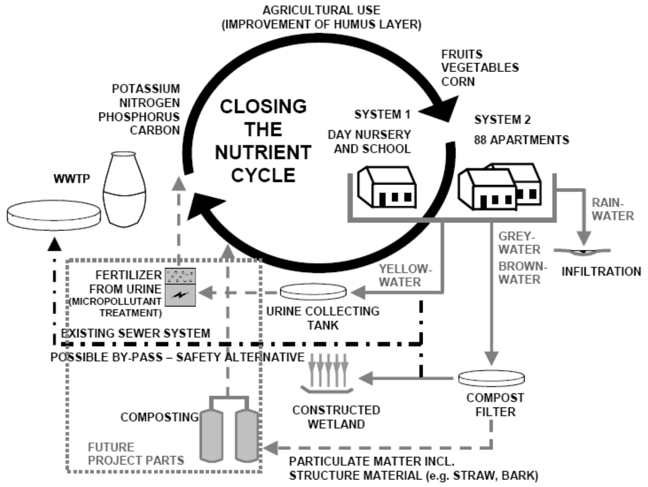

Fig. 4: Technological concept applied in the solarCity project (source: LINZ AG).

System 2 (88 flats; average household size is 2.8 persons)

- 115 urine-diversion flush toilets
- 2 separate pipe networks for urine and other wastewater
- 6 fibreglass tanks for urine collection and storage (total volume is 4.5 m³)
- 2 compost filters for pretreatment of the combined brownwater and greywater (solids removal)
- 2 constructed wetlands for the treatment of the filtrate from the compost filters

In the project area in Linz-Pichling a conventional sewer is provided: the wastewater streams of the ecosan system can be connected to the existing public sewer system (see Fig. 4). This sewer connection can be utilised in case of malfunctions or optimisation works (it is currently being used for urine and constructed wetland effluent, see Section 11).
Rainwater is infiltrated on-site through infiltration ditches.

6 Design information

Urine-diversion flush toilets

The urine-diversion flush toilet model “NoMix toilet” (supplier: German company Roediger[3]), which is implemented in the school and residential buildings, is made of ceramics. Its bowl is separated into a urine and a faeces section. It requires utilisation in a sitting position because a urine pipe valve is activated by the user’s weight on the toilet seat to allow the collection of pure urine (without flush water). The valve closes when the user stands up, so that the flushing water does not enter the urine pipe but drains off through the faeces outlet in the rear. This reduces the required urine storage volume, because the urine is collected without dilution. The user has two different flush buttons available: 1-3 L of flushing water

[2] Brownwater: faeces mixed with flushing water (without urine)
[3] www.roevac.com

are used for the urine flush (volume set during installation) and 6 L for the faeces flush.

Fig. 5: Roediger urine-diversion flush toilet showing knob to activate urine valve at the front of the toilet bowl (source: Roediger).

Waterless urinals

The waterless urinals (meanwhile widespread in many Western European countries) are also made of ceramics and supplied by Hellbrok[4]. The special surface prevents sticking of a urine film that could cause odours. In the model used in system 1 (school and day nursery) a liquid with lower density than water and urine works as a sealant liquid in the odour trap. It has to be refilled regularly (see section 10). The liquid is biodegradable when discharged to the sewer.

Fig. 6: Waterless urinals for boys from the Austrian company Hellbrok in the school building – hung lower than for adults (source: OtterWasser GmbH).

Urine storage tanks

The separate urine pipe network (100 mm diameter, 1-2% slope) leads to 6 double wall fibreglass tanks in the housing area and to 2 storage tanks in the basement of the school. With a volume of 1.5 m^3 each in the school (total volume: 3 m^3) and 0.75 m^3 each in the residential buildings (total volume: 4.5 m^3), the tanks are designed for 30 to 60 days storage time[5]. They are closed (to reduce odour and ammonia losses), and the pressure equalisation takes place through the inlet pipes from the houses. The storage tanks are equipped with level indicators, a leakage warning system, an overflow to the sewer, and a fitting for emptying by a vacuum truck. The actual amount of urine produced is currently not measured.

