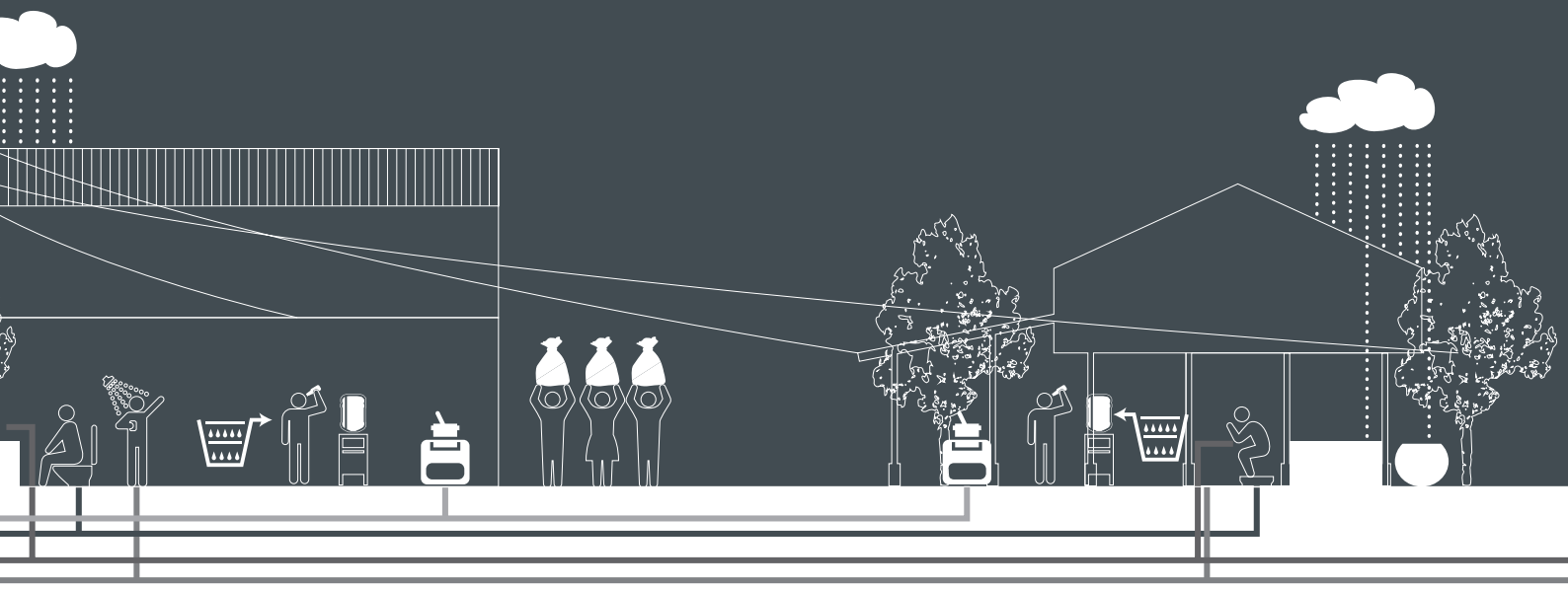
Research Project

iReBa: Integrated Resources Management Battambang



Research Project

iReBa: Integrated Resources Management Battambang

Bauhaus-Universität Weimar

Federal Ministry of Education and Research

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iReBa: Integrated Resources Management Battambang | Cambodia
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Abstract

The international student cooperation project “Integrated Resources Management Battambang (iReBa)” between the University of Battambang and the Bauhaus-Universität Weimar intends to find an urban resource management system that the people of Battambang can profit from. The major outcomes of the workshop that was held in Battambang as well as further analysis are included in this work.

An overall concept for the city is found by combining sustainable and resource-economic based urban water management and waste management with modern urban planning. To achieve this goal, several steps were necessary. First the current situation had to be analysed according to the spatial and infrastructural context. As a further step, the city was defined as a mosaic of different typologies for being able to make a detailed analysis and to find suitable options for each typology. Because an overall concept for the whole city is needed, the integrated infrastructure systems are combined in one system with several interconnections between the six typologies. Further, this concept is examined referring to its benefits, weaknesses and threats and finally, a short future outlook is given.

Keywords

Integrated Resource Management, Resource Recovery, Urban Typologies, Infrastructure, Battambang, Cambodia, Sustainable Water and Waste Management, Sustainable Sanitation

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CHAPTER I:
INTRODUCTION

1.Introduction

1.1. Battambang

Battambang is the second largest city of Cambodia and the capital of the Battambang province. It has a long history that can be tracked back to the Khmer Empire. It has a population of around 1.02 Million people living in the Battambang province and 140,000 people living within the municipality – according to the District Data Book 2006. The province of Battambang is known as the 'Rice Bowl' of Cambodia, because of its 'strong agricultural base, fertile soils and extensive irrigation systems' (Schirmer 2014, p.9). The agriculture sector is also profiting from the tropical monsoon climate, with an average annual temperature around 27.2°C and 1364 mm of rain. The precipitation ranges from around 5,1mm in months of the dry season up to 259,1 mm in months of the wet season (Cf. Weatherbase 2014).

The city of Battambang as well as the country of Cambodia went through a turbulent history, starting with the colonization by France in the middle of the 19th century. Infrastructure like roads railways, sewage systems and houses in colonial style were built during this period. Between 1969 and 1973 Cambodia went through a period of extreme damage. It was bombed during the Vietnam War and was later overtaken by the Red Khmer with Pol Pot as a leader. During this time, almost one third of the population was killed or displaced including the intellectual elites. The already existing infrastructure was completely destroyed (BMZ 2014). Since these days Cambodia is slowly recovering but still has a major lack of infrastructure. For example only 34% of the Cambodian population had access to improved sanitation in 2011 (Hor et al. 2006; Hor et al. 2011).

This situation can also be found in the city of Battambang where only 10% of the city is connected to the sewage system (Miller et al. 2010). The waste management in the city is on a low level, too. The 'collection rates are poor, with much of waste being burned and dumped at or near the source locations' (Miller et al. 2010, p.7). This inadequate service leads to worse hygienic conditions and can cause health problems like diarrhoeal diseases and infections in the population, transmitted by the faecal-oral route (Lüthi et al. 2011). This circumstances should be improved as soon as possible due to the fact that specialist consider that the number of inhabitants will increase to more than 200.000 citizens in 2020 (Pen et al. 2009). Improvements will directly effect people's daily life and will support the upcoming tourism and industry.

Fig. 1:
View of the Battambang city centre with the central market and the main transportation axes visible (Vencel 2012)

1.2. Frame of the Project

The project iReBa was conducted in co-operation between the Bauhaus-Universität Weimar, Germany and the University of Battambang, Cambodia. It was funded by the German foundation DAAD. The project was divided into two steps, a preparation in Germany on three workshop days by the students from the Bauhaus-Universität Weimar and the main part of the project that took place in Cambodia for two weeks with 20 participants. This project was organized as a part of the study programmes Umweltingenieurwissenschafften (Environmental Science) M.Sc. and European Urban Studies M.Sc., for the students from Bauhaus-University. A detailed project description can be found in the Appendix.

1.2.1. Task/Aim of the Project

The official aim of the Project iReBa consists of different tasks, which needed to be considered to achieve the common goal of 'combining sustainable and resource-economic based urban waste and water management with modern urban planning'.

To reach this goal, a close collaboration between Environmental Engineering, Urban Planning and local experts is necessary and ways to bring these different professions and cultures together need to be found.

The proposed result of this collaboration is the development of a conceptual model for waste and water management with a special focus on resource recovering and treatment of organic matter for the city of Battambang. On-site research is necessary in order to find a suitable and sustainable system that fits for the existing local structures of infrastructure, urban development and culture. This involves collaboration with local stakeholders, experts and communities, visits to existing facilities like the wastewater treatment plant or the local composting plant, as well as the collection of missing data.

The developed system should be a theoretical basis that shows which possible technical components and methods can be used in the current urban situation in the future and to give a practical contribution for the further development of the city of Battambang.

1.2.2. Structure of the Work

1.2.2.1. Interdisciplinary Work

The main goal of the iReBa project is "to bring together sustainable and resource-economic based urban water management and waste management with modern urban planning" (Stäudel 2006). This task required a close collaboration between students of Environmental Engineering and students from Urbanism. Combining both professions on one task gives the chance to plan together and to find concepts that consider technical and urban needs at once.

Planning settlements without considering infrastructure is a major mistake that was repeated in the past and can also be seen in Battambang. For example, there are some areas that have no connection to the sewage system which indicates that these houses are planned and built without thinking of technical infrastructure. A different example can be found in Germany. There are some regions where the urban planning was not considered in a suitable way while planning the sewage systems. These systems are now oversized due to the demographic change and flight from the land.

Planning together helps to avoid failures like this and to manage the existing problems in a suitable way.

1.2.2.2.Team

The team for the project included 8 Students from Bauhaus-Universität Weimar and 8 Students and one instructor from University of Battambang (UBB) as well as one employee from COMPED (a local NGO) who is running the local compost plant and one employee from the Municipality of Battambang. All students and group members had a different background and were able to give specific input to the project.

The group from Bauhaus-Universität Weimar (BUW) has included 4 master students from Environmental Engineering and 4 master students from the Urban Planning. Students from University of Battambang

Fig. 2:
The team after the final presentation of the workshop in Battambang (Stäudel 2014)

(UBB) were mainly graduates of Nuclear Engineering programme while some also had education in Civil Engineering or Agricultural Studies.

Local experts were Mr Bora from COMPED, Mr Samnang from the University of Battambang and Mr Tonghann who is working for the municipality of Battambang. Mr Bora works at the local compost plant and the related social centre nearby. Mr Tonghann works for the municipality on the topic of informal settlements and the master plan development for the City of Battambang. Both were full members of the team and they provided valuable information for the project.

1.2.2.3. Preparation in Germany

The preparation for the workshop started in January 2014 when the group from BUW first met. There were 3 different workshops. The first workshop had the aim to introduce the students from BUW to get to know each other and to compare baseline studies which were started after the confirmation of the project. Work packages were made by the group to deepen the knowledge about the current situation in Battambang and according to the different professions of the students. Presentations were given by Dipl.-Ing. Stäudel and Dr. Stratmann to introduce main concepts related to resource management and urban planning.

The results were then presented during the second workshop to inform each other and reach a certain level of knowledge. Talking about expectations and the possible outcome of the project was the second major topic of this workshop. Shortly before leaving to Battambang, the group met again for the third workshop, which was used to plan the two weeks of the iReBa workshop in detail.

1.2.2.4. Time schedule

Therefore a detailed time schedule including milestones was created. The time schedule includes the plan to use the first week in Battambang to get to know the Cambodian students, to meet stakeholders, to learn about the current situation, the area and to define what and where the group of students

Fig. 3:
Weekly plan preparation in Weimar (Stäudel 2014)

should work on. Therefore fieldtrips, meetings and group works were planned. Whenever group work was planned, the schedule included a cross-cutting module, which was used to inform other groups about ongoing work, experiences and to reach a similar level of knowledge.

Creating a future plan and finding possible technical systems to use resources in the City of Battambang, as well as preparing the final presentation was planed as the major task for the second week.

Due to working conditions, different levels of knowledge, time-intensive group work and additional field trips during the two week workshop in Cambodia, the requirements and expectations for the time schedule could not always be fulfilled.

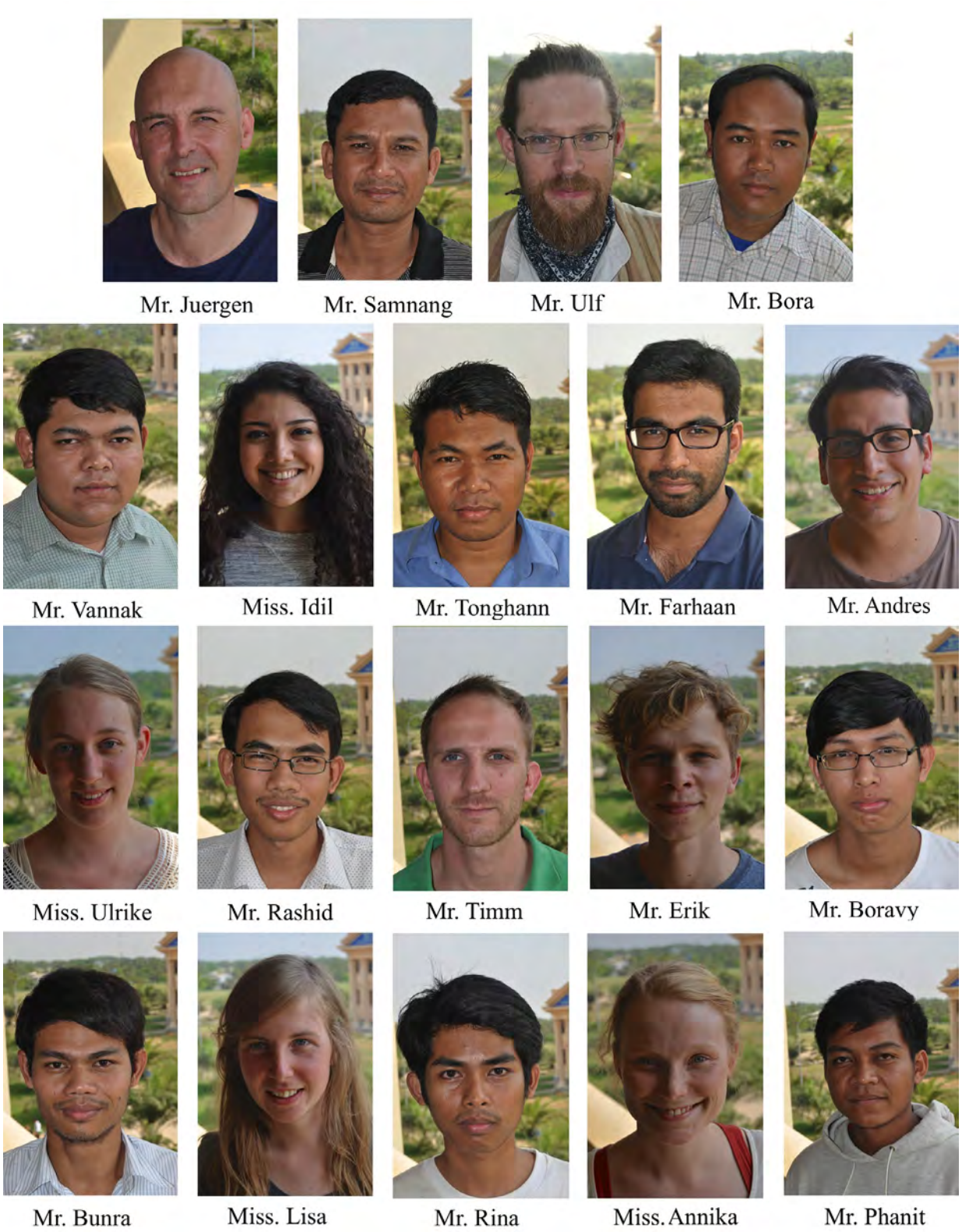


Fig. 4:
Team Members
(Stäudel 2014)

CHAPTER 2:
IMPORTANT TERMS & METHODOLOGY

2.Important Terms and Methodology

This chapter provides basic information for a better understanding of the following chapters. Important terms will be described and the concept of material flows will be introduced. The planning process with its eight different steps will be shown in a flowchart and described with different examples.

2.1. Important Terms and Concepts

Some important terms for the project are explained below, which are material flows, wastewater and solid waste.

2.1.1. Material Flows

Material flows can be described as "…the flow of materials (i.e. substances or resources) being used and transformed within a system defined in space and time. The sources, pathways, as well as the intermediate and final sinks of a material are included…" (Brunner and Rechberger 2004).

These materials are more or less important for an efficient resource management due to their different values or potential to be reused. Major material flows, according to environmental engineering and this project, are solid waste especially the organic matter and wastewater. These flows have a high potential due to their quantity and possibilities to use or treat them with benefit . Analysing these materials and their flows between different steps of usage and treatment was necessary for the project. Thereby the focus was on the points were the material is created e.g. wastewater from households which is the input to the flow system and the points it left it e.g. clean water into the river which is the output. The possible technical treatment steps between input and output were chosen in a way that the outputs have a good benefit according to the targets of resource management.

2.1.2. Wastewater:

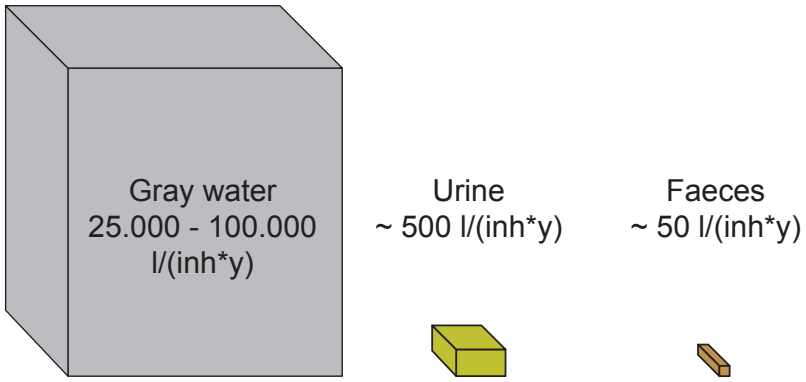
Wastewater is a mixture of different materials such as water, urine and faeces in the common understanding. In the understanding of modern resource management it is not only wastewater, it is a variety of ingredients that can be mixed in different ways as shown in the following table.

These materials and mixtures can be collected together or separately as shown in the table. Mixing these flows is common practice in many countries but makes intensive and expensive treatment necessary.

Term	**Definition**	**User interface**
Faeces	Solid human waste	Dry toilet without flush
Brownwater	Faeces with flushwater	Separating toilet with flush
Urine	Urine, liquid human waste	Separating toilet without flush
Yellowwater	Urine with flushwater	Separating toilet with flush and urinal with flush
Excrement, excreta	Urine and faeces	Toilets without flush
Blackwater	Excreta with flushwater	Flush and Vacuum toilets
Greywater	Used water from households without flushwater	Shower, bathtub, sink, washing machine, dishwasher, kitchen sink
Rainwater/stormwater	Water on plots from precipitation (Snow, Rain, Fog...)	
...		

Fig. 5:
Source Seperated Flows (Illustration by the authors based on AG 'Wasser und Umwelt' 2013)

The different qualities and quantities of the flows are shown in the graphic below. It can be seen that faeces and urine contain a large number of nutrients and are produced in small amounts. Greywater, which is not high polluted or loaded, is produced in a large quantity. Separate treatment and collection of these materials is a possible step and one major requirement to use new sustainable sanitation systems.



N	~ 4 - 5 kg/(inh*y)	~ 3 %	~ 87 %	~ 10 %
P	~ 0,75 kg/(inh*y)	~ 10 %	~ 50 %	~ 40 %
K	~ 1,8 kg/(inh*y)	~ 34 %	~ 54 %	~ 12 %
COD	~ 30 kg/(inh*y)	~ 41 %	~ 12 %	~ 47 %

Fig 6: Wastewater Content Volumes (Illustration by the authors based on TUHH n.d.)

2.1.3. Solid Waste:

Like wastewater, solid waste consists of different materials in different quantities which can be seen in the following diagram.

Collecting these materials separately gives the chance to treat them more efficient and reduce the amount of waste, which is dumped on landfills. After the recycling of valuable materials like metal cans, paper or plastic bottles, organic waste is the most important material to work on for resource recovery, due to its high quantity and the possibility to use it for the production of biogas or compost. Separating organic matter from waste going to dumpsites also helps to protect the climate cause organic matter on dumpsites is a major reason for methane emissions.