Fig. 7: The two plastic urine tanks (currently bypassed) in the school building's basement have a capacity of 1.5 m^3 each (source: OtterWasser GmbH).

Compost filter units (pretreatment)

A filtration system for solids removal is the first treatment step of the greywater and brownwater mixture. The two 1-m³ filter units are located in the two operation buildings which are integrated in the hills of the artificial landscape. Apart from the pretreatment filters, the operation buildings contain a storage area for the containers for the dewatering process and all the control and maintenance facilities.
The filter units (Fig. 11) are made of stainless steel containers, serving as a carrier for a filter bag of acid-proof plastic material, which is filled with organic structure material (e.g. straw). The brownwater and greywater mixture is pretreated in the filter bag (by composting) under aerobic conditions and drains through the structure material. The filtrate runs off through slots in the base of the container and flows to a pump sump, from where it is pumped to the constructed wetland.

Constructed wetlands

The two constructed wetlands are of the sub-surface vertical flow type, planted with reed (*Phragmites australis*). Since the urine is separated, the remaining wastewater has a low nutrient content. Therefore, the required size of the constructed wetland is up to 1 m² per inhabitant smaller than in constructed wetlands for domestic wastewater where it is 2.5 - 3 m² per person. Two wetlands exist, each containing two beds of 8.9 m x 22 m each. Overall, a wetland area of 771 m² is available for treatment.
The intermittent batch feeding is achieved by submerged pumps. To prevent dehydration, e.g. due to low wastewater volumes during summer holidays, the wetlands can be switched to an operation mode where the wastewater is recirculated. The wastewater flowrates to the wetlands are not known.

7 Type and level of reuse

The reuse of urine is not yet carried out because the Upper Austrian legislation prohibits its application in agriculture.
At the moment the composting process of the compost filter material is not functional due to optimisation works (see Section 11).

[4] www.hellbrok.at
[5] For safe urine application in agriculture further storage, treatment steps or other barriers may be necessary (WHO Guidelines, 2006 http://whqlibdoc.who.int/publications/2006/9241546859_eng.pdf).

In the future, nutrient recycling (through use of urine, compost and reeds from the constructed wetlands) and on-site infiltration of the treated brownwater and greywater shall be realised in cooperation with research partners (see Section 8).

8 Further project components

The ecosan project solarCity provides the “hardware” for future research activities. Research partners have been chosen and a proposal is finalised. Together with these research partners and in dialogue with the authorities the final stage of the ecosan project – closing the nutrient loop by using compost and urine as fertiliser in agriculture (under consideration of micopollutants) – shall be realised in the near future (funded by Austrian research funds).
Besides the ecological sanitation concept solar energy and energy-saving technologies are also implemented in solarCity.

9 Costs and economics

Until 2008 the total costs of this project amounted to about EUR 2.3 million, encompassing investment, operation, maintenance, and research sponsorship. The costs are fully covered by LINZ AG, and the company is granted tax concessions (8% of the project costs). The construction costs including design and project management have been about EUR 1.7 million. Sponsorship of research (e.g. Hamburg University of Technology, ARC Seibersdorf Research GmbH, and the University of Applied Sciences Upper Austria) resulted in expenditures of EUR 0.5 million. Moreover, the operation and maintenance costs amounted to EUR 100,000 in the time from mid 2006 to mid 2008.
The inhabitants of the houses that are connected to the ecosan system are paying the normal wastewater fees (sewer system and wastewater treatment included). The calculation of the fee in Linz is a combination of number of toilets and water consumption. E.g. a family (4 persons) with 160 m^3 per year (EUR 0.32 per m^3) and one toilet (EUR 112 per year and toilet) has to pay yearly fees of EUR 160 per year (plus 10% tax). All inhabitants of solarCity involved in this ecosan project pay the same fees as users of conventional toilets.

10 Operation and maintenance

The maintenance of the ecosan system’s technical equipment is carried out by the LINZ AG as the operating company. Currently the last optimisation steps are being carried out. In the future, the main work will be operation, customer service, public relations and project management.

Urine-diversion flush toilets

The operation of the urine-diversion flush toilets is similar to conventional toilets. However, the user has to be seated also for urination. As discussed in Section 11 the cleaning is slightly more difficult compared to conventional flush toilets.
Annually, LINZ AG inspects the toilets and provides user information and public relations work. If necessary, urine scale is removed with boiler scale remover and worn-out bowden wires (for the operation of the urine valves) are replaced. For the prevention of urine scale deposition in the urine valves, the users are provided with 1 L of diluted citric acid (20%) every year, together with information on how to use it (monthly application with open valve, exposure time over night).

Waterless urinals

The reliability of the waterless urinals (no odour) highly depends on regular maintenance. The urinals at the school are cleaned daily by the cleaning service and the odour traps with the sealant liquid cartridges are exchanged regularly (after one to two years) by the maintenance service of the school and childcare.

Urine storage tanks

Currently the urine is discharged into the public sewer system and not collected in the urine storage tanks. However, if the urine was collected and reused, the tanks would have to be emptied monthly by a vacuum truck that would transport the urine e.g. to a nearby farm for application. For this reason, there is currently no information available about the urine production per day.

Constructed wetlands

The technical installations of the treatment facilities, especially the pumps, are controlled by remote systems (SCADA) installed at the wastewater treatment plant Asten, which is located 2 km away.
The reed of the constructed wetlands is growing quite slowly; therefore nothing was done with it yet. If the plants were big enough they could be harvested in spring. Reeds die off in autumn, but to prevent frost they should be left on the wetland during winter time. In the future the harvested reeds could be used in the filter units as organic and structure material.

Fig. 8: Constructed wetland under construction (source: LINZ AG, April 2006).

Fig. 9: Constructed wetland (reed beds) in operation (source: LINZ AG, May 2008).

Compost filter units

The compost filters are still at a trial stage (see Section 11). It is planned to operate them intermittently: after filling the first filter unit, the inflow will be connected to the second unit, while the first one is resting for dewatering. The container content

then keeps dehydrating until it is transported to the neighbouring room in the operation building by fork lift. There, 6-8 full, stackable containers (1 m^3 each) can be stored.
After finishing the optimisation work of the filters, bulking material shall be added to the containers at least once a week. LINZ AG will then collect the containers from the storage rooms once or twice a year and empty them at a central composting ground for post-composting.

11 Practical experience and lessons learnt

Surveys about performance and maintenance of the toilets

About 90% of the people who live in the houses equipped with urine diversion toilet did not move there purposefully for the ecosan system. Therefore, the experiences made with these inhabitants provide valuable information about the general acceptance of ecosan concepts.
After half a year of operation (early 2007) the first survey was conducted by LINZ AG with a focus on the performance and maintenance of the urine diversion toilets. Some practical problems became evident, mainly resulting from the improper maintenance and use of the Roediger toilets.
67 out of the 88 households took part in the survey. 66% reported that flushing water splashes onto the toilet seat. This problem can be solved by reducing the amount of flushing water. However, 68% (among single, male occupants only 13%) complained about a weak flushing strength which does not completely carry away the solids (faeces and toilet paper) resulting in increased cleaning requirements compared to conventional toilets. This trade-off relates to the design of the toilet and should be addressed in further development and optimisation of the toilet.
71% of the polled users said that the toilets require special maintenance work, e.g. for the urine pipe valves. For the prevention of urine scale everybody used scale remover. In total, about 95% of the toilets were perceived as clean by the interviewers.
The residential cooperatives did not provide adequate user information about the ecosan system: only 77% of the households had been informed in advance about the source separation concept. Based on LINZ AG's promise for total cost coverage for retrofits to a conventional sanitation system in case of a failure of the ecosan system, one cooperative tried to convince the occupants from the beginning that the ecosan concept would never work. Therefore, the public relation work was taken over by the LINZ AG itself.
In a first step, confidence was restored by means of an on-site information campaign, along with a toilet check (particularly of the urine pipe valves) and immediate repair of toilet malfunctions. Due to this information campaign, trust restoration mostly succeeded.
According to the survey only 11% of the users had a negative opinion about the ecosan project, and the other users were positive to indifferent.
A second survey, conducted in December 2008 with 55 households, showed that the general acceptance for the ecosan project is neutral to very good, but for the urine diversion toilets the result is very bad to neutral (despite the information campaign), due to the above named issues.