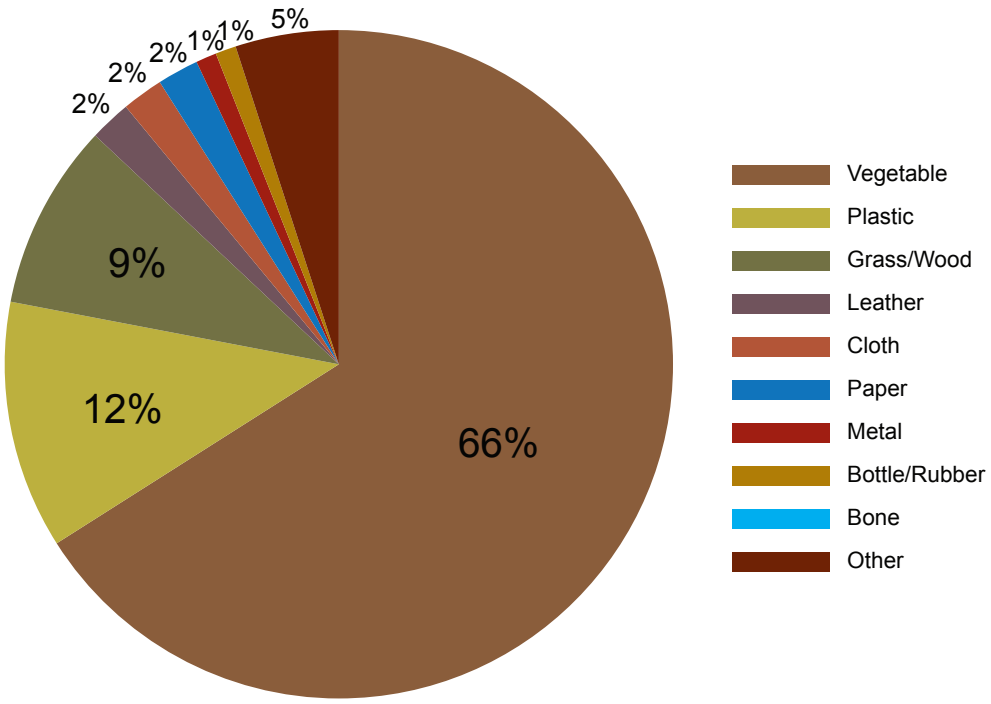


Fig 7: Waste Composition of the Households in Battambang (Illustration by the authors based on COMPED 2011)

2.2. The Planning Process

The planning process of the project can be simplified in 8 steps which are described below in a more detailed way. These steps were followed during the project in order to reach the final goal. The steps are explained in detail, with the help of examples where necessary. These examples were required for a better understanding of the project.

1. Define Objectives	• Given task for the project
2. Problem Identification	• Baseline study • Fieldtrips • Discussion with local students and stakeholders
3. Analyse Chances	• Where can the loops be closed • On which material flows should be focused on
4. Identifiying Starting Points	• Defining where to work on • Identify suitable starting points • Choosing representive areas within the city
5. Using Criteria	• Defining useful criteria • Analyse the areas with criteria
6. Design options	• Design systems regarding to the criteria • Using a tool to find these systems • Discuss advantages and disadvantages
7. Evaluation of feasible System Combination	• Finding possible combinations for the options • Creating a possible overall concept
8. Outlook for Implementation	• Define implementation methods

Fig. 8:
Steps of the Planning Process (Illustration by the authors)

2.2.1. Define Objectives

The objectives of the project were given by the official project description.

> *"Development of an model-like overall concept for water/wastewater with focus on resource recovering and with specific treatment of organic matter"*

2.2.2. Problem Identification

The second step focused on the local current situation. Therefore baseline studies were made with focus on existing programs, data and experiences from other projects. In Cambodia, the group has worked with the local students, made fieldtrips and had meetings with local stakeholders. As a result, impressions of the current situation were gained on-site.

Many problems were found during this step that are not only related to the topic of the project. The following picture shows a collection of discovered problems, which were collected during a group work after a fieldtrip.

Example:

During the first fieldtrip it was found that there is a high amount of plastics received at the composting plant due to the fact that there is no separated collection of organic waste in the city of Battambang. The lack of separated collection makes a separation of plastics and organic waste necessary at the composting plant, which is done by hand. Harmful contents, heat and odour lead to bad-working conditions for the employees.

Fig 9 & 10:
Scenes from the Composting Plant (Photos by the authors)

2.2.3. Analysing Chances

Existing material flows and technical systems were analysed to find points in the current system and ways to use them for an integrated resource management in Battambang.

It was found that the city of Battambang produces a high amount of organic waste. About 66% of the produced waste is organic mater, as shown in the previos pages. This organic fraction can be used in future to produce compost or biogas in centralised or decentralised facilities.

2.2.4. Identifying Starting Points

A city is complex being with complex structures and interrelated problems. Due to the fact that there is no ‘one-fits-all-solution’ for the whole city of Battambang starting points needed to be defined. The fact that the city of Battambang consists out of different typologies within the city gave the opportunity to define them as starting points.

These areas have potential for sustainable improvements and have a representative character for larger parts of the city. Dividing the city into smaller areas made it possible to understand local problems better and to form smaller work packages for the on-going progress of the project (Susana 2011).

Example:

As an example for these areas the inner city and the rural areas can be named. They both have different types of settlements, houses and existing services like waste collection or sewage connection. But at the same time both have a high potential for sustainable improvements e.g. the direct usage of home made compost for agriculture in the rural areas or the treatment of wastewater from the inner city that can be combined with a bio gas plant for the incidental sludge from the waste water treatment plant to produce biogas or electricity.

2.2.5. Using Criteria

To design the different possible systems in the next step further information about the areas was needed. With help of specific criteria, such as existing infrastructure, density of buildings or already working resource management systems, the different areas were analysed. Both profession added criteria which were needed for the in the following steps. The combination of criteria from both profession made it possible to find design options in the next step, that are fitting for technical requirements and to urbanism needs or conditions.

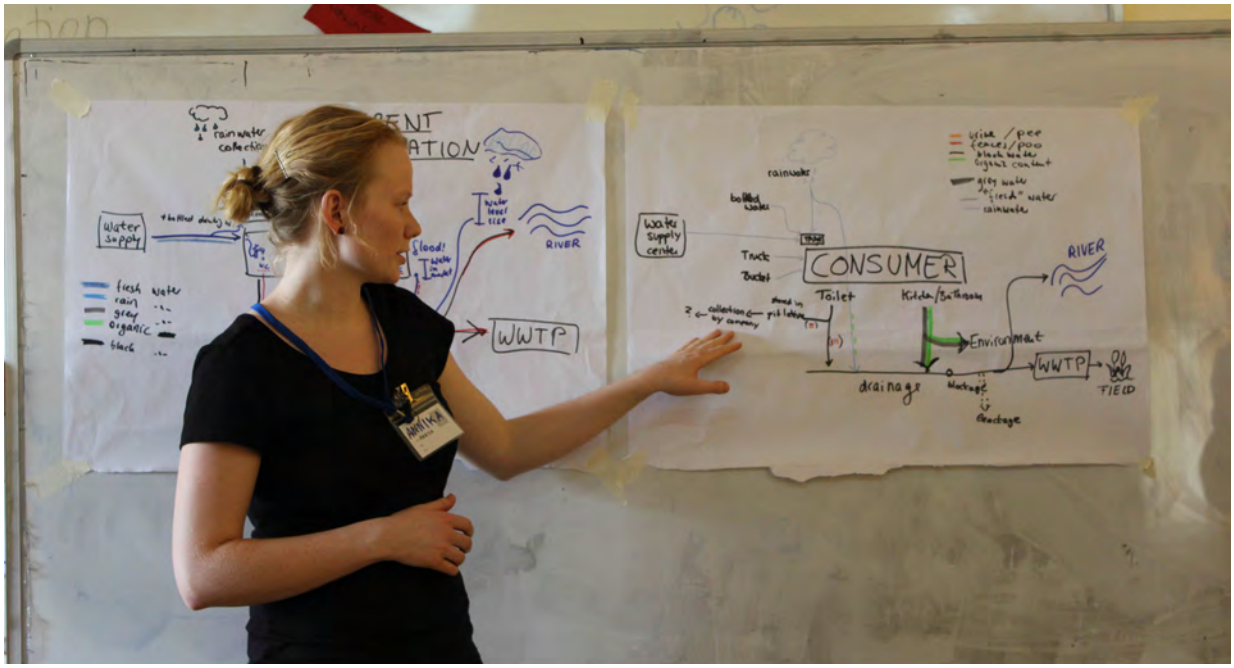


Fig. 11:
A Scene in the Battambang Workshop (Photo by the authors)

The criteria are divided into two topics. Some criteria are more related to the Urban Planning and others are related to the Environmental Engineering. Nevertheless both are interrelated and need to be analysed.

The full list of criteria can be seen in the Appendix 3.

Example:

A high ratio of build up area and land makes decentralised treatment of material flows necessary. If it is low, on-site solutions can be used. The plot size is a criteria which can be used for this decision as well. Other criteria e.g. the occupation of the areas gives information about the income of the citizens in these areas. That in fact is important for the affordability of different technical options.

2.2.6. Design Options

With findings of step 5 the design of technical systems was made, by using the “Compendium of Sanitation Systems and Technologies“ from Swiss Federal Institute of Aquatic Science and Technology (Eawag), as a tool. This tool provides several technical system templates to use different material flows and it points out their advantages, disadvantages and possible combinations. The templates needed to be adapt to the local conditions, cultural habits and possible technical components were chosen. Several possibilities for each area were carefully compared and balanced with advantages and disadvantages.

Example:

This concept poster shows different material flows together with user interfaces, conveyance methods, treatment facilities and possible outcomes of the system for the inner city. Systems like this were made for every area of the city and alternatives were compared. The final systems for each area can be seen in later chapters.

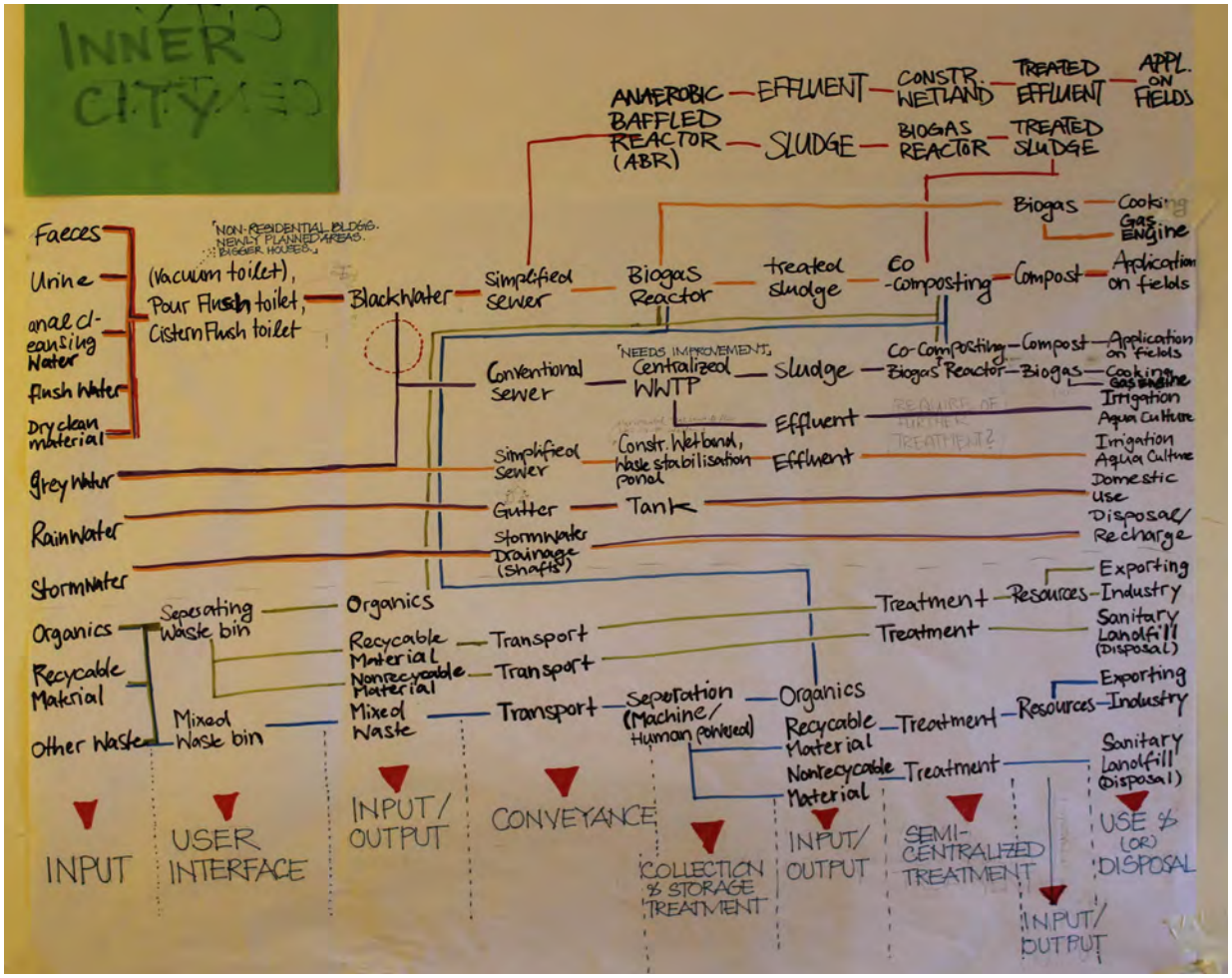


Fig. 12: Concept Poster for Possible Systems (Photo by the authors)

2.2.7. Evaluation of Feasible System Combinations

Each of the designed systems contains the same kind of resources but with different ways to transport or treat them. Comparing these materials flows and finding ways to combine them in one were possible and useful was done in step 6.
After designing several possible systems and combinations the final concept for the city was found.

Example:

An easy example for this is organic waste that can be collected in the inner city, at the non-residential buildings, the outer city and can be treated together in a central composting plant.

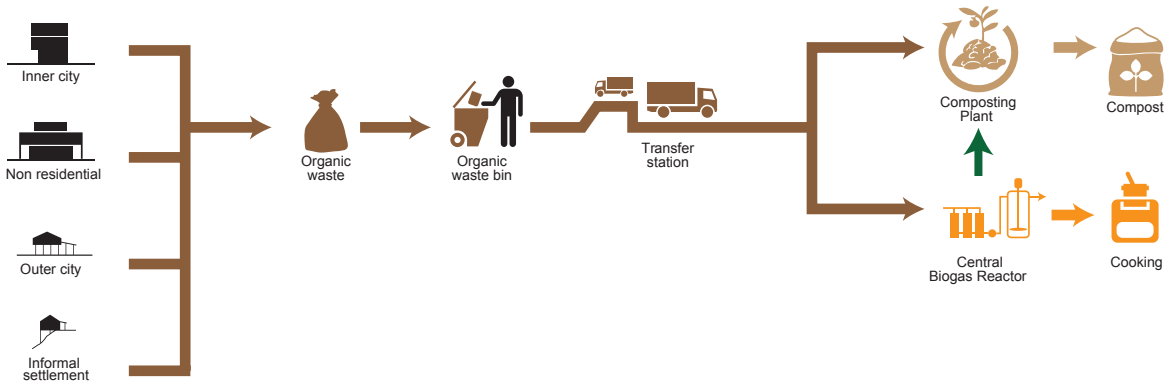


Fig. 13: Detail from the Waste Flow: Organic Waste (Illustration by the authors)

2.2.8. Outlook for Implementation

Due to the short timeframe, this part was not fully covered during the project. The next step would be to set up a strategy for implementing the system on the city scale. Important points for the implementation are the user acceptance, participation and education of the users and the detailed technical design. The legal framework and administrative structures need to be strengthened according to the implementation process and the financial capacity needs to be proven. Further information for the implementation can be found in Chapter 5.

Chapter 3:
CURRENT SITUATION

3. Current Situation

The following chapter describes the current situation in the city of Battambang according to the observations during the workshop and the literature review. The analysis was divided into two main topics: the Social-Spatial Context and the Infrastructural Context. The Social-Spatial Context was analysed according to the legal framework, stakeholders, the socio-cultural and economic factors and the spatial structure of city. The technical infrastructure was analysed with focus on water supply, wastewater management and sanitation as well as the solid waste management. The topics of stormwater, energy supply and transportation were also analysed, but in a more general understanding.

3.1. Socio-Spatial Context

This chapter deals with the current development situation of Battambang within the socio-spatial context. Spatial history and analysis are briefly discussed based on the 2009 Master plan and the workshop conducted at University of Battambang. A research was done over the legal situation, current stakeholders, socio-economic conditions (such as income levels, culture, education etc.) and the future plans. It is critical to be aware of the current situation in order to work on possible systems and improvements.

3.1.1. Legal Frame for Urban Development

3.1.1.1. History in Mind

Legal context in Cambodia is directly connected to Cambodian History. After 1979, Cambodia had to build up the legal system from scratch. The government needs to reorder the existing law system. The regime of Democratic Kampuchea destroyed the whole law system and land cadastre data of Cambodia. This causes many challenges today, on all levels. As Dolores (1993) puts it:

> *"In 1975, the Khmer Rouge destroyed the Cambodian legal system. Legislators, prosecutors, judges, lawyers, and law professors were killed or forced to flee the country. (…) Cambodia now has laws, but they are few and far between. The country has established courts, but most of them are barely functioning. (…) The absence of human and financial resources and the need for redefinition of values at the fundamental levels of political ideology and legal culture hamper reconstruction in these two realms."*

3.1.1.2. Urban Planning Law

The legal framework for planning processes is a must for social, economic and ecological development in Cambodia. The constitution gives the framework for political action. The laws regarding land management, urban planning and construction can be found in the Cambodia Constitution. The main objectives are respecting common and individual interest, developing the towns and cities, as well as the rural areas according to their character. Furthermore, the state is assuring natural and cultural wealth and economic development, as well as the quality of the environment. Independent from the ruling government, legal framework should guarantee sustainable urban development. It gives a clear mandate to the National Government to care for good living conditions. The ownership of land is the basis of the implementation of a working planning system. As a result, it should be organized in a cadastre of ownership, which will be the base for future steps (MLMUPC 1994).

3.1.1.3. Land Title

The Democratic Kampuchea regime destroyed the whole law system as well as land cadastre data of Cambodia. All the land was under the control of the government from 1979 on, which gave the government a huge power and enforced corruption. Changing from a communist system to a capitalist/democratic one, the government needs to guarantee private landownership titles again as stated in the Article 2 of the Law on Land Management, Urban Planning and Constructions (MLMUPC 1994).

There is a Land Law to reconstitute the ownership over immovable property, but most of the Cambodian land wasn´t protected by law or land titles. Thus 30% of the state properties were sold to mostly foreign investors within 18 months, in 2008. The government sold land without basic concerns, even the areas that were considered public or the ones that people were living on. These residents were mostly people

who were displaced during the Khmer Rouge, who returned home, but were left landless one more time. This took place in 2008, and the government reacted in 2010 with a new legal basis. Circular 03 was prepared on 'Resolution of Temporary Settlements on Illegally Occupied Land in the Capital, Municipal and Urban Areas', to handle informal settlements. Today the land registration has a higher priority in governing thus "the state has been able to issue more than two million private land property titles so far" (GIZ 2013).

3.1.1.4. Local Administration and Battambang Master Plan

The first master plan in Cambodia was developed for the Battambang District, by the Municipality of Battambang in collaboration with German development agencies DED and GIZ, since 2003. A digital database was created for the whole district, to analyse the existing situation, give population prognoses and develop future plans for 2020. Although there is no legal binding yet, it is being taken into account by stakeholders for the future plans.

The government is working on a decentralisation process, instead of guiding all the urban development from the Central Government in Phnom Penh. To achieve this, planning competences are given to sub-committees on province and municipality levels. The local expertise is valued, as it can identify and solve local problems better than the central government. The master plan has to be delivered and signed by the central government, which means that the provinces and municipalities still lack planning authority. It is necessary to improve the competences of the local government, in order to deal with the rapid urban development and population growth of ca. 2% per year in Battambang. Planning is left behind the economic dynamics and migration movements, which creates a serious threat for the city and inhabitants. This will lead to an uncontrolled settlement development which will also cause infrastructural difficulties and problems for the quality of life.

3.1.1.5. Building Permissions

A building code guarantees the quality of the building, as well as the health and safety of the inhabitants. The construction market is booming in Cambodia. According to the Planning Department, 994 construction companies got registered in the interval of 2000-2011. Until now, a Sub-Decree on Construction Permit is the main instrument to regulate the building activities in Cambodia. The procedures take up to 658 days to get permission and it costs officially KHR 1295,05 (World Bank 2014).

The building code is developed according to international standards. The considered elements are the construction material, floor area, access, sanitary installations and sewer connection. Although the plans need to be approved by the department, the following process is not being inspected. This creates an inconvenience in the execution of the regulations. Although the buildings might have been planned according to the regulations, there are cases that the construction is not accurate to the plan. The first case of a construction being stopped for not being built in accordance with the permission happened recently in Phnom Penh.