Measurement campaign for system 1 (school and childcare) in May 2007

In order to assess the performance of the urine diversion toilets, a three-week monitoring programme was conducted in the framework of a diploma thesis for the school system (system 1) in May 2007. The analysis of daily collected samples from several monitoring points of the system showed that a part of the urine is not collected properly (elevated nitrogen concentration in the mixed brownwater and greywater stream).
Most of the losses result from improper maintenance of the urine pipe valve or incorrect use for urination (users not sitting down). The results of the monitoring program also showed that approx. 60% of the total nitrogen contained in urine is being collected here. The amount of urine collected annually is unknown.

Operating experience with the urine diversion toilets and waterless urinals in the school (system 1)

Experience with the urine diversion toilets has shown that they are too large for small children and therefore not suitable for primary schools. A small child (shorter than 1.4 m) cannot get into the right sitting position (compare Fig. 10), which may result in faeces ending up in the urine collection bowl of the toilet. The faeces in the urine bowl are not flushed away completely, which leads to odour problems. This problem occurred in the school but also in the flats of families with small children. In the childcare facility it is prevented by staff helping the children with the use of the toilet.

Fig. 10: Left: ordinary (problematic) sitting position of a child on a Roediger NoMix toilet. Right: optimal (but less comfortable) sitting position of a child (source: LINZ AG).

A raised platform around the toilet, aiming to ensure a better sitting position by maintaining the contact of the child's feet with the ground, succeeded only partially. The reason was that it was called a "baby's toilet" amongst the children. As none of them wanted to be a baby anymore they did not want to use a "baby's toilet". Due to the varying ages of the primary school children no universal solution could be found. The pupils had to be educated to use the toilet brush for cleaning purposes. Since then the cleanliness of the toilets improved a lot.
The measurement campaign for system 1 revealed that the pupils used the urine-diversion toilets for urination, but they avoided defecation. Whether this is a phenomenon related to this particular toilet type or a general behaviour of pupils (preferring to defecate at home rather than at the school) could not be identified. Another assumption might be that this time of the day is not the main time for defecation.
After two years in operation, the LINZ AG **changed the UD flush toilets at the school to conventional flush toilets** until the urine separation toilets are improved for small children. The pipes and connections still exist so that the toilets could be exchanged again at a later stage.
Due to regular operation and maintenance routines the waterless urinals are functioning well, with neither blockages nor odour problems occurring.

Operating experience with the urine diversion toilets at the flats (system 2)

There are some practical problems resulting from wrong or neglected maintenance, incorrect use or the design of the separation toilets:

- the urine inlet valves have to be cleaned regularly to prevent urine scale
- most of the nitrogen losses result from the malfunction of the urine inlet valve or the incorrect use of the separation toilet
- the odour problems are caused by wrong depositing of the faeces in the front part of the separation toilet
- the flushing water splashes onto the toilet seat
- it is often necessary to flush twice, because the water flush volume is not enough to carry away faeces and/or toilet paper.

LINZ AG started an information campaign to avoid problems due to wrong maintenance or use and recommended to the manufacturer of the toilet to change the design.

Performance of the compost filters and constructed wetlands

So far the performance of the compost filters has not been satisfactory due to clogging of the filter bags: The cellulose of the toilet paper substantially decreases the hydraulic permeability of the filters' material. Further research and optimisation work had to be conducted. Tests of different structure materials (such as bark and straw) were conducted. They showed that the adding of a pre-treatment step e.g. a settling tank would reduce the sludge load and enhance the permeability of the filter bags. The implementation of further optimisation steps will be done together with future research partners in 2009.

Fig. 11: Compost filter bags at trial stage, here with straw as structure material (source: LINZ AG, November 2007).

The performance of the two constructed wetlands is excellent. The measurement campaign for system 1 showed that the effluent concentrations are less than half the legally required values[6]. Nevertheless the final effluent is being discharged into the local public sewer network, because the relevant local authorities[7] have not granted a water quality discharge consent yet.

[6] According to the first wastewater emission directive of Austria ("1. Abwasseremissionsvereinbarung" in German)
[7] The German name of this local authority is: Wasserechtsbehörde (Amt d. Oberösterreichischen Landesregierung)

Lessons learnt

The ecosan technologies applied in this project are not yet fully mature and functional. There is a need for optimisation of the NoMix toilet design. The slightly increased demand for cleaning is acceptable. But for young children, e.g. at primary schools, the Roediger toilets are not suitable. The waterless urinals are trouble-free.

The project at the school has had significant problems with the urine separation flush toilets for small children who find it difficult to sit back far enough for defecation.

Public relations work, i.e. user information, is extremely crucial for the acceptance of innovative sanitation systems and the users' willingness to cooperate. The general acceptance of the innovative sanitation concept is good, despite the challenges that are brought about by the urine diversion flush toilets.

Valuable experience with the medium-scale application of compost filters could be gained in this project. One problem is that the filter units were undersized (the permeability of the filter bags turned out to be lower than expected).

Moreover, it became evident that it is important to include the local authorities from the beginning as it avoids many problems in the long run.

12 Sustainability assessment and long-term impacts

In Table 1 a basic assessment was carried out to indicate in which of the five sustainability criteria for sanitation (according to the SuSanA Vision Document 1) this project has its strengths and which aspects were not emphasised (weaknesses).

Table 1: Qualitative sustainability assessment of the system. The crosses indicate the relative sustainability for each project component (column) and sustainability criterion (row).
(+): strong point of project, (o): average strength for this aspect, (-): no emphasis on this aspect in the project.

	collection and transport			treatment			transport and reuse[a]		
Sustainability criteria:	+	o	-	+	o	-	+	o	-
• health and hygiene	x			x					
• environmental and natural resources		x		x					
• technology and operation		x				x			
• finance and economics		x				x			
• sociocultural and institutional		x			x				

[a] No reuse practised yet

Sustainability criteria for sanitation:
Health and hygiene include the risk of exposure to pathogens and hazardous substances and improvement of livelihood achieved by the application of a certain sanitation system.
Environment and natural resources involve the resources needed in the project as well as the degree of recycling and reuse practiced and the effects of these.
Technology and operation relate to the functionality and ease of constructing, operating and monitoring the entire system as well as its robustness and adaptability to existing systems.
Financial and economic issues include the capacity of households and communities to cover the costs for sanitation as well as the benefit, e.g. from fertilizer and the external impact on the economy.
Socio-cultural and institutional aspects refer to the socio-cultural acceptance and appropriateness of the system, perceptions, gender issues and compliance with legal and institutional frameworks.

For details on these criteria, please see the SuSanA Vision document "Towards more sustainable solutions" (www.susana.org).

The main long-term impacts of the project are:

1. It has provided useful experiences to others as a demonstration project, as it is always open to visitors.
2. The experience and the cooperation with the inhabitants illustrated the demand to optimise these urine-diversion flush toilets by the manufacturer (or, possibly, to switch to a different manufacturer).

The final aim of solarCity, the use of compost and urine as a fertiliser in the agriculture, still has to be realised with research partners.

13 Available documents and references

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- Winker, M. (2009) Pharmaceutical residues in urine and their potential risks related to agriculture, PhD thesis, Technical University of Hamburg-Harburg, Germany, http://www.tu-harburg.de/aww/english/publikationen/index.html (click on Ph.D. Theses).

Further documents are available on request from the contact persons indicated below.

14 Institutions, organisations and contact persons

Project management and owner of project

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