3.1.1.6. Environmental Law

As Peng, Phallack and Menzel (2012) put it, "Cambodia has acknowledged the 'right to a healthy environment' and the importance of the environment because the country has been known as a country that is enriched with natural resources […]." To achieve this general goal, there are legal instruments for environmental protection on a national level. Some examples are the Law on Environmental Protection and Natural Resource Management, Sub-decrees on Water Pollution Control, Solid Waste Management, Laws on Water Resources or Protected Areas (Peng, Phallack & Menzel 2012). As stated in the Article 14 and 16 of Law on Environmental Protection and Natural Resource Management (1996):

> *"The Ministry of Environment shall collaborate with concerned ministries to require the owners or responsible persons of factories, pollution sources, industrial sites, or sites of natural resource development activity: to install or use monitoring equipment, to provide a sample, to prepare or maintain and submit [for] review records and reports" and "shall provide information on its activities, and shall encourage public participation in environmental protection and natural resource management."*

The administration is organized in a very centralized way. For example, the Ministry of Environment needs to take a sample at every discharge point of pollution sources and analyse them in its own laboratory which is located in Phnom Penh (Article 19 and 20, Sub-decree on Water Pollution Control).

The regulations are specified in the Sub-decrees, as seen in the Article 8 of the Sub-decree on Water Pollution Control: “The disposal of solid waste or any garbage or hazardous substances into public water areas or into public drainage system shall be strictly prohibited.” Disposal of the waste has also been regulated by law: “The disposal of waste in public sites or anywhere that is not allowed by the authorities shall be strictly prohibited” (Article 7, sub-decree on Solid waste management).

In general, most of actions that are harmful to the environment are mentioned and prohibited. If someone acts contrary to the environmental laws, there are penalties as paying money, repairing the damage that was made or even going to prison (Chapter 9, Law on Environmental Protection and Natural Resource Management).

Nevertheless there is a gap between the laws and the reality for the citizens. For example, on one side it is prohibited to burn waste because of the harmful emissions, but on the other hand people do not have another option since their waste is not getting collected. Lack of law enforcement is another encouraging factor for delinquency.

3.1.2. Stakeholder Analysis

As explained by Nang et al. (2011), the stakeholders and the main actors can be identified by asking three key questions:

- Who benefits from the use of the resource(s)/targeted schemes?

- Who has rights and responsibilities over the use and management of the targeted resource(s)/ schemes?

- Who controls the targeted schemes or makes decisions that affect the use and status of the resource(s), and who does not?”

Furthermore, the interest of different stakeholders needs to be identified as well as their importance, influence and function. This step is essential to manage the interaction of the different players and guarantee participation of all of them (CLUES 2011).

It is important to analyse all involved players, their interest and their influence in order to make a project work. Stakeholder theory can also deal with conflicts. It leads to cooperation and creates win-win situations for all participants (Donaldson & Preston 1995).

3.1.2.1. Public Institutions

The state is a highly influential stakeholder on urban planning and natural resource management. The government sets laws and the administrative structure regarding urban planning and infrastructure. It also has a mandate to care for good living conditions and public services in Cambodia. The state is a veto player, which means it has the ability to decline a choice being made.

There are decentralised departments of the ministries on provincial and municipal levels. The third level is the commune and Sangkat. Depending on the administrative structure and law, central government directs guidelines to commune level. This creates a weaker position for the City of Battambang although the municipality is the actor that has to face local problems daily. The lack of hierarchical structures and responsibilities causes serious problems with the implementations.

The main interest of the government is to stay in power and the actions of it are strongly shaped by this interest. To fulfil their mandate they have to provide public services, guide the development and guarantee economic growth of Cambodia.

3.1.2.2. Private Sector

Foreign investors sponsor most of the basis investments in Cambodia’s infrastructure. In some cases, investors provide infrastructure for free; accepting the condition to manage and run the system in the long term, which already makes the investment profitable. In these public-private partnership contracts

between the state and the company, it has to be guaranteed that the company completes their task; otherwise it will cause the lack of public services and affect people's daily life.

The main goal of the private companies is to invest in order to gain profit. Furthermore, they want expand their business, implement their technical system and open new markets. As a result, the development of a city cannot be left in the hands of the open market system. In order to control the private investor and provide public welfare, the actions of the private sector need to be regulated by the public institutions.

3.1.2.3. Non-governmental Organizations and Development Aid Agencies

In Cambodia many non-governmental organizations and development aid agencies are players, initiators and donors for progress in planning and resource management. These agencies collect data and compare them with international standards in order to define problems, if the parameter is below or above the average. Furthermore, they monitor and observe to measure the progress. These agencies are working according to their own visions and mandates.

The main interest of these organizations is to accomplish their mandate, mission and vision. But they also strengthen their position and are willing to get influence in the general development of the country. They can work in a more constructive and efficient way with the help of central regulation and encouragements.

3.1.2.4.Households

The errors within the infrastructural systems or the absence of administrative and legal security affect the households the most. These conditions affect their health and are against their basic rights. Inhabitants are in a weak position without a local organisation advocating for their interest.

The neighbourhood has a huge interest in improving the infrastructure and the living conditions. The residents are the direct beneficiaries from a working infrastructural system. The participation of every household is important. In the existing situation, the households have to pay up to 50% of the total infrastructure cost, due to the lack of investment from the government. Therefore saving groups were created to pay for the improvement of living conditions in their neighbourhood.

The households look forward for a working supply service to organize their daily lives and improve their hygiene and health condition. They have a crucial role in the implementation and acceptance of any development project or improvement of the systems.

3.1.3. Society

In the last 20 years, Cambodia has put the efforts in improving the patterns of inequality that affects the country. There had been progress in the increase of children enrolled in school and reducing child mortality, but there are also efforts which had been inadequate. Even if the economic growth is over 6%, most of this growth is still depending on the international donors (Sarath 2011). High levels of corruption in the

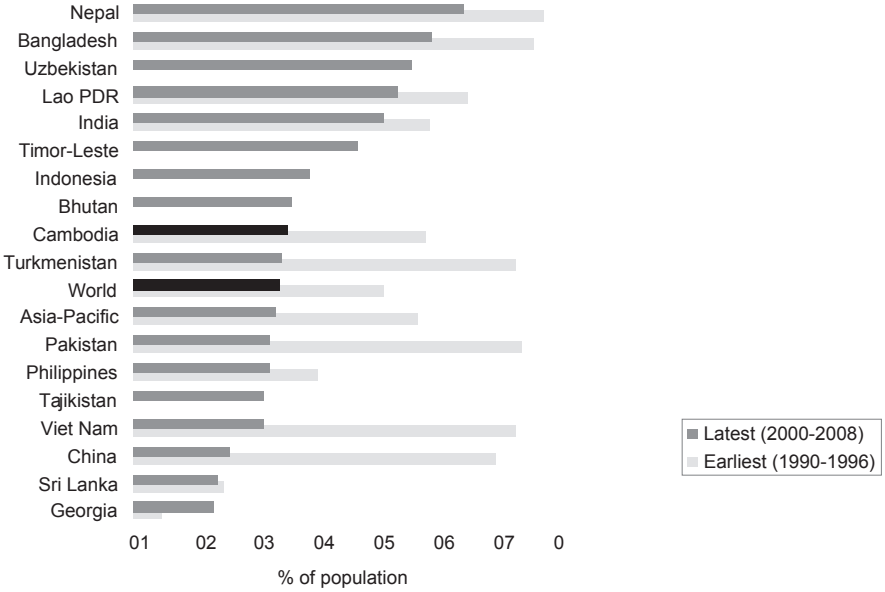


Fig. 14: Population Living in Poverty (2005 PPP$1.25 a day) for Asia and the Pacific (Illustration by the authors based on World Bank 2005)

country have not allowed Cambodia to develop at the same speed as the economic growth. The indicators such as economic growth are not reflecting the unequal distribution of income.

The age structure in Cambodia can be represented by a broad-based pyramid structure. 45 percent of the population is under 20 years of age. It is a society depending on the upcoming generation. The distribution of population reflects recent Cambodian history. The civil war and the Khmer Rouge influence can be seen in the age group of people age 30 to 39, having fewer births and higher child mortality. Around 60 percent are married or living with their partner, which influences the average household size, which is 4.7 persons. While the urban households have 5.0 persons per household, the rural ones have 4.7 persons. There is a tendency of more people living in the urban areas (CDHS 2010).

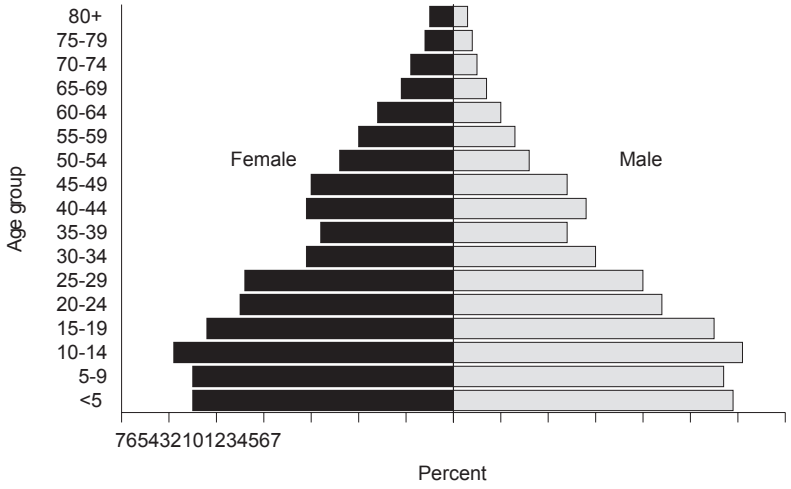


Fig. 15:
Population Pyramid Cambodia, 2010 (Illustration by the authors based on CDHS 2010)

The society in Cambodia is homogeneous according to their race, religion and language. In a population of about 15 million inhabitants, 90% belong to the Khmer ethnicity, 96.9% are Buddhists and 95% speak the official language Khmer. There are small groups, but there is no segregation according to these parameters (Central Intelligence Agency 2013).

The textile industry, agriculture and specially human resources, are seen as the main assets to overcome the Least Developed Country Status in the following years. (Sarath 2011) Most of Cambodians are working in the agricultural sector, 56% of women and 59% of men. Still more women are involved in sales and service sector, while men are more likely to be employed in skilled manual labour. Residence and education level have a direct impact in the type of occupation. In urban areas, people are more likely to work in technical, professional, sales and service sectors, while the ones in rural areas, with lower education level, are mostly working in agriculture (CDHS 2010).

Main Occupation	Women	Men	Both
Armed forces occupations	0.1	1.60	.9
Manager	0.4	1.00	.7
Professionals	2.3	2.82	.5
Technical and associate professionals	0.5	1.41	.0
Clerical supports workers	2.1	3.0	2.6
Service and sales workers	21.6	11.1	16.2
Skilled agricultural, forestry and fishery and fishery workers	42.4	41.0	41.7
Craft and related worker	15.4	13.9	14.6
Plant and machine operators and assemblers	0.3	6.23	.3
Elementary occupations	14.9	18.0	16.5
Other/ Don't know/ Not steated	-	-	-
Total	100	1001	00

Fig. 16:
Employment Population (15-64 years) by Main Coccupation and Gender, 2012 (Illustration by the authors based on CSES 2012)

Compared to other countries in the same income level, Cambodians spend more on health care (CESR 2009), which shows the decline of expend in public health, and the lack of investment in basic needs such as water supply, housing, waste disposal, nutrition, etc. Proper hygienic and sanitation practices can reduce major diseases, but the lack of health, infrastructure are not perceived as a major problem at the present, which shows a lack of commitment of the government and that the population perceive only the economic situation as the main obstacle (TWG 2009).

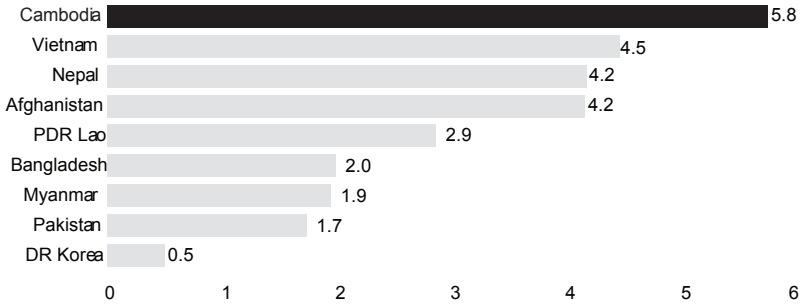


Fig. 17: Private Health Expenditure as % of GDP, Low-income Countries, 2006 (Illustration by the authors based on World Bank 2008)

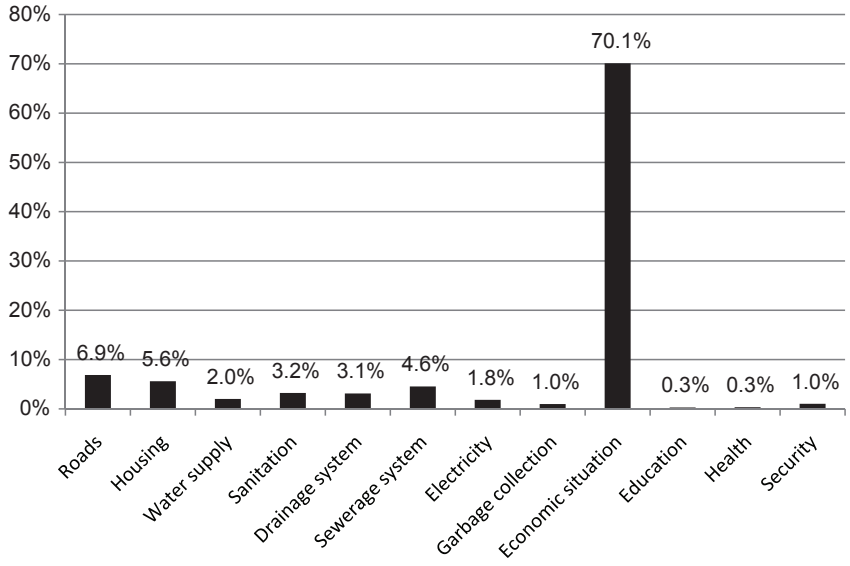


Fig. 18: Major Problems at Battambang, 2009 (Illustration by the authors based on TWG 2009)

Education access plays an important role in the improvement of the life quality, and even if in latest years it had improved, there is still a gap to be improved. Although the majority of Cambodians have not completed primary school, nowadays just 3 % of the girls and boys age 10-14, have never attended school, which shows an improvement in school attainment in new generations. The education level is quite similar between girls and boys; it is after age 14 that the proportion of girls attending school is lower than boys. As expected the attendance to school is higher in urban areas compared to rural areas, especially secondary school (CDHS 2010). There is no adequate education about the influence of sanitation in people's daily life. Education can really make the difference in the change of habits on improving personal and food hygiene and improving the life quality.

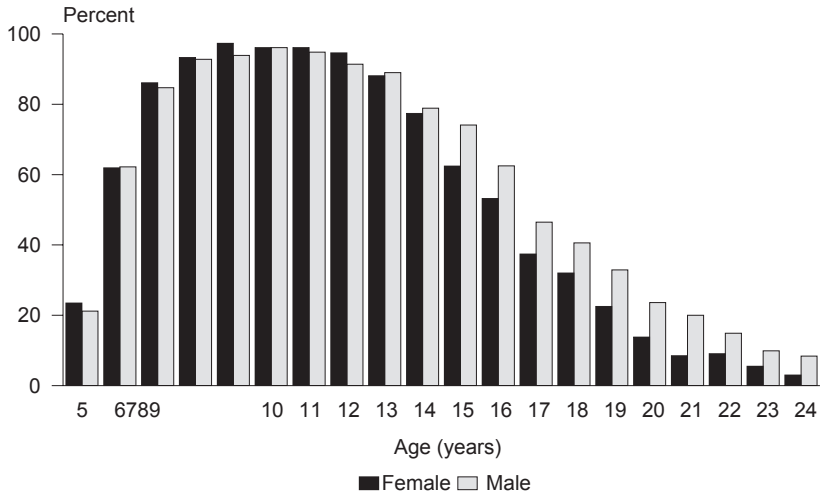


Fig. 19: Age-specific Attendance to School, Cambodia 2010 (Illustration by the authors based on CDHS 2010)

In the case of housing, there is not an adequate policy or legislation that guarantees access to adequate and secure housing. In Battambang 66 informal settlements were identified in the six inner-city sangkats of Battambang Municipality. It means around 2250 households and 10,600 people living in informal settlements, which is the 7.4% of the city's population (TWG 2009). A challenge to the city of Battambang is to reduce the number informal settlements, providing new affordable housing, or improving the current conditions and developing infrastructure to transform them into formal ones.

3.1.4. Spatial Analysis

Battambang developed drastically over a short period of time. From a small fishing village with a meagre population of 2500 inhabitants in the 18th century to a major Thai outpost in the 19th century and then growing into a major regional hub after the independence in 1950's.

The planning structure has undergone significant changes during the French protectorate era when Battambang was returned back to Cambodia in 1907 from the Thai influence. The city's grid pattern layout, well laid streets, drainage facilities is one of the salient features and first steps in the modernization of the city. In 1917, 3 main streets were constructed parallel to the Sangker River along with two bridges connecting perpendicularly on both sides. Rectangular block layouts were planned on the east side of the river (Ross 2003). In 1926, a second urban development plan was initiated where a railway line connecting Phnom Penh was constructed and eventually the city started extending towards the west side with its axis oriented on the railway station. French colony influenced the city's architecture, nowadays more than 800 examples of French colonial architecture can be found in the inner city (Roy 2008). Famous market places like PsarNath, a landmark and a good example of an Art deco structure (Goad 2012, p.6) and BoeungChuk, are still active areas in the city.

Urban Development Plan 1907

Urban Development Plan 1926

Urban Development Plan 1970

Fig. 20: Battambang Urban Development Plans (Koditek 2007)

After the construction of the railway in 1926, rectangular grids were planned with shop houses, which can still be seen today. The diagonal streets which overlap with these grids form squares and axes. More covered markets were built after the independence in 1954 throughout the city. In the northern part, more rectangular grids were planned and the BoeungChuk Market was built in order to serve these areas (Biljard 2011). Between the years 1953-1970, Battambang was developed as an industrial and commercial hub of the province. Under the modernization program of the Prince Sihanouk, many important infrastructure and public facilities were built in the 1960's. Involvement of Chinese and French investors resulted in the setting up of many textile garment factories (Goad 2012, p.6).

There are some green spaces through the city, especially the development around the Sangker River. Along them, public activities take place such as exercising, playing sports or jogging. PrekMohatep and Banyan Tree Garden are the existing gardens located in north and south of the old town (Battambang Municipality 2009, p.55). These green spaces contribute to the historical urban structure of the city. Un-

fortunately due to uncontrolled extension of built up areas, the typical landscape around the town is at risk (Battambang Municipality 2009, p.55).

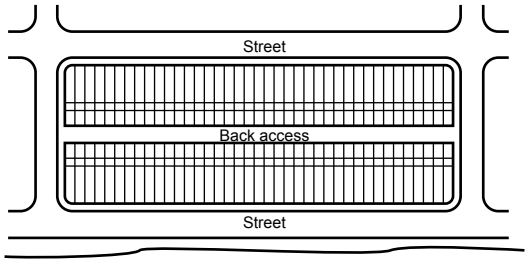


Fig. 21:
Grid Street Structure & Plots (Koditek 2007)

The development patterns in the outer and rural areas are different in terms of population and densities. The informal settlements developed in the last years, have grown up largely. In 1979 at the end of the Pol Pot era and then again in 1993 during the repatriation from the Thai border, migration into these settlements were the major factors (Goad 2012). The location in the city can vary, but normally are located along roads, railways and canal edges, or in public areas as Pagodas (Goad 2012).

Transportation has also played an important role in the development of the city. The existing transportation systems in the city are a result of different socio-economic factors. The modernization programs in the earlier times, introduction of railway lines and airport facilities redefined the land use patterns of the city. An airport and a university were built in the east side, which was well connected to the town centre along the west bank by a bridge in 1968 (Bijlard 2011). The area where the airport was located was found to be not suitable for future flights due to its close proximity to the city centre. Noise and pollution problems would prove to be harmful to the overall urban quality of the neighbouring residential and commercial areas.

Battambang's existing road network is planned and functional especially in the city centre. Most of the roads planned in the past have not yet been constructed. Because of this, many main important links are missing making the already planned grid system incomplete. Road networks in the sub urban areas were also found to be insufficient. The national highways meet directly within the inner city areas causing traffic congestions. Some roads are poorly maintained: with potholes, absence of proper drainage systems and in some locations narrow. There is a requirement for good road infrastructure especially in the extension of settlement areas in the North, West and East in order to catch up with the fast urbanization process (Battambang Municipality 2009, p.64).

Battambang has a diverse land use pattern for agriculture such as rice fields, fruit plantations, vegetable gardens and orchards. "Agriculture is an important economic basis, not only for the local population but also for the tourism sector" (Battambang Municipality 2009, p.59). They are mainly tied with the rural areas and partly connected to the outer city areas. The agriculture zones adjacent to the inner and outer city areas are facing high development pressure due to increase in land prices and potential building construction. The agricultural fields are an important part of the city landscape and they portray the Cambodian tradition and culture (Battambang Municipality 2009, p.59).

Future Plans

As the city faces a fast paced urbanization, the municipality had developed strategic plans to catch up with the infrastructural development in order to support the growth of the city. The main goal is the improvement of living conditions of the inhabitants.

Informal settlements are still a major concern for the city. The municipality has a program underway to solve this issue by developing strategies for different cases, assuring a land title to the ones in areas that don't affect the future infrastructure plans, but the ones in high-risk areas may be relocated.

For new developed areas is intended to establish Detailed Development Plans (DDP) prior the construction. In the case of agricultural sector, there is a demand for planning and preserving agricultural areas from sporadic development. Plans are being made to make irrigation systems available in all parts of the city especially the planned reserved areas (Battambang Municipality 2009, pp.88-90). There are different concepts planned, but still the competences of the municipality should be reinforced in order to accomplish these plans.

3.2. Infrastructural Context

This chapter provides an overview of the current state of technical infrastructure in terms of public supply, services, technologies and management in Battambang. Problems and risks will be discussed from an interdisciplinary perspective.

Since there is a dynamic development due to urbanisation, land speculation and economic boom, a lot of research has been done considering infrastructure. Several reports, projects, master thesis´, interviews and especially the experiences of participated students on the excursions meanwhile the iReBa- project are contributing to this section.

The city of Battambang is challenged by capacity building of technical infrastructure. The more the city grows the more urgent is the need for action in sectors such as water- and waste management including sanitation systems, road network, energy supply and so forth. The main aim is to enhance the socio-economic situation.

“It is a race against time” (Koditek 2007). On the one hand ministries, provincial departments and donor organisations of several countries initiated detailed sector planning. The implementation of public supply and infrastructure projects is running as well. The Cambodian government has given high priority to infrastructure construction and is confronted with several complications. On the other hand the uncertain legal framework, responsibilities in spatial- and urban planning and increasingly high land prizes are hindering proper foresighted planning for public facilities and infrastructure (Koditek 2007). Nevertheless, the process of emerging infrastructure development is promising due to the encouragement of stakeholders and the projects of numerous organisations. Generally, planning and implementation of infrastructure is a complex topic which requires multidisciplinary methods, instead of an isolated consideration due to sustainability.

3.2.1.Water

3.2.1.1. Water Supply

Most of the people in Battambang get their water for domestic use from several sources. First of all there is the water supply centre run by the department of water authority. It serves less than 70 % of the urban population of Battambang, especially rural areas and the informal settlements are not served by piped water (National Commitee for Sub-National Democratic Development 2009). Interviews and field trips added up to that rain water and river water mostly from the Sangker River are further sources for water. Unfortunately there are no official reports about the quality of the water available. During fieldtrips it was recognized that the water of the water supply centre is not drinkable which does not have to be necessary, but it should have bathing water quality as the people use it for showering. The treatment from the water supply work includes sedimentation, flocculation and filtration. As the water is not drinkable afterwards, many people buy drinking water from shops or truck sellers. It is purified by private companies through UV-light radiation, reverse osmosis or filtration.

According to information of the Cambodian students the price for one cubic metre water from the network of the waterworks are 1500 Riel, which is approved by the Battambang Krong Data Book 2009. If it is resold, it can be more expensive, as for example at the Beoung Chuk Market, where it is at least three times more expensive according to the information given by the assistant of the owner. It is problematic that some people cannot afford to buy drinking water in bottles and thus have no chance to get water with a sufficient quality to drink and prepare food with, which can cause diseases.

Besides the insufficient quality of water for some parts of Battambang´s population, there is a shortage during the dry season as the station’s water comes from the Sangker River (Battambang Municipality 2014). Due to these problems, the municipality initiated a cooperation with China in 2005 and with the Japan International Cooperation Agency in 2013 (Japan International Cooperation Agency 2014).

“The Project for Expansion of Water Supply System will construct Intake and Raw Water Transmission Facility, Conveyance Facility, Water Treatment Facility, Distribution Facility, and Distribution Network, that would increase the water supply capacity […] in Battambang by 338% (from 8,132 m3/day to 27,518 m3/day). Consequently, by 2019, about 84.4 % of the people in both provincial cities (Battambang and Kampong Cham) will have access to safe water (59,000 in Kampong Cham and 127,000 in Battambang). In

addition to the construction of the facilities, equipment for water quality analysis, materials for service connections, and technical assistance for operation and maintenance of the treatment facility will be provided to ensure a comprehensive and long-term water supply in the target communities" (Japan International Cooperation Agency 2014).

Till the project achieves its goals the people of Battambang are on their own to store water in tanks, as long as it is sufficient and to boil or filter it, if it is not drinkable. (National Commitee for Sub-National Democratic Development 2009).

3.2.1.2. Sanitation and Wastewater

Beginning at the source of the wastewater, the inhabitants of Battambang use different toilets. Most common are squatting pans combined with pour flush water, but also western style flushing toilets exist, especially in the inner city. Simple pit latrines are common in the rural areas around the city centre. Furthermore there are a few people practicing open defecation.

The toilets are mostly used by one household, but in the informal settlements for example, also shared toilets are in use, as it is said in the interviews from "Untersuchung von Möglichkeiten einer Implementierung eines integrierten Sanitärsystems unter sozial-ökonomischen und kulturellen Gesichtspunkten in Battambang, Kambodscha" by Seyfarth (2013). So far, public toilets do not exist.

As different as the types of toilets are, as different is the further collection and treatment of the produced wastewater. Only 10% of the city is connected to the sewer system leading to the Wastewater Treatment Plant, located outside the city in Chamkar Samraong Sangkat (ADB 2010). This piped network carries both, storm water and sewage water with diameters ranging from 400 to 1500 mm (ADB 2012). As it was built in the colonial period and not well-maintained, there are several leakages and it is blocked at several points as you can see in the following map.

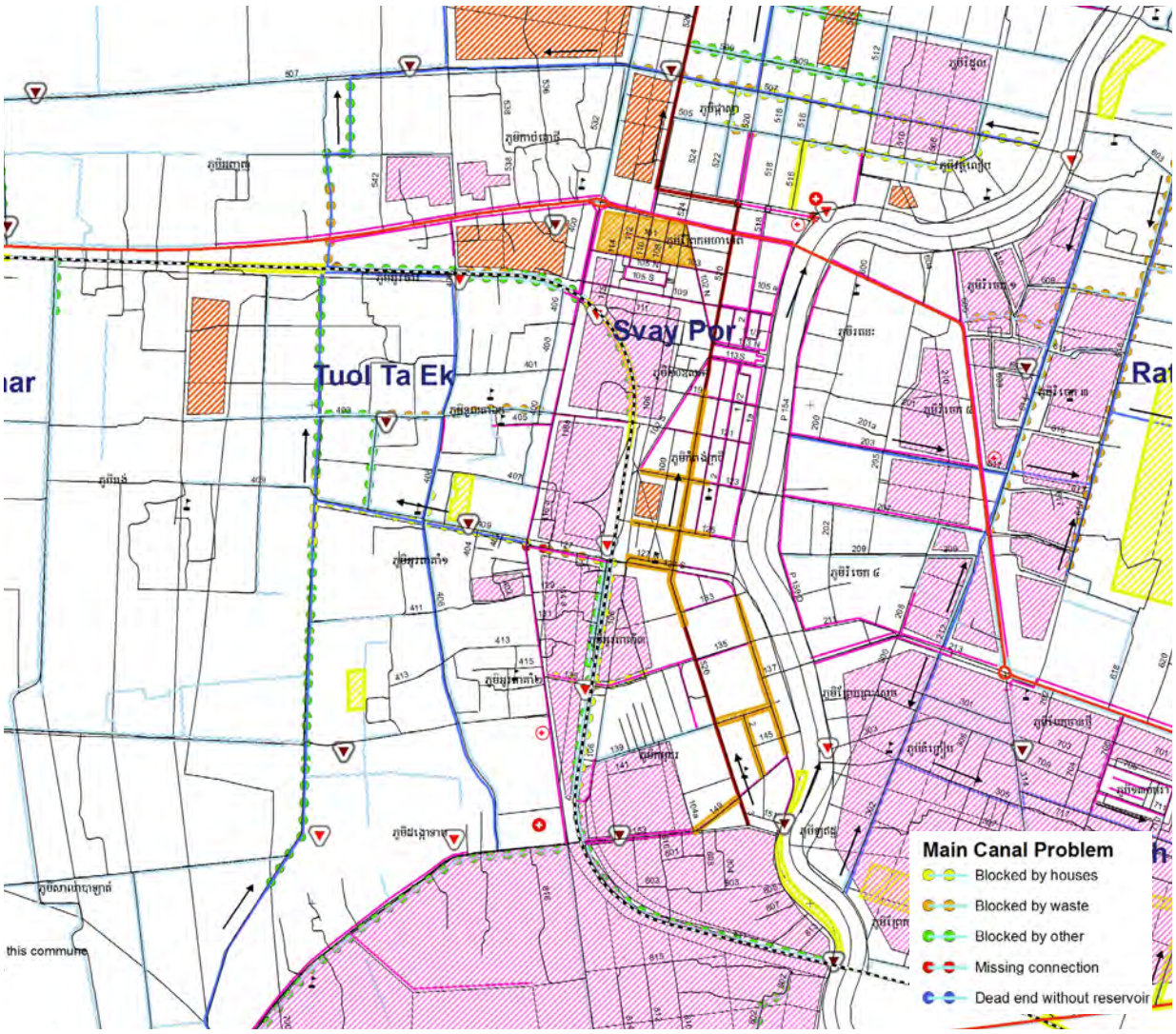


Fig. 22: Map of pipe network and related problems, sangkat Svay Por (CDIA & GIZ 2010)

An excursion to the Wastewater Treatment Plant showed that the diameters of the technical equipment as the pump station of the WWTP are not sufficient according to the amount of wastewater that arrives at the WWTP.

During the heavy rain periods, around 60% of the incurring wastewater is discharged to the Sangker River without any treatment (ADB 2012). The outlet of the WWTP leads to the surrounding rice paddies, although the quality of the treated wastewater does not seem to be sufficient for irrigation. According to information from COMPED in 2013, the treatment consists of sedimentation ponds, where also plastic bags are taken out, polishing ponds and vegetation ponds. Problematic is the low maintenance and operation (ADB 2012). The sludge for example has never been removed since the construction of the WWTP in 1994 (COMPED 2013). As a result, the reactions of the student group during our workshop were quite strong. The Cambodian students regarded the WWTP as not useful for Battambang and asked why the government does not do anything about this situation. The Department of Public Works and Transportation is responsible for the WWTP. As the sewage system is just installed on the western side of the river, there is a second WWTP planned for the eastern side of the city (ADB 2012).

Those households that are not connected to the piped sewer system rely on septic tanks or pit latrines. Vacuum trucks empty septic tanks but the liquid portion of the excreta from the pit latrines can seep into the soil ground as some walls are perforated (ADB 2010). It is not clear what happens with the sludge of the septic tank as this is done by a private company. As a result of some personal interviews, it was learned that it is put on surrounding fields in some cases. The greywater produced by the households is either discharged on the streets, surrounding fields or the piped sewer system. In fact, it always depends on existing options and where greywater is emerging. In chapter 4 and 5 this will be discussed more in detail.

The negative effects caused by this wastewater management are various and chances are being missed. Hygienic standards are not adhered when wastewater is distributed on the rice fields which serve the city with food. Additionally, it is discharged into the Sangker River where the water supply work and some low-income households are taking the water from. This can cause diarrhoea and other diseases. The environment is polluted with excreta and greywater as it is poured on the streets or the fields. Besides, the excreta are seeking into the soil ground through perforated walls of latrines.

In addition to this possible resources for fertilizer, compost, biogas production and water for irrigation are lost, as the material flows are either not collected and/or not treated.

Furthermore there is no adequate implementation of existing regulations for industrial wastewater although there is a noodle production company existing. In general you can say that there are a lot of regulation existing to protect the environment like it is mentioned in the environmental law, but the implementation of these laws is missing as well as the supervision of these regulations.

3.2.1.3. Stormwater

In the rainy season the area of Battambang receives enormously amounts of water due to heavy rainfalls and water that comes with the river from upstream regions. The worst flooding is mostly on the eastern side of the Sangker River in Preak Preah Sdach (ADB 2010). Here the flooding is caused directly by the overflowing river. In other parts of the city storm water is flowing back from the river through the pipes and into the households, for example at Beoung Chuk market. During fieldtrips blocked drainage pipes were seen and houses that are constructed in natural water flowing ways. This in fact prevents water from flowing back into the river after rainfalls so that it stays in parts of the city. The Cambodian students confirmed that the flooding level during the rainy season increased over the last years. The latest map found from 2010, probably considering the flood of 2009, points out the areas concerned depending on the period of time (see Figure 21). Consequently, there is an urgent need for action in flood management. Unfortunately no detailed information was found, if there are any projects and activities. Even though this was not content of the iReBa-project, the flooding needs to be considered in nearly every single part of the project.

The problems related to storm water cannot be fully solved only by the city of Battambang. A regional or countrywide storm water management is needed with recreated natural inundation areas. A first step would be to open the blocked drains and to separate rain water from sewage in the future (ADB 2010).

Fig. 23:
Various Water Infrastructure Elements in Battambang (Photos by the authors):

WWTP, Sewage Pipe Leakage, Water Treatment Pond, Pumping Station for the Water Supply Centre, Household Pump (clockwise)

The graphic illustrates the current water supply system and wastewater system in Battambang. It is divided into the sections consumption, used resources, collection/ transport, treatment, disposal, resource, treatment/ collection/ transport. To start with the water supply there are several options. One is the water supply centre, so the waterworks of Battambang. Unfortunately less than 70% of the population of Battambang are connected to this system. The quality of the treated water does not have drinking water quality. This is why most of the people buy bottled water. However, not all inhabitants can afford to buy it. The drinking water is treated by reverse osmosis, UV radiation or filtering referring to the different companies that offer the bottled drinking water.

Another source of fresh water is rain water or water from water supply trucks. After the "consumer" uses the water or eats food, he "produces" human waste like urine, faeces and used resources like greywater. These "products" have to be discharged somewhere. The human waste from the toilet goes either to the central sewage system or septic tanks or simple latrines. As there are leakages in the sewage system and some walls of septic tanks or latrines that are perforated, excreta can seek into the soil ground and pollute groundwater. The greywater from some parts of the city is also going to the central sewage system, in other parts the people just pour it to the streets or the fields due to the lack of another option. The now mixed wastewater should be cleaned in the wastewater treatment plant, but as it could be observed it is not working properly. This is the reason why it is problematic if it is discharged on the fields, because the fields are also the source for the food. A similar problematic can be observed at the Sangker river. Wastewater is discharged into it through the sewage system or directly from people living at the river side, although the water for the water supply is also taken from there and the people in the rural areas are also using it for washing themselves, for example. In general, although the illustration looks like a circle, there are gaps in the loop and resources are lost or could be used in a more valuable way.

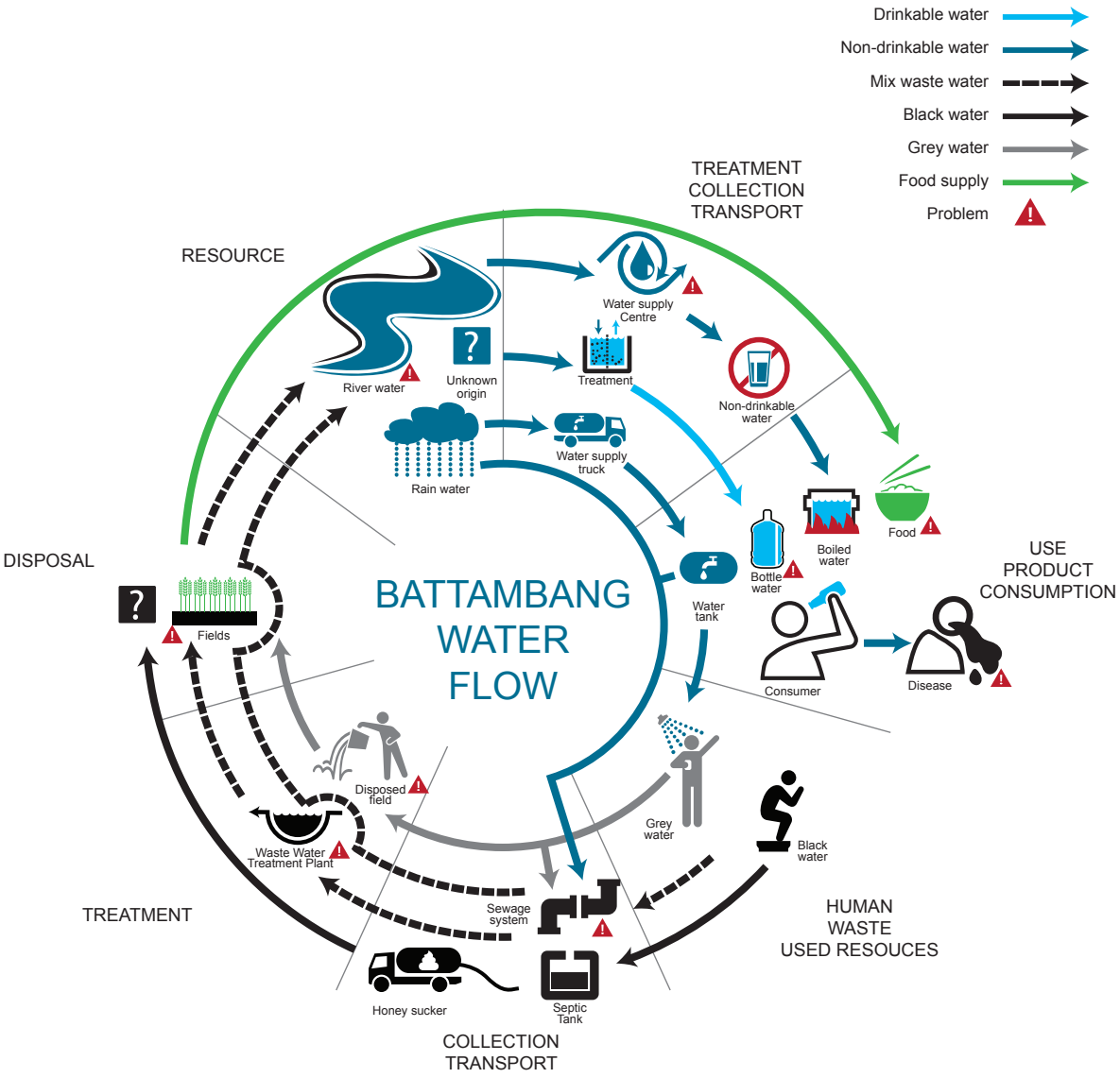


Fig. 24:
Battambang Water Flow Diagram (Illustration by the authors)

3.2.2. Solid Waste

The streets of Battambang are partly characterised by open dumped waste, wrapped waste and small plastic bags carried throughout the streets to the outer city or rural area until it is caught, especially next to the roads. In general streets are shaped by all kinds of plastics. A common practice for people is to burn or dump their waste near the source location. The smallest sangkat Svay Por is the central business district of the city. Most dumping and burning locations are placed here. Five out of 15 random dumping locations and three random burning locations out of eleven in total are situated in this Sangkat, even though it´s the smallest (ADB 2010).

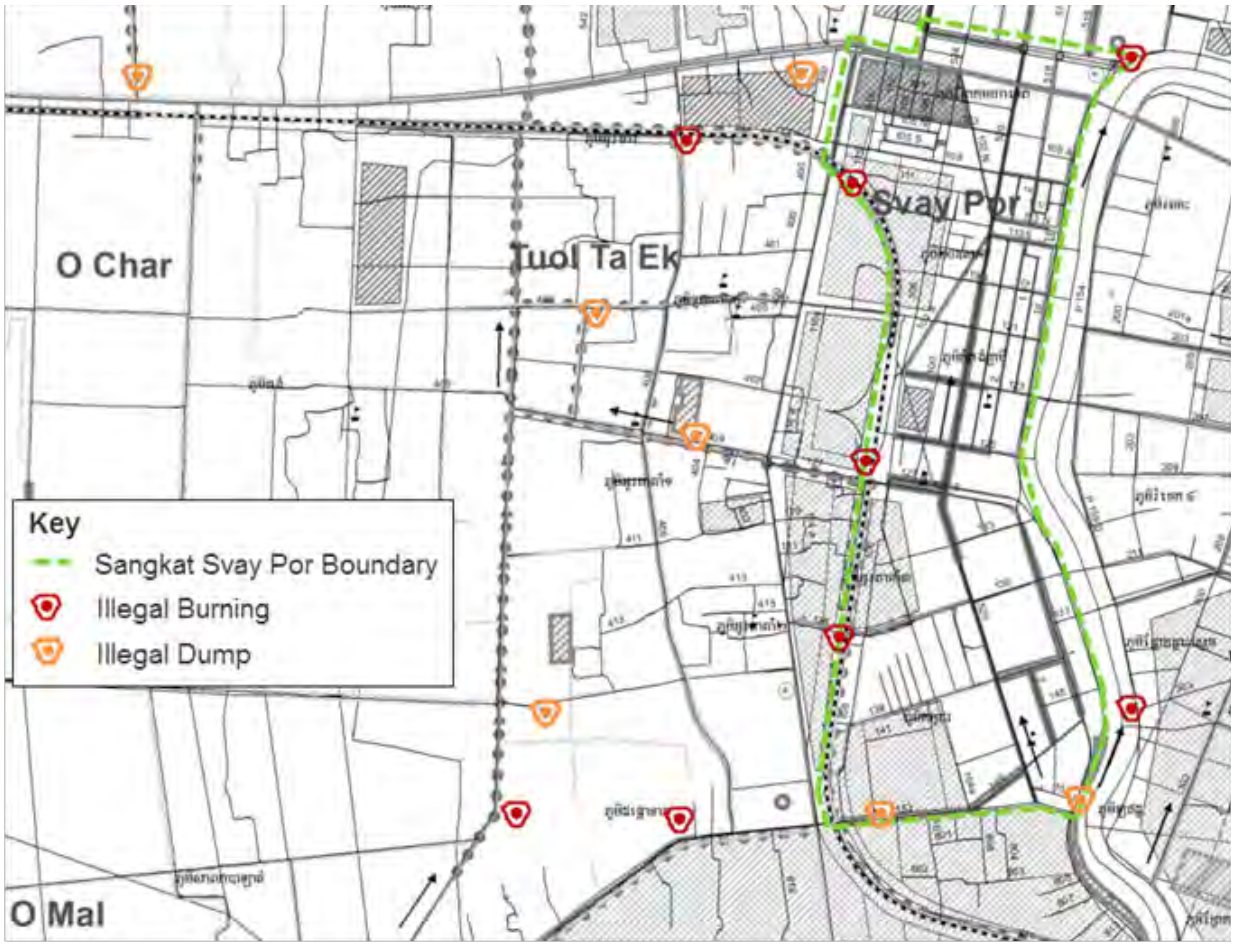


Fig. 25: Map of Illegal Burnings and Dumps of City Centre, sangkat Svay Por (CDIA & GIZ 2010)

In 2009 the Municipality of Battambang developed a map considering sewage and drainage system, flooding areas, canal problems, education/health as well as solid waste. They determined illegal- dumping and burning spots throughout the city. Figure 24 shows a modified extract of those spots and the boundary of the Sangkat Svay Por. It is quite outstanding that there are not as many illegal dumps as stated in ADB (2010), which is probably due to subjective observation, different definitions or quick development of main illegal dumps and burnings. Major burning locations occure along the rail way, where very poor settlements are situated. Illegal dumping happens in the south and west of Svay por as well as in other areas, not illustrated on this zoom in. It is strictly forbidden to burn or dump waste on not designated areas as there is a punishment of 25 US-Dollar (ADB 2010). During the stay the project group realised a big diversity of odours each day. Either temporarally dumped organics around the markets or the pervading smoke of burned waste mostly next to main roads.

As the project group experienced the absence of waste bins or collection points in Battambang, it confirms to the major concerns of the villagers questioned in the report COMPED, 2009. One of the surveys' findings is that citizens averagely generate 0,60 kg waste per day and person. In total the Economic and Social Commission for Asia and the Pacific (ESCAP) determined 147 tonnes of waste per day for the whole city of Battambang (250.000 inhabitants), which proofs the rough accuracy of numbers (Economic and Social Commission for Asia and the Pacific 2012). Several disposal practices e.g. burning, empty spaces near the houses, inside the houses, next to the roads or in dustbins show that there is no satisfying environmental awareness or common practice, respectively. Due to poverty waste disposal is obviously not the biggest concern of the people. The survey COMPED, 2009 confirms that prior needs at community level are water issues like supply, drainage or sanitation. Never the less there seems to be

strong support for community based waste management on municipal and sangkat level. Pilot projects were already initiated (ADB 2010).

The provincial referral hospital has an incinerator, which is certainly too small for all kinds of items. Sharp waste, such as syringes are burned in another one which is located outside the city and is used from other clinics as well. There is no current information regarding to an initiated project which promises a new incinerator for the hospital. General waste is disposed for collection service and liquids are discharged into combined sewer or stored in bottles (ADB 2010).

The private enterprise CINTRI provides the service of waste collection and disposal in several cities. An 80 year contract with the municipality is the basis of the service delivery in Battambang. Despite the extremely long contract period, the contract does not contain accurate performance descriptions. Considering this long lasting contract there are obviously no leverages by the municipality to motivate the private operator to continually improve its operations and providing service due to enhancements of living conditions and environment. Still, according to their website, this is one of CINTRI´s formulated goals (CINTRI 2011).

In general the citizens of Battambang as well as the hospitals are certainly not satisfied regarding waste collection service. They address their complaints to the municipality who seems to be not in the position to improve the service-delivery. The contract states that CINTRI has to have enough staff and vehicles to provide the waste management service in all ten Sangkats. The waste collection is accomplished by seven compactor trucks, which are collecting every day between 4 a.m. and 1 p.m depending on location. The vehicles have different sizes. The biggest one has a capacity of 8 tons, while the smallest loads 4 tons. In fact the trucks do not have chambers to collect different kinds of waste separately. On household level mixed waste, except valuable materials e.g. metal and plastic bottles, is collected in dustbins or different kind of baskets prepared for pick-up-service.

Due to low accessibility in terms of narrow streets, flooding, the availability of trucks and other circumstances like low hanging power lines, only 25% of the households are being reached by the contractor. In fact there are lots of people who aren't able to afford the waste collection service. The charging fee for households ranges from 0,5 US-Dollar up to 10 US-Dollar, while a hotel pays around 50 US-Dollar and a business up to 80 US-Dollar per month (COMPED 2009).

One of the biggest challenges for the operator is to run the service during the rainy season where large parts of the city are flooded. This is especially true when the important roads to the dump site and composting plant are blocked. In this case waste is piled up nearby the dumpsite which extends by two hectare and is located seven kilometres north of the city centre. The official municipal landfill has been established in 2009 and is already running out of capacity. Four basins have been constructed measuring 40x40m in a square and a depth of 4 meters (COMPED 2009).

The lack of a drainage system as well as the poor managed landfill in general is conducting to a high level of pollution in the groundwater. In the rainy season there is even more leachate that infiltrates into the groundwater. Apart from that, the surface run off, which mainly distributes all different kinds of waste,

Fig. 26:
Dumpsite Battambang: Housing of Waste Pickers, Collection Vehicle Surrounded by Waste Pickers, Compactor Vehicle, Dumping Cell with Standing Waste (left to right) (Photo by the authors)

is heading into nearby agriculture. Additionally, due to the burning waste toxic fumes are causing health problems. Depending on the wind direction the emission gases are carried to residential areas around.

The shape of the landfill is alarming and calls for urgent action in terms of limited capacity and environmentally issues. The municipality is monitoring the CINTRI, who empties 15 truckloads of waste per day at the landfill (COMPED 2009). As Mr. Bora confirmed an employee of the department of environment is supervising once a week if the waste is discharged at the right spot (Mr Bora 2014, pers. comm., 4 March). Anyway, as the project group experienced the sight of the landfill there was no proper dumping system identifiable. Figure 25 shows a typical situation of a discharging collection vehicle, while several waste pickers are searching for valuable materials. On the right hand site at the edge to a basin you can see a compactor vehicle, which is used to compress the waste. The report by COMPED (2009) states that the cells, which were constructed by the municipality are certainly too deep to enter with this machine, which also contributes to the fact that the dump is quickly filling up.

As in many other developing countries the informal recycling by waste pickers is a common practice. It does not only cause problems in terms of increasing collection fees through disturbed waste in the streets but also plays a significant role in protecting the environment and reducing poverty (Martin Medina 2008). There are around 20 recycling shops spread all over Battambang (COMPED 2009). Those are collecting, wrapping and transferring materials such as plastic bottles, cardboards, glass, aluminium cans or metal in general normally to Thailand or Vietnam. Hence, the informal waste sector is also seen as a sub area of waste management (Jürgen Stäudel 2010). Waste picking for recyclables is not limited to the streets.

The report of COMPED (2009) estimated that approx. 350-400 people in Battambang earn their main income with these activities. Around 50 people, of which 15 are children, work and live at the dump. The average income of those people is estimated by around 1 - 1,25 US-Dollar per day. Compared to that, better organized waste pickers with adequate vehicles can earn up to ten times as much as an average waste picker (COMPED 2009). To get an impression what it is like to work as a waste picker at the dumpsite in the capital of Cambodia Phnom Penh, see www.wastepicker.de.

According to Timo Schirmer's master thesis "Design and assessment of a resource-oriented sanitation system for the city of Battambang, Cambodia", the biggest issue concerning the social aspects of this informal waste sector is child labour. A lot of children are involved as soon as they are old enough to contribute to collecting valuables and help their family.

In order to improve their living- and working conditions as well as to provide extra education to the children, the project "Soziales Abfallzentrum Battambang" (SAB) (Social Waste Management Centre Battambang) has been initiated in 2008. It is a showcase project which demonstrates lots of sustainable synergy effects. One of the greatest social impacts is to encourage the children to increase their chances for a

Fig. 27:
Waste Pickers at Dumpsite (TKG 2010)

better future. The community building is located on the dumpsite and is part of the already mentioned compost plant operated by COMPED.

Waste pickers can use sanitary facilities as well as the cooking place which is operating with biogas out of two simplified underground concrete-digester.

Fig. 28:
Biogas Plant Next to the Community Building (Photo by the authors): Outlet (down left), Inlet (upper right)

The delivery to the compost plant is done by COMPED trucks. Every day the plant receives three truck-loads with each four tons of market waste (Boeung Chuk Market). The manual separation of the organic waste which is estimated by 65% (Mr Bora 2014, pers. comm., 4 March) is done by two workers. Market waste generally consists beside the major part of organics (86.5 %) of plastics, clothes, leather and metal (9.5 %) (COMPED 2009). Differences are probably caused by season. However, by now the only machine for sorting the waste at the compost plant is a front loader for moving the piles of waste The inorganics are pushed off to the dump site which begins at the edge of the concrete foundation.

Mr. Bora assured that it is planned to upgrade to a separation machine soon, which will be organised by the Thuringian-Cambodian-Association (TKG). Another essential and quiet new tool is a thermometer for supervising the composting piles. As Mr. Bora checked the temperature of a pile the thermometer pointed to 70°C, which indicates a very well running process. Mr. Stäudel commented that earlier research on composting in Cambodia pointed out that weight reduction of organic waste was determined by 90 % to the residue of compost (Mr J Stäudel 2014, pers. comm., 4 March). Compared to the report of COMPED, 2009, which determined seven tons of compost per month, Mr. Bora said that the plant generates three to four tonnes of compost in a month (Mr Bora 2014, pers.comm., 4 March). Even if these numbers are not accurate due to the lack of monitoring technologies, the plant is running very well and in particular independently by COMPED. Furthermore the project group noticed that the general demand of compost is bigger than the supply. The compost costs just increased from 75 to 100 US-Dollar per ton but there is also the chance for free trial (Mr Bora 2014, pers. comm., 4 March).

Considering the composition of domestic waste and the major part of organics (60-70 %), the potentials of substantial and energetic utilisation is very high. Hence, there is a need for separation into organics and inorganics to supply environmental friendly fertiliser through composting. Nearly 50 % of all households depending on either more urban or rural location, consider the separation of organics (ADB 2010). Due to the tropic climate, methane production through biogas plants is a suitable option to provide gas for energy purposes and especially for cooking. Several programmes and projects, especially in rural areas, have already been initiated and run successfully. In the Energy supply section this will be discussed more in detail. The high potential of methane generation using the huge amount of rice husks or vegetables emerging in the province of Battambang, needs to be considered more.

The Battambang waste flow illustrates the current situation of material flows of solid waste, especially the occurring gaps and problems. Even though, the diagram represents a cycle, there are lots of harms and their interrelations visualized. The Flow chart is separated into seven sections e.g. storage, collection and transport, pre- treatment, etcetera and concentrates on the waste flow of market- and domestic waste. It needs to be mentioned that the market waste belongs only to the Boeung Chuk Market which is an exception due to the collection, separation and composting by COMPED. Even though the manual separation is a little problematic, this is exemplary for sustainable resource management.

On the other hand there is the conventional waste collection and disposal at the inadequate dump site, accomplished by CINTRI. Open dumped waste and burned waste are producing high pollution of ground water, soil and the atmosphere, which badly affects health and environment. Uncollected solid waste attracts animals and insects, which are potential carriers of enteric pathogens and diseases (ADB 2010). The open disposal of organics, which is the main part of generated waste, is problematic due to uncontrolled methane emissions and toxic fumes through ignitions at the dump. Methane has a 21 time higher warming potential than carbon dioxide, considering the greenhouse effect. The burnings are created through bacteria activities during digestion process underground the landfill body. Produced fume is very harmful due to dioxins and further substances which can reason respiratory infection. The polluted leachate of the dump site is not drained. More or less it is badly influencing the ground water body while surface distribution of waste through stormwater and flooding can even worsen the impact on nearby agriculture. This can cause negative environmental impacts as well as health implication according to harmful substances of harvest. Even though there are obvious threats regarding the environment and human health, so far impacts can only be imagined and not certainly determined.

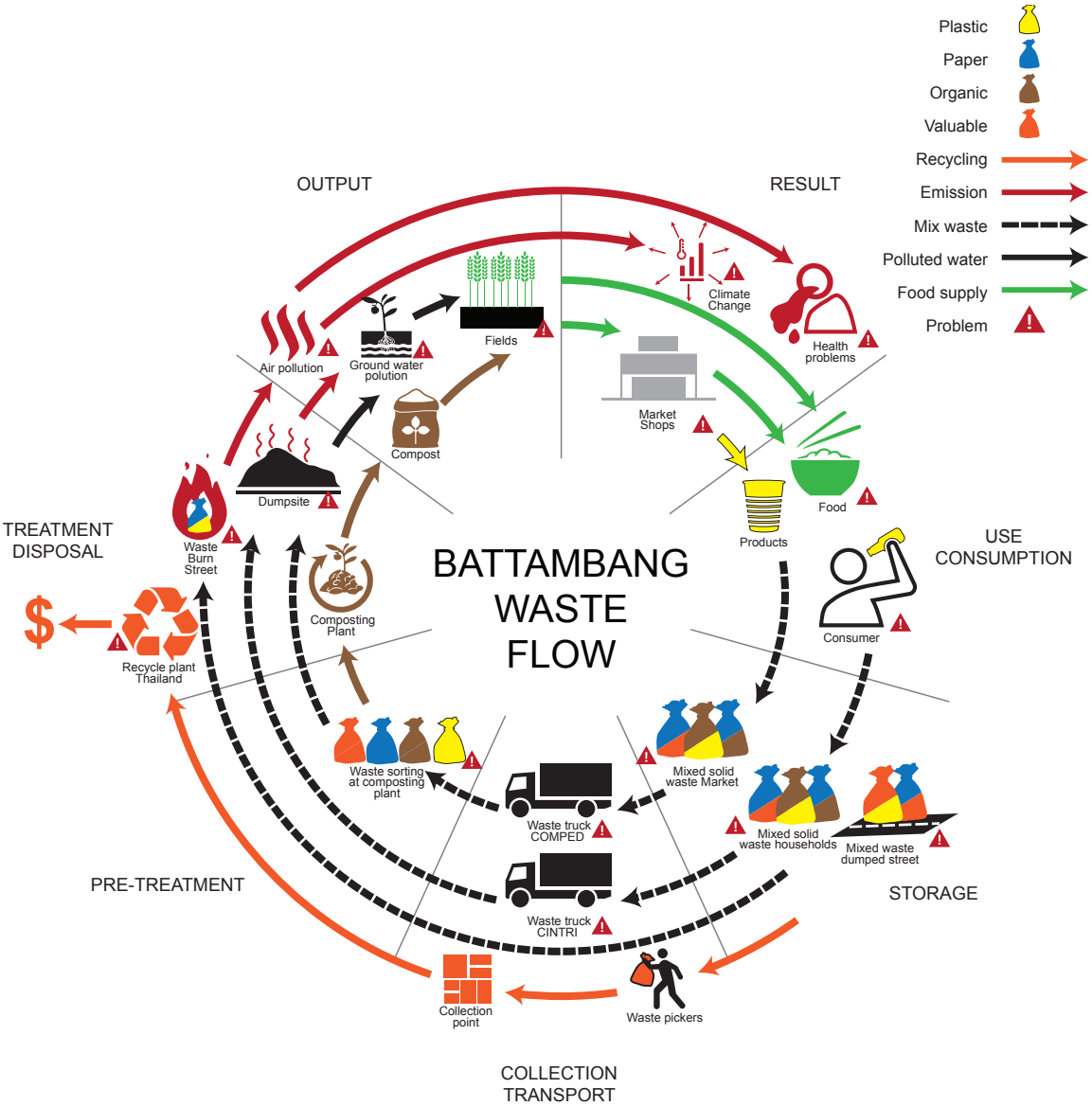


Fig. 29: Battambang Waste Flow Diagram (Illustration by the authors)

3.2.3. Other Infrastructure

3.2.3.1. Energy Supply

A comprehensive and reliable energy supply is a basic need for the development of Cambodia. In order to assure livelihood, while improving the living conditions and the source for business competitiveness, energy supply is an indispensable foundation for people. According to an article of the World Bank in 2011, 26 % of the Cambodians have access to electricity. The Prices are ranging from 600 riel/kWh to 4,000 riel/kWh for grid power supply. This is caused by the main part of people, who live in the rural area, where the accessibility to power supply is not common yet. In fact, the Royal Government of Cambodia aims to raise the access of affordable electricity for rural households to 70 % by 2030. Indeed, there are efforts by the government to implement decentralized grids for communities.

In 2006 the National Biodigester Programme (NBP), which is a government owned programme was initiated in cooperation with the Netherlands Development Organisation (SNV). Until now more than 20,000 biodigester were installed, while approx. 100,000 people are benefiting from it. Due to the technical potential throughout Cambodia, 5 % of households installed a biodigester. Another achievement of the programme is, that 2,500 (15 % of total users) connected a sanitary toilet to the biogas plant. Only 114 of the plants were implemented in the province of Battambang (NBP 2014). Another example for the establishment of renewable plants is a project of the Federation of Cambodian Rice Millers Association (CRMA) in the province of Battambang. Referring to an article of Phnom Penh Post a biomass plant using rice husks, with a capacity to generate 10 megawatts, is set up for providing the energy to the rice milling factory as well as to their federation members. Besides the benefit of reducing costs of producing milled rice for export, the energetic potential of rice husks which are otherwise useless, is also an important fact. The president of the CRMA stated, that the plant should be ready in early 2014 (Reuy 2012).
Furthermore, the 40 million US-Dollar project named “Rural Electrification and Transmission Project“, accomplished that 19,400 households in the province of Battambang were connected to electricity in the end of 2010 (World Bank 2011).

Generally, the streets of Battambang are typically branded of over ground hanging power lines wrapped around poles like a cobweb reaching across the streets, somehow confusing. The project group realized, the city itself is covered properly, even power cuts occur quite often. There are only a few public lights in the streets which is quite dangerous, because not every vehicle is lighted. As the project group confirms and no information was found, due to criminality there are no big concerns.

Until December 2007 the local power supply for Battambang was accomplished by a power station in the city center (Ry 2009). The Cambodia Power Transmission Line Co.,Ltd was set up to develop a transmission network in northwestern Cambodia. The power is transmitted from the Aranyaprathet substation in Thailand to the provinces of Banteay Meanchey, Siem Reap and Battambang. A power purchase agreement between the national power utility enterprises, Electricite du Cambodge and Electricity Generating Authority of Thailand was the basis of this project. Within two years the project was completed and energized. From this point on the Provincial power utility bodies were able to increase its supply capacity and distribution network as well as reduce reliance on high cost oil based energy supply (Soma Group 2013).

Fig. 30:
Battambang Street with Power Lines (Photo by the authors)

3.2.3.2. Transportation

The road system consists of national roads, asphalt roads, laterite roads and other roads. The national roads No. 5 is crossing the municipal area from west to east while No. 57 is entering from the south and ends when it connects to the main road No. 5. These major roads have a length of 21 km, while 89,6 km of the 434,4 km in total are asphalt roads. Compared to the sub-urban and rural area, the city center is mostly covered with asphaltic roads. The laterite is distributed from the dirt roads to living areas next to the road, which can causes hygienic difficulties. In the past some roads such as the ring road have been planned but not constructed. Due to the inadequate road network merging traffic and increasingly number of accidents are resulting. At present there is a lack of sidewalks, traffic signs, traffic lights and street signs and general road maintenance (Ry 2009). Especially in regard to the urbanization process and the demand of future tourism development, an improvement of the traffic system is needed. The project group was going mostly by tuk tuk or motorcycle and experienced that the traffic runs surprisingly well.

Areas for large transportation infrastructure are located in the outskirts of the city. The bus station is situated in the west of the city at a big open space, where also public events are taking place. The report Hap et al. 2009 states that 64,2 ha, less than 0,6 % of the municipal area, is determined as transportation zones. The only public transportation facilities of the city are the railway station and the airport in the east. The rail road crosses the city from southeast to northwest. It is in very poor condition and not used for several years. Due to renovation, which already has been started the railway line to Phnom Penh and Poipet will be very important for the city development. The airport is inoperative since 2004 and the area is not used for any other purposes. Even though it might be needed in future development, the location is not adequate for intensive flight service (Ry 2009).

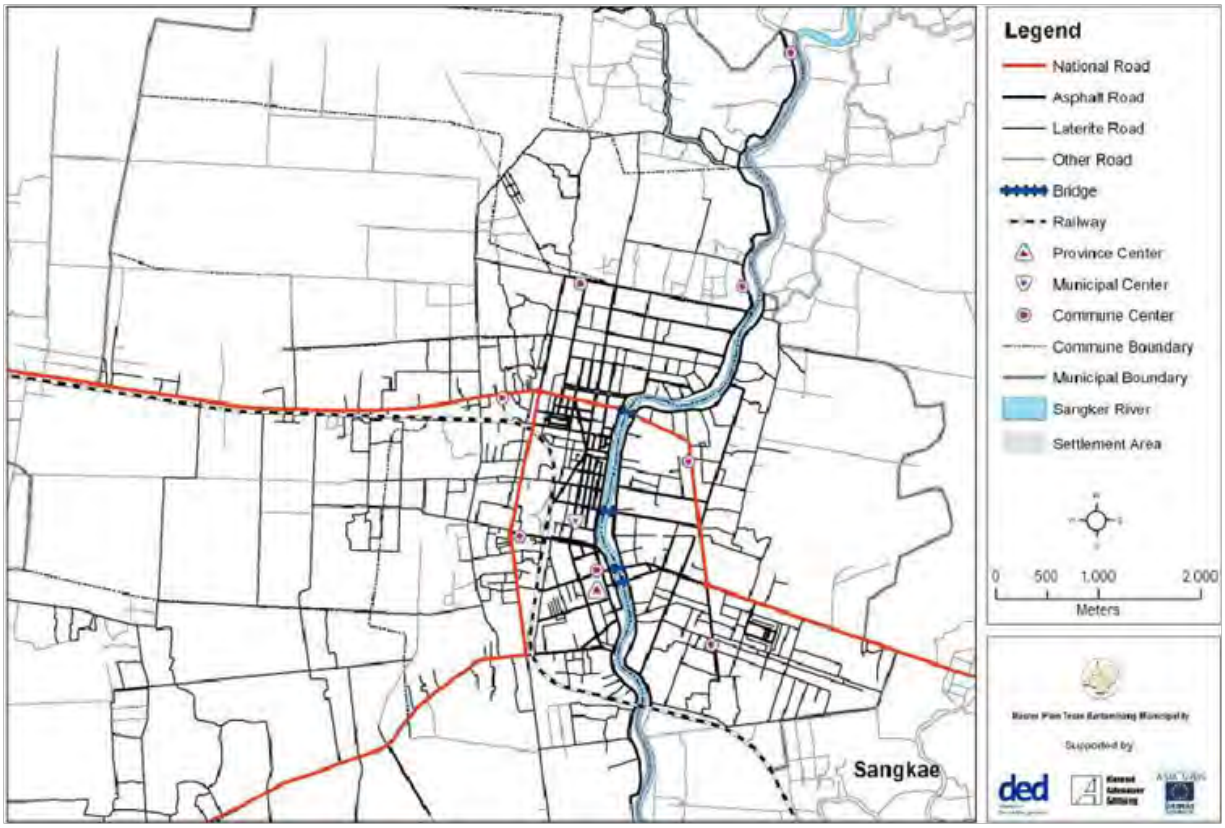


Fig. 31: Existing Road Network of the City of Battambang (Ry, Hap, & Koditek 2009)

3.2.4. Overview

The situation in Battambang, regarding environmental conditions, is problematic in many sectors. The solid waste management is a major problem due to the insufficient service provided by the private company CINTRI. People are unsatisfied and the streets are polluted. Improvement of the waste collection service cannot be expected in the near future due to the contract that was signed for 80 years. The lack of alternatives forces the population to dispose or burn their waste within the city. This in fact leads to air and environmental pollution and can cause serious health problems. The waste that is collected is disposed at the local dumpsite, which has a poor design and is already running out of capacity. The composting plant that is processing some of the cities organic waste is the only resource recovering facility beside the informal waste sector that is collecting valuables like cans and bottle in the city and at the dumpsite.

Similar to the waste management is the wastewater management, which is insufficient as well. Only 10% of the city is connected to an old and in many spots blocked sewage system. The wastewater that is collected is treated in an undersized and poor maintained WWTP with questionable success. The discharge of the WWTP and the wastewater that is not collected are polluting the environment and the river, which is at the same time the major domestic water source.

Water supply via pipes is only common in the city centre and the water that is delivered is not of good quality. Due to this fact, people need to buy bottled water for drinking and cooking. People who cannot afford this need to drink the water that is delivered and some people have to drink even river water due to the lack of alternatives. Diseases that are related to bad water quality can be found in the city for this reason.

Sanitation especially in the rural areas is on a low level. Unimproved pit latrines and open defecation are common practices there and should be improved because it is affecting the health of the people due to groundwater pollution.

The issue of stormwater is effecting peoples life directly and especially in the rainy season when large parts of the city are flooded. The large amount of water that is coming with the river and from heavy rainfalls can't flow out of the city due to the fact that the drainage system is blocked or houses are constructed in natural flow-lines. This is also affecting the road conditions which are quiet good in the inner city but mostly dirt roads in the rural areas. Due to the flooding the access road to the dumping site is sometimes not useable which is affecting the waste collection service.

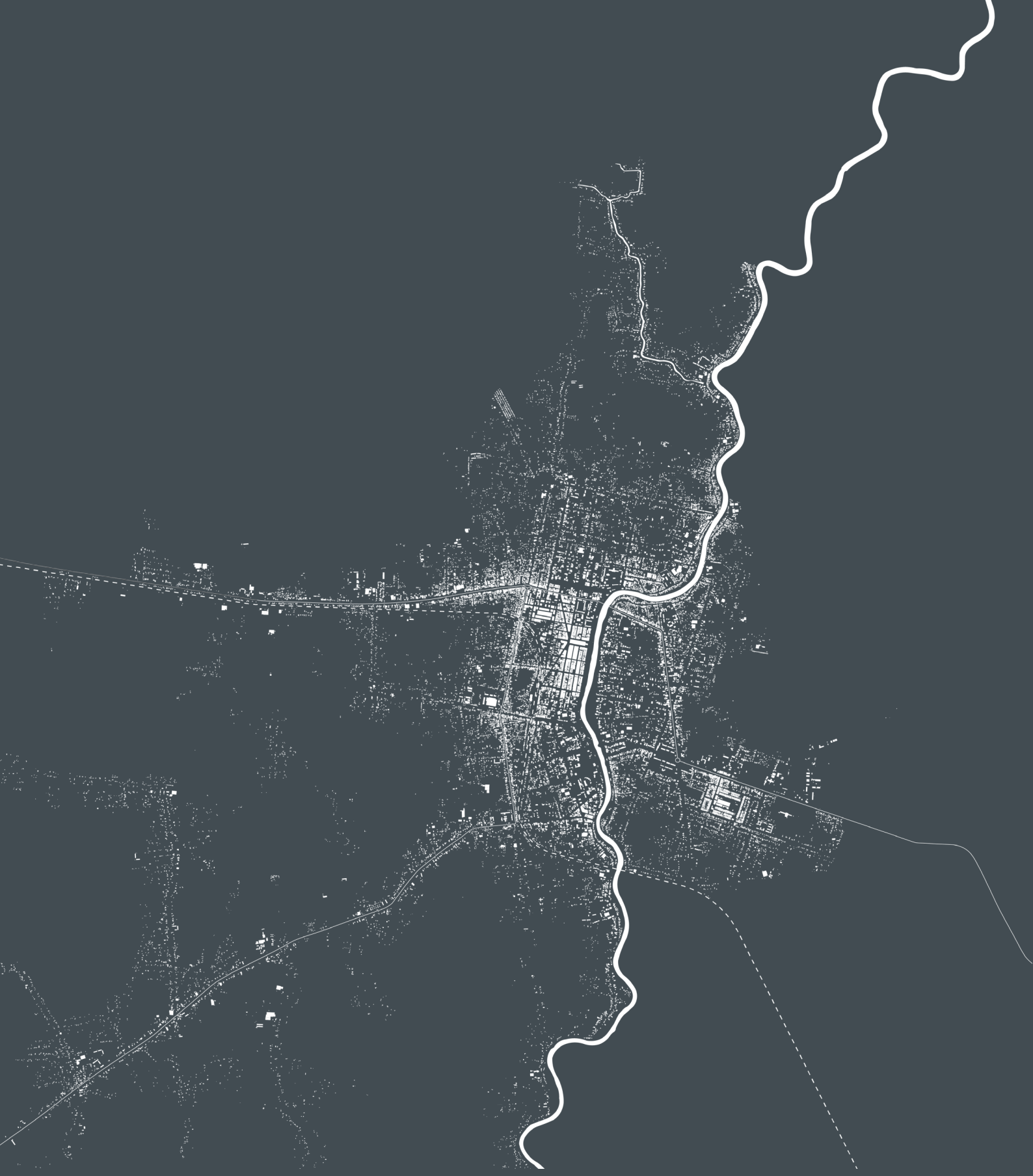
Referring to these problems of the technical infrastructure in the present status, there are interrelating complications the project group discussed. One infrastructure part affects the others. The already mentioned blocked open channels, drains and sewer that are also seen in the map of the municipality are, for an example, due to randomly open dumped solid waste, which needs to be addressed to the lack of environmental awareness and waste management in general. However, the waste collection is connected to the road condition and the accessibility of the houses. Additionally, the yearly flooding has an impact on almost every part of the technical infrastructure: the water for the water supply is taken from the river, the roads deteriorate when they are flooded, the waste collection is more complicated, the dumpsite is flooded and the wastewater treatment plant cannot deal with this amount of water. As a result, the different parts of technical infrastructure should not be seen as single patterns, but in an overall and integrative way. Furthermore, injurious effects on environment and human health need to be considered in a cycle, an interrelated system. Besides also other aspects like the settlement structure, legal framework and the citizens themselves have a great influence on the infrastructure and should be taken into account.

Nevertheless there are already a great number of projects and efforts existing to improve the situation for the inhabitants of Battambang. Also the masterplan for the city was developed which is a good start to plan the city, although it is not containing technical infrastructure. In conclusion, lots of people, departments, countries and the Kingdom of Cambodia itself are putting a lot of effort into the development of technical infrastructure, but an interdisciplinary communication and organization could bring out more efficiency or chances, respectively.

3.3. Conclusion

Like it was already mentioned in the overview of the infrastructural context, the urban planning should be combined with the design of technical infrastructure. This is the reason why the current situation was analysed according to socio-spatial aspects like legal framework for urban development, involved stakeholders, Cambodian society in general and spatial development, and technical infrastructure like water supply, wastewater management, solid waste management, transportation and energy.

The city of Battambang faces several challenges related to the spatial and infrastructural context and many factors have to be considered. However, efforts are made and the planning concentrates more and more on the city-level. As the city itself is a complex being and the conditions vary a lot in the different parts, the following chapter will examine the current situation in more detailed way.



Chapter 4:

URBAN TYPOLOGIES & INTEGRATED INFRASTRUCTURE SYSTEMS

4. Urban Typologies and Integrated Infrastructure Systems

The city is a complex being. Therefore ‘it is important to think of the city as a patch-work of different domains and physical environments which each present their own challenges and opportunities’ (Lüthi et al. 2011). To understand the different parts of a city and how they work together as a whole, it is important to identify the factors.

Specifically for the implementation of a new or improved infrastructure, it is important to identify the different urban typologies the city consists of. Each typology is facing its own threats and problems but also has its individual chances and possibilities. Hence, it is not possible to find a simple infrastructure system that will work for the whole city. However, breaking the city down in different areas makes it possible to find systems and technologies for each area, according to its threats and chances.

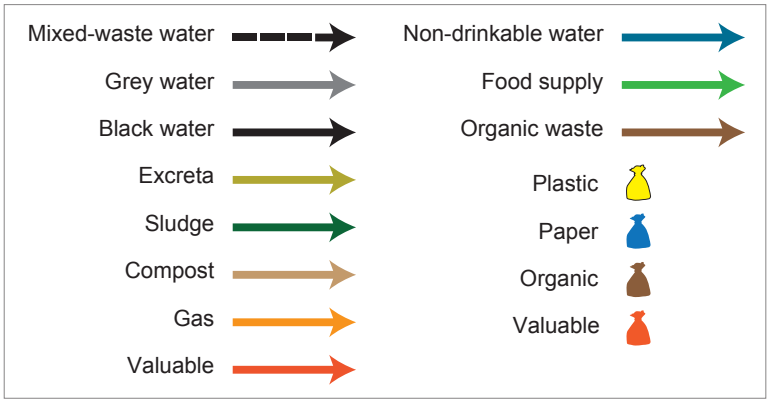
Therefore, representative areas within the city were chosen. From the urban planning perspective, the 6 typologies the inner city, the outer city, rural character areas, impermanent informal settlements, non-residential buildings and planned urban development areas were identified.

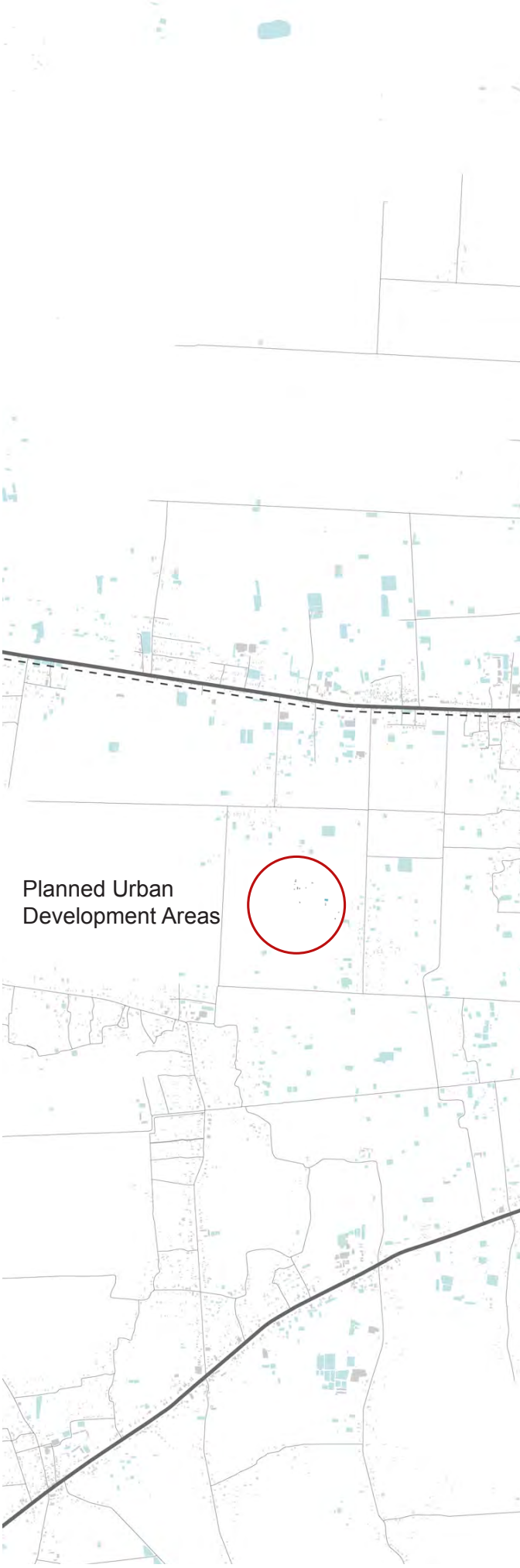
All the areas were visited during the workshop except the planned urban development areas. For the analysis of the typologies and infrastructure only specific spots were visited. Hence, the following pages give examples of the typology of the areas and not a comprehensive analysis.

Based on the analysis of the current situation it was worked on finding suggestions for improvement possibilities. This was done with the help of the CLUES guideline which contains a compendium of sanitation systems and technologies. The best options were chosen from the compendium by using an exclusion procedure. The integrated infrastructure system is shown for each area in the following pages. How the different systems work together and the optimization possibilities on the city scale are explained in the chapter afterwards.

The urban context, the existing infrastructure and suggested integrated infrastructure systems are explained and visualized for each area. The diagrams show the characteristic structure of the areas with examples of the existing and the proposed infrastructure.

The figure numbers in this chapter are valid for the whole page due to clarity reasons. The legend for the illustrations and diagrams can be found below.





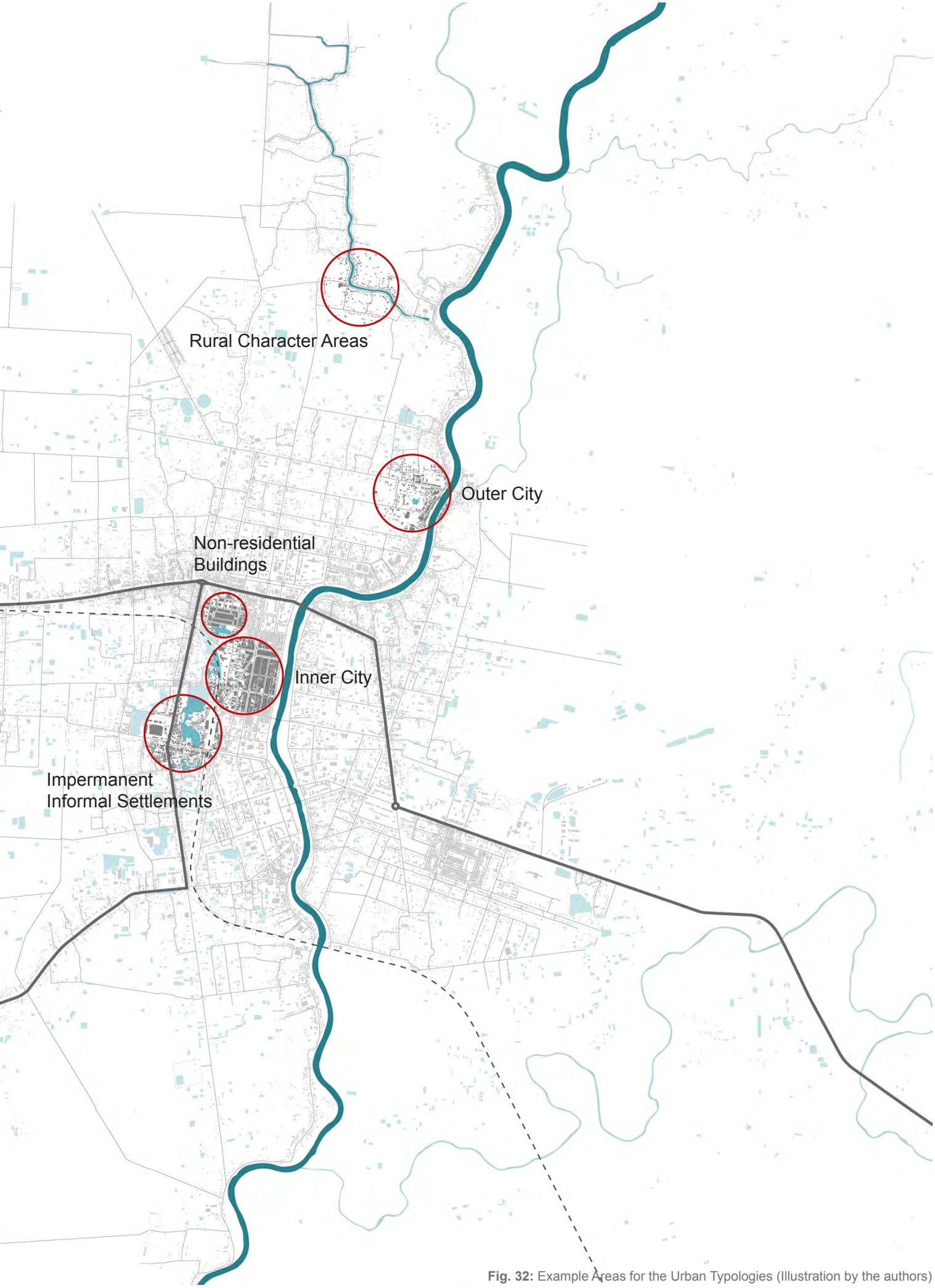
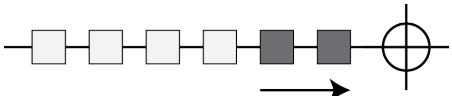


Fig. 32: Example Areas for the Urban Typologies (Illustration by the authors)

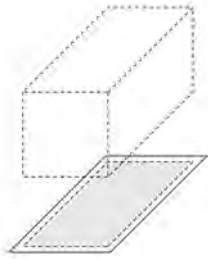
4.1. Inner City

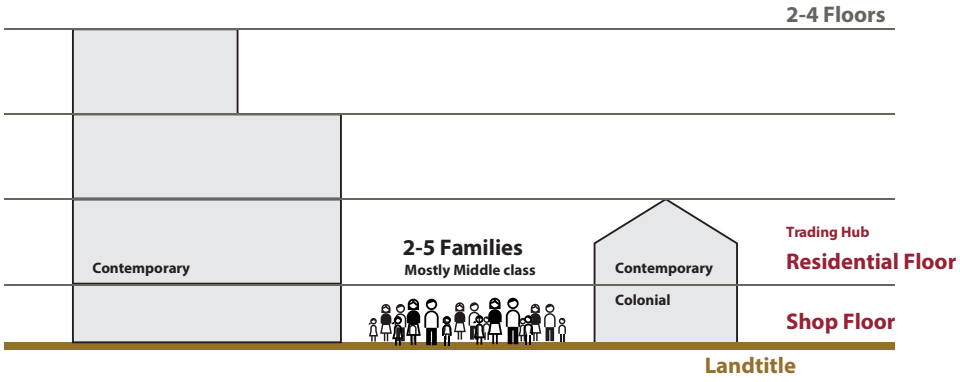
Income Level:

Distance to the Centre:



House/Plot Ratio:
The houses mostly take 100 percent of the plot while the plot size is mostly 5-7x10 meters.





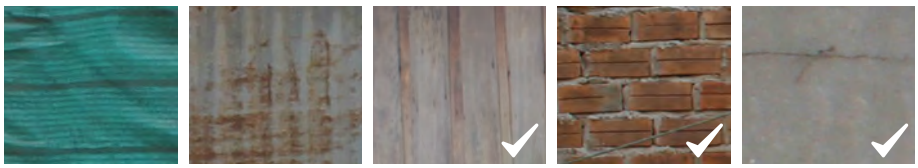
Introduction

The inner city is the heart of Battambang with its commercial use, good connection to services and the representative character. Easily identified by the colonial street structure, the inner city is the trading hub of Battambang and the whole region. This part of the city has colonial structures as well as modern apartments in multi-storey buildings up to 10 floors. These residential buildings are complemented by small-scale businesses, shops, restaurants, hotels, office buildings, etc. Buildings higher than 4 stories are mostly hotels, while the residential-use buildings are mostly shared with two to five families. The will to invest is high.

Community Structure

Despite the community centres provided by the government, the community structure is quite weak in the inner city, especially compared to the other areas. The meetings take place mostly before the elections, organised by the government.

Housing Typologies

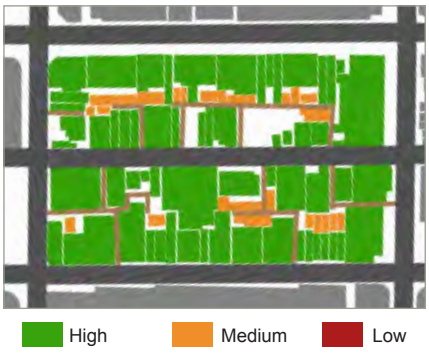


plastic | metal | wood | brick | concrete

The most common materials in the inner city are brick and concrete, although wood also exists in some traditional Cambodian structures. Concrete is a popular material for contemporary houses.

Accessibility

The inner city has the highest accessibility in Battambang. Almost all the buildings are already serviced by road infrastructure and central services. The road system works properly, while the only ones with a lower accessibility are the houses located within the blocks, mostly developed against the plans.

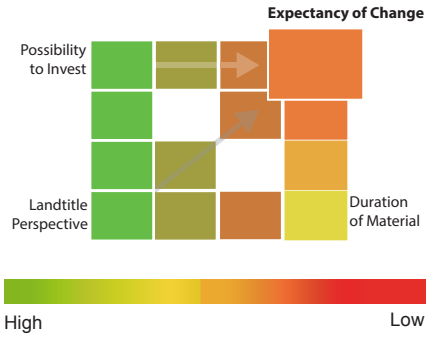


Living Conditions

While the location and public services provide a good environment, the inner city is affected by some urban problems such as fairly low air quality, sound emission related to the growing traffic and parking problems. High density and some public uses (e.g. markets) also have some downsides for the residents. Concrete and brick buildings ensure safety for the flood, although they might not work well with the hot and humid climate. Since they are not restored, some old colonial buildings might have lower living conditions for the residents.

Expectancy of Change

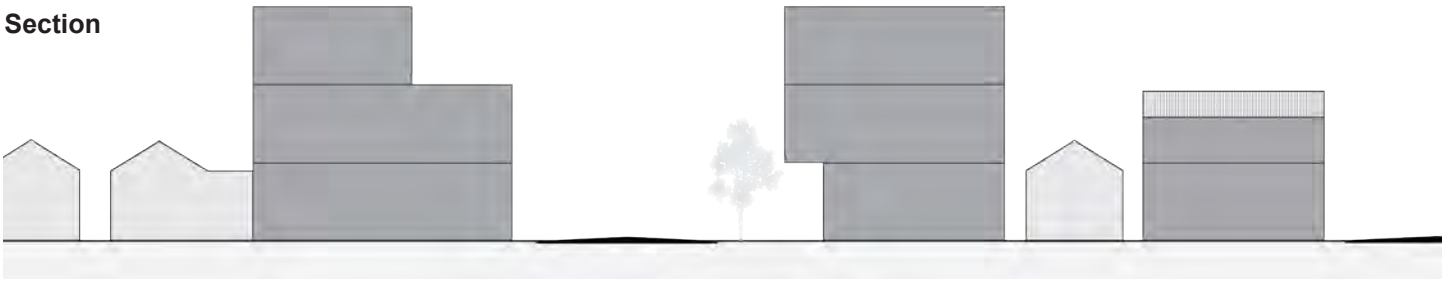
The expectancy of change is low in the landtitle perspective. But due to its representative location and the middle/high class population, the will to invest is high. With the high level of investment and the accumulation of capital, the inner city has a potential for further development and growth.



Urban Morphology and Density

French Colonial Plans have a strong effect in the inner city structure with concrete, grid street system and colonial houses located in the historic centre of the city. But the inner city doesn‘t only consist of colonial parts, contemporary concrete houses are really common as well. Population density is the highest in the city, due to dense, multi-storey housing character. Prime urban locations, such as green areas, waterways and parks for recreation are located in this area, as well as the main markets.

Section



Chances and Possibilities

- High will for investment and the good economical conditions of the residents is a plus for development.
- Many of the existing systems in this area are reaching the end of their design lifetime and are in need of upgrading, which presents an opportunity for improvement.
- Improvement of the existing sanitation system is a complex task because it has to deal with the conditions and difficulty of the existing situation, as well as the inertia of existing habits.
- Step by step, the system can be improved and developed to an environmental friendly system, with upgrading and retro fitting (Lüthi et al. 2011).

Fig. 33: Urban Analysis of the Inner City (Illustration and photos by the authors)

4.1.1. Inner City - Current Situation

The connection to the infrastructural services in the inner city is better than the other areas. There are two reasons for this. First, the inner city has a longer history than the other parts. Therefore it had the most time to work on the infrastructural development. On the other hand, it is also one of the most important areas due to its representative character and the non-residential uses located within. The systems used in the inner city are more centralized as everything is very close and easy to connect. The diagram shows combination of different situations that can be found in the inner city areas.

Energy Supply

Electricity is distributed via overland cables from the central system. Despite frequent power cuts and the visual disturbance, the existing system works well. Another energy source used is gas, especially for cooking.

Water Supply - Rain Water

Some houses have an additional rainwater collection system. The rainwater is collected on the roof in the gutters. For multi-storey houses it is stored in a tank on the roof and small houses collect it in big traditional buckets. There's a risk of pollution for the open buckets, while the tanks are more secure in terms of hygiene. Hygiene has special importance when the water is used for drinking and showering.

Water Supply - Central System

The inner city is getting water from the water supply centre. Most of the houses are serviced by the central system. However, the water has no drinking water quality. This water is used for every mean as cleaning, showering, cooking and for the toilet. Some houses store the pipe water for the times of shortage, especially in the dry season.

User Interface and Waste Water

There is no common style of toilets used in the inner city. There are squatting pans as well as western style toilets and both can be used with either cistern flush or pour flush systems. However the western style toilets are more common in the places frequently visited or used by the tourists, such as hotels and restaurants. Most of the inner city is connected to the sewer system and grey and black water are disposed in it. Some of the houses do have a tank for the black water collection, which are emptied by trucks that are called 'honey suckers'.

Storm Water

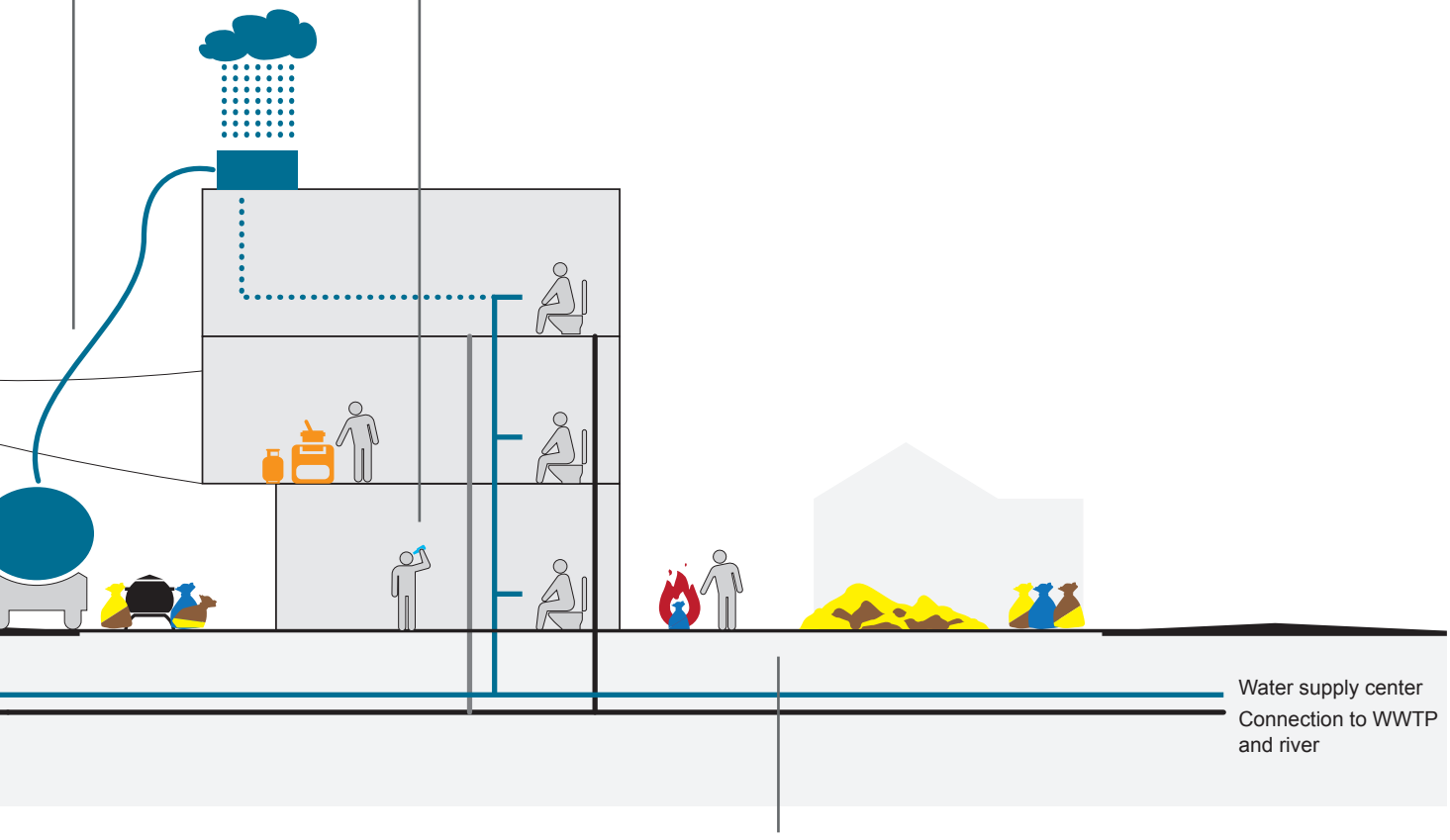
The rainwater and water from floods are collected in the central sewer system in addition to the black and grey water. Since the pipes are not big enough to transport the water in the rainy season and the blockages are common, the waste water can be pushed out of the pipes into the streets and houses. The water coming out of the pipes is even more polluted than the stromwater itself, because it's mixed with the waste water. In addition, the shafts are not working well since they are not enough in terms of size and amount.

Water Supply - by Truck

The water supply by the central water supply system is not very secure. In dry season it is possible that there is not enough water for every household. Therefore, some houses have tanks on the roof that can be filled by a truck delivering water.

Water Supply - Drinking Water

In the inner city most people buy drinking water in bottles or barrels. There are delivery trucks that bring water barrels to households. However the quality of the water in barrels is questionable, as it might be not as well treated as the bottled drinking water. Sometimes people also boil the tap, rain or river water for drinking.



Waste Management

The waste is collected by the company CINTRI, but it is not separated before collection or after. The only thing that is sorted out is the valuables. They are picked out by the informal sector at the source, as well as on the dumpsite. Everything else including the bio waste is deposed on the dumpsite.

The collection points are not well signed and there are no bins provided that can take up all the waste from the households. Therefore, most of the people put their waste on the street in plastic bags or boxes, in the spots that are convinient for them.

In some parts of the old town, metal containers are placed as bins. These containers are not suitable for easy emptying due to their weight and many are already broken. The size of these bins is questionable as most of the waste is clustered around them.

If the waste is not collected it gets also burned on the streets or empty plots, although the law forbids it. This causes disturbance because of bad smell and health problems.

Littering is also a problem. Especially the empty plots are used as open dumping sites.

Fig. 34: Current Infrastructure of the Inner City (Illustration and photos by the authors)

4.1.2. Inner City - Integrated Infrastructure Systems

One of the important attributes of the inner city is the high density. The benefit of the dense housing is that everything is very close and distances to drive for collection are not so long. On the other hand, that also means there is no space for an on-side treatment.

Because of its representative and commercial use the inner city has a bigger development potential and more investment involved. Also a lot of infrastructure already exists in the inner city, like a sewage system with pipes mixing the grey and black water. Therefore it is suggested to keep the existing infrastructure as far as possible and to work on the improvement and resource recovery. As the system before was more centralized and the space available is limited, the system will be kept on a central level. Detailed explanation about the improvement strategies for the central systems can be found in the next chapter.

The material flow chart on the right is giving an overview about the supply, collection and treatment steps that are involved on the different levels for the suggested system. It is not a comprehensive collection of all material flows but a selection of the ones that are important for the system. The water supply is given on the left side, while the collection and treatment of the organic compounds in the waste water and bio waste are shown on the right side. The different steps involved are also described and shown in the diagram below.

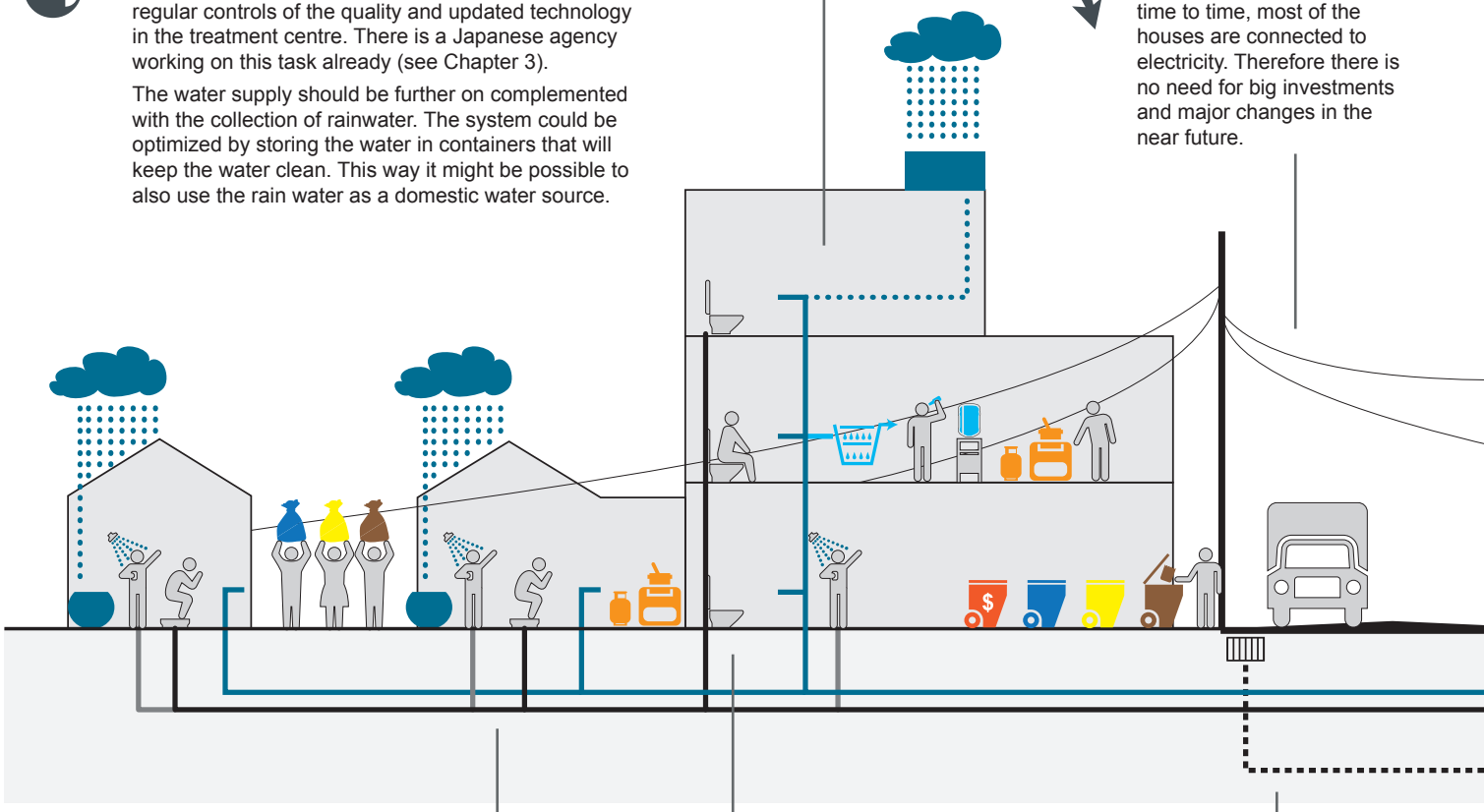
Water Supply - Central System & Rain Water

The water coming from the water supply centre should have bathing water quality. This can be reached by regular controls of the quality and updated technology in the treatment centre. There is a Japanese agency working on this task already (see Chapter 3).

The water supply should be further on complemented with the collection of rainwater. The system could be optimized by storing the water in containers that will keep the water clean. This way it might be possible to also use the rain water as a domestic water source.

Energy Supply

Despite the common power cuts and the problems from time to time, most of the houses are connected to electricity. Therefore there is no need for big investments and major changes in the near future.



Waste Water Treatment

In order to take care of all the waste water that is collected, more treatment facilities are needed and the existing waste water treatment plant needs to be improved. The treated water coming out of the WWTP (the effluent) should have a sufficient quality for the irrigation of the fields. There are a lot of possible steps to reach the goal to improve the current WWTP, such as better maintenance and operation. For example, the sludge needs to be taken out from the ponds.

Storm Water

There is a general problem in the city with flooding during the rainy season. Therefore this problem needs to be dealt with on the city scale. One thing would be the separated collection of the storm water in a second sewer system. This has several benefits like the reduced waste water amount that needs to be treated and no wastewater pushed into the houses via the pipes. Further explanation can be found in the next chapter.

User Interface and Waste Water Collection

The collection in the central sewer system of the city should be kept as it would be very costly to change this system. In this way, people can keep their preferred toilets and habits. However, the canal system needs to be improved, regarding leakages, blockages and the optimal outflow of the pipes.

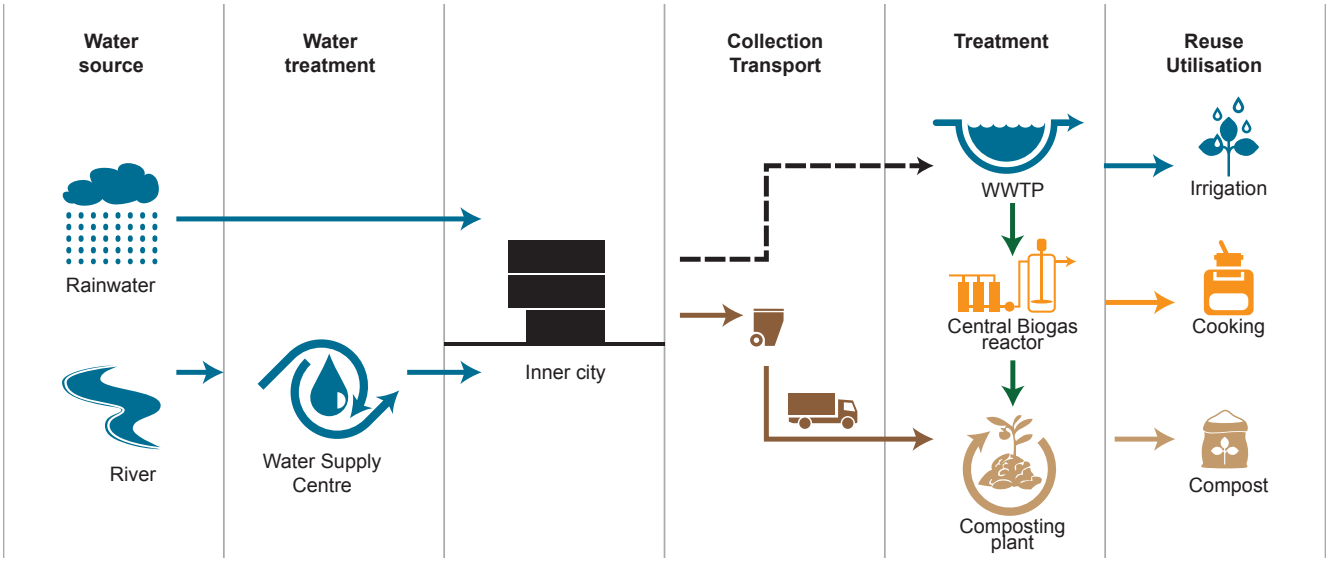
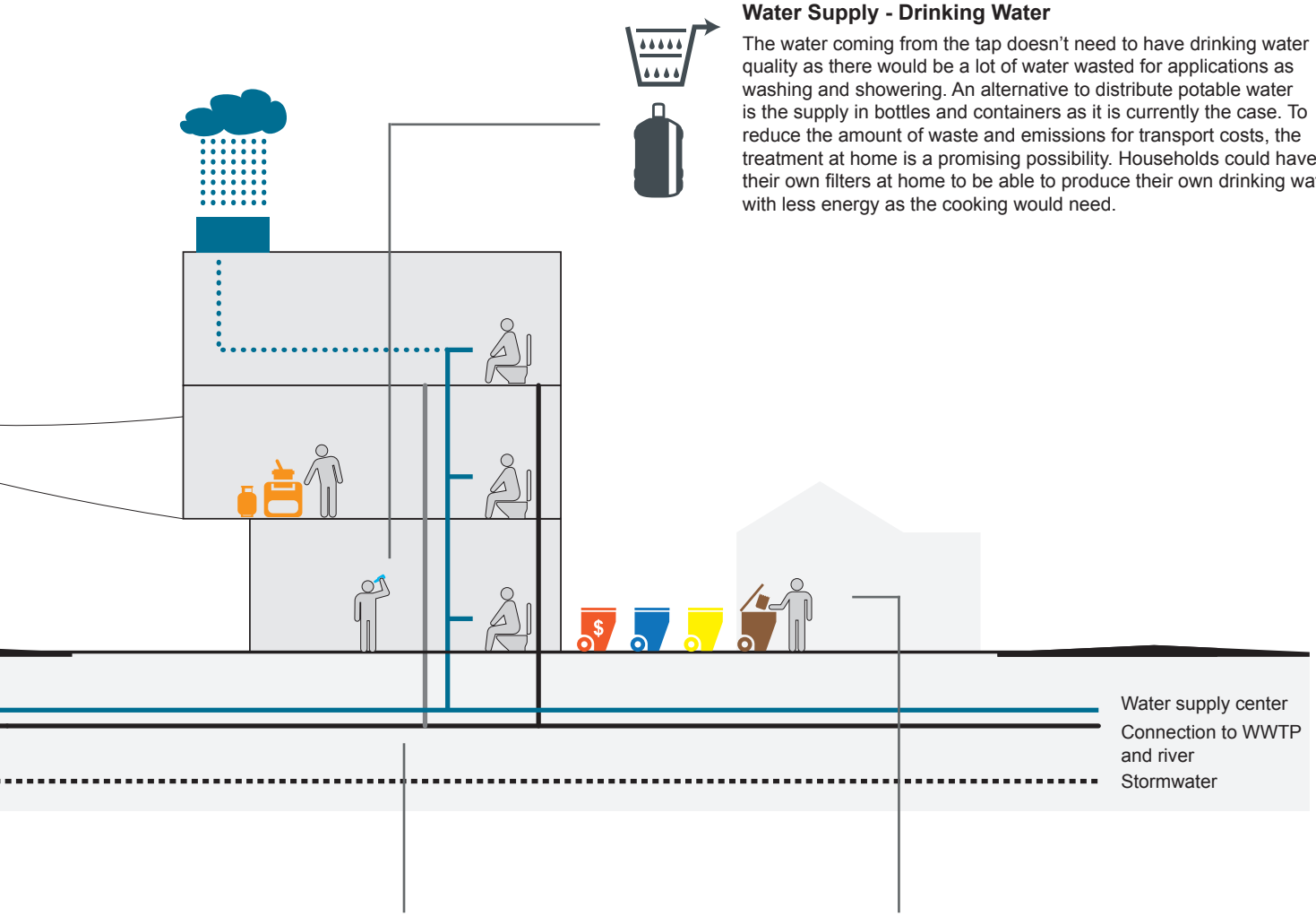


Fig. 36: Material Flow Chart of the Inner City (Illustration by the authors)

Water Supply - Drinking Water

The water coming from the tap doesn't need to have drinking water quality as there would be a lot of water wasted for applications as washing and showering. An alternative to distribute potable water is the supply in bottles and containers as it is currently the case. To reduce the amount of waste and emissions for transport costs, the treatment at home is a promising possibility. Households could have their own filters at home to be able to produce their own drinking water with less energy as the cooking would need.



Resource Recovery from Waste Water

The waste water of the city contains a lot of resources like organic matter and phosphor. After the treatment in the WWTP most resources are still in the sludge. To recover some of these resources, the sewage sludge can be further treated. This can be done in a biogas reactor where the sludge gets digested by microorganisms. During this process biogas is produced which can be used e.g. for cooking which is reducing the amount of firewood and other fossil sources needed otherwise. There is also a sludge produced during the digesting process. This digestate can be together with the bio waste of the city composted in the composting site.

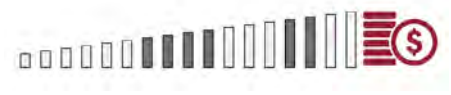
Waste Management

The waste can be continued to be collected by CINTRI. However, the collection should be optimized regarding different aspects. Firstly, it would be helpful for the collection if there were designated collection points with containers provided where people can leave the waste inside. This would also improve the appearance of the city. Secondly, it would be good if the waste is collected everyday due to the climate and the increased number of commercial uses in the inner city. Seperation of the waste should also be considered and improved since it is done only by the waste pickers at the moment, and the conditions are not adequate.

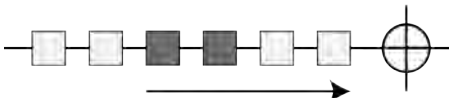
Fig. 35: Integrated Infrastructure System of the Inner City (Illustration by the authors)

4.2. Outer City

Income Level:

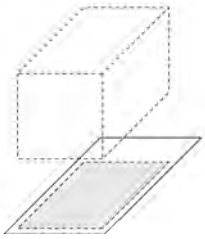


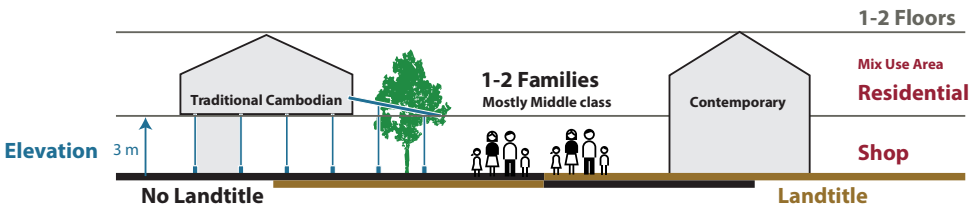
Distance to the Centre:



House/Plot Ratio:

The houses mostly take 70 to 80 percent of the plot while the plot size is around 7x10 meters.





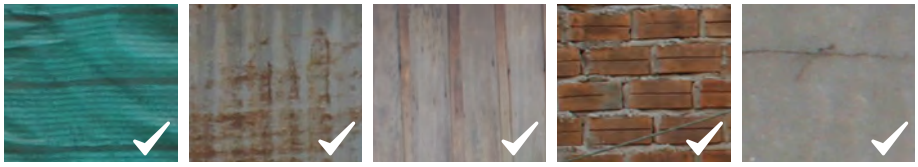
Introduction

The outer city encircles the inner city without clear boundaries. Although they have common points, the outer city differs from the inner city in terms of access to the central infrastructure, accessibility and density. Unlike the inner city, the outer city is dominated by the residential use. The residents are mostly from the middle income group, living in either traditional Cambodian houses or contemporary concrete structures. The houses are mostly shared by one or two families. Some commercial uses can be seen in the ground floor of the buildings.

Housing Typologies

Community Structure

The community structure in the outer city is relatively stronger than the inner city areas. Village and Commune Chiefs are defined by the government to enhance a community structure. Despite some monthly and annual meetings, there is no visible organization by the residents themselves.

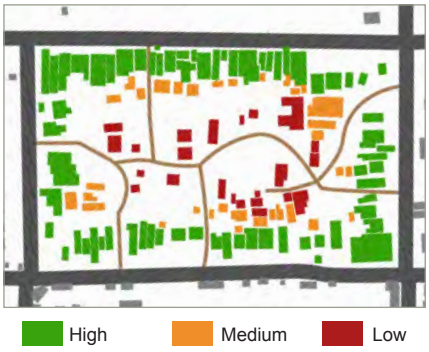


plastic | metal | wood | brick | concrete

Wood, concrete, brick and metal are the most common building materials in the outer city. Traditional wooden houses mostly have concrete additions for the toilet and kitchen. Plastic can also be found in some temporary structures.

Accessibility

The outer city is connected to the existing infrastructural system along the main roads. The accessibility gets more problematic within the urban blocks. There is no public service provided within the block and no fire truck can enter the quarter. Many have to enter their property through others, which can cause conflicts.

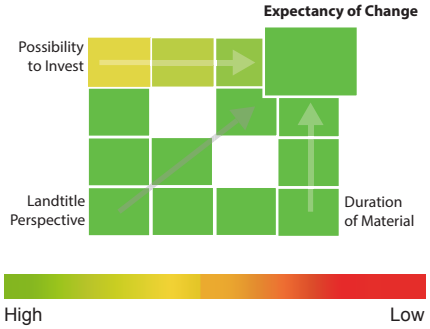


Living Conditions

People staying in the outer city have the advantage to be close to the inner city while having more living space around their house. It is less dense and people can walk freely within the blocks because there is no car access. The traditional Cambodian style houses have a good quality in space and air condition, since it is shaped and developed according to the local climate. They provide shadow and community places underneath the house. People get food supply by little shops in the neighbourhood. The quality of life is high.

Expectancy of Change

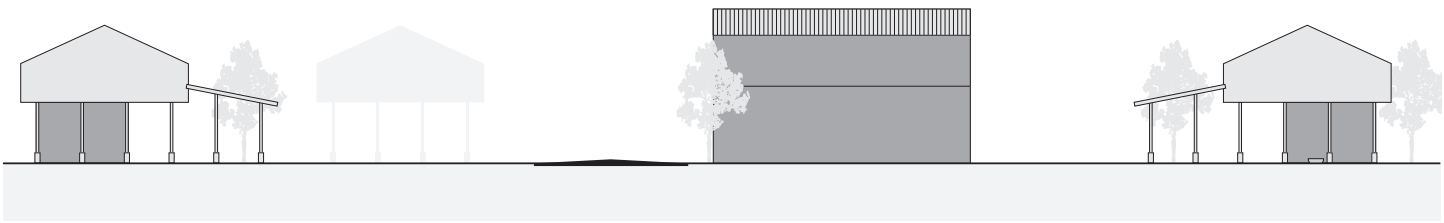
The expectancy of change is high in the outer city. While many residents have landtitles, the ones without is also getting one in the near future. Since people have the land security and there is no replacement risk involved, they improve their houses according to their financial possibilities. As a result, the change takes place plot by plot.



Urban Morphology and Density

The density of the outer city is lower than the inner city, due to the scattered and low-rise structure of the buildings. The size of the urban blocks is bigger than the inner city blocks, since they were mostly planned in the Independence Period and the last decades. Although the building structure is planned along the roads, there‘s a lack of regulation and services within the blocks. Small footpaths within the blocks can only be used by small vehicles (such as tuk-tuks, motorbikes, bicycles) and on foot.

Section



Chances and Possibilities

- The outer city is has a high potential for future developments and introduction of systems, because it is in a developing stage and changing continuously.
- Since the density is not as high as the inner city, there is enough space to establish more decentralized solutions for the households, which are not connected to infrastructure yet.
- As many houses do not have land titles, the process of land registration can enhance the chance to reorder the blocks, which would guarantee access to every house and plot.

Fig. 37: Urban Analysis of the Outer City (Illustration and photos by the authors)

4.2.1. Outer City - Current Situation

The urban structure in the outer city is not fully planned and the block structure with low accessibility within is a problem. As a result, some parts have a good connection to central supply systems, such as water, while some others don't. Therefore the latter have found some decentral systems that are working as an alternative to the central ones. The sketch is giving an overview about the infrastructural systems that are provided and used in this area.

Water Supply - Central System

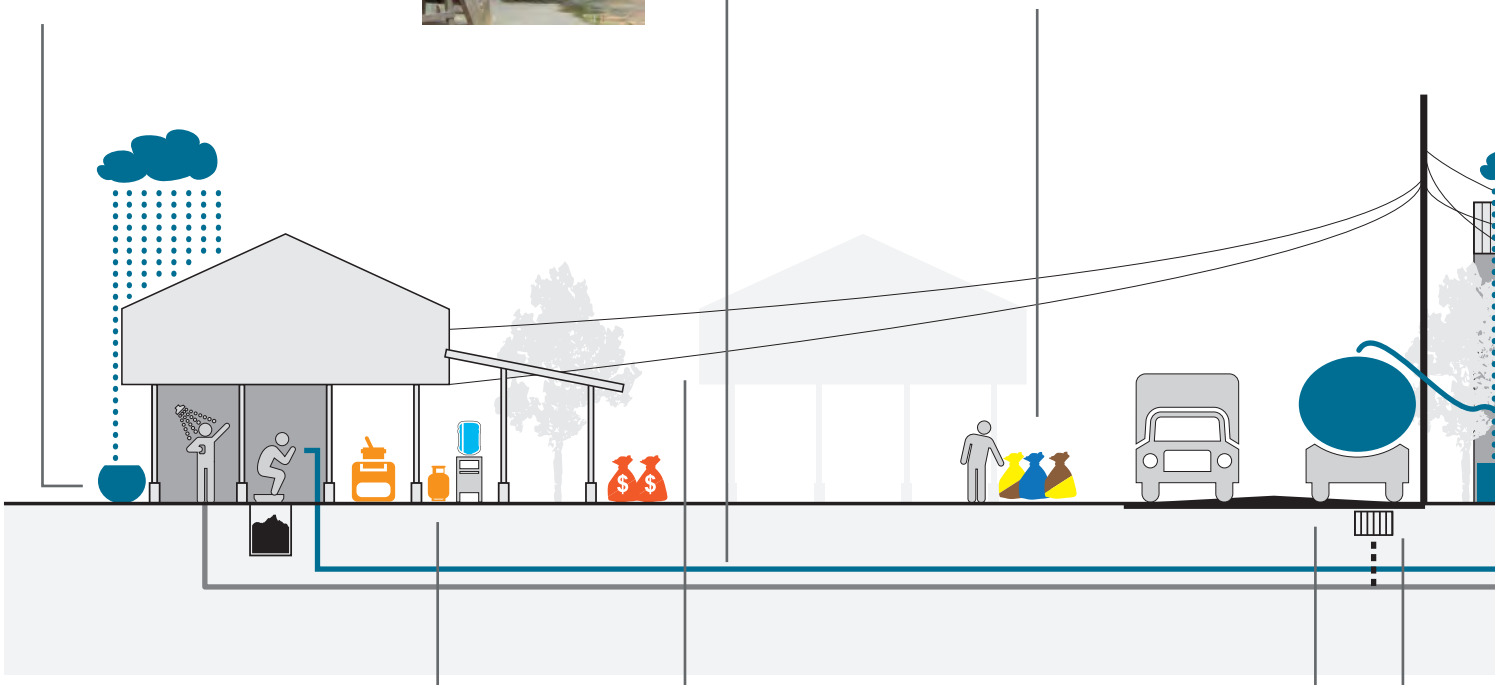
The water is supplied via pipes from the water supply centre for the houses along the roads. The houses within the block do not have central water supply. In the rainy season central water supply is replaced by the rainwater collection, whenever possible. This water is used for every mean as cleaning, showering, cooking and for the toilet.

Water Supply - Rain Water

The rain water is collected by gutters on the roof and stored in traditional pots, as well as tanks outside or inside the houses. Although the system works well, the collection points are sometimes polluted because they are not covered properly.

Waste Management

The waste is not separated except for the valuables that are sometimes kept by the residents which then are picked by the informal sector. Some waste pickers also collect valuables from the street. There are waste collection points, which are managed by CINTRI. The valuables are also seperated by the CINTRI workers during the collection of the waste. The collection is done once or twice a week, which causes disturbance for residents (visual, smell, unhygienic) due to the warm climate.



Energy Supply

Electricity is distributed via overland cables from the central system. Burning wood used to be the main source for cooking. Now it is replaced by electricity and gas in some households.

Water Supply - by Truck

Some households are also supplied with water from the trucks, which can be stored in tanks. Especially in the case of water shortage from the water supply centre, the supply by truck becomes crucial.

Storm Water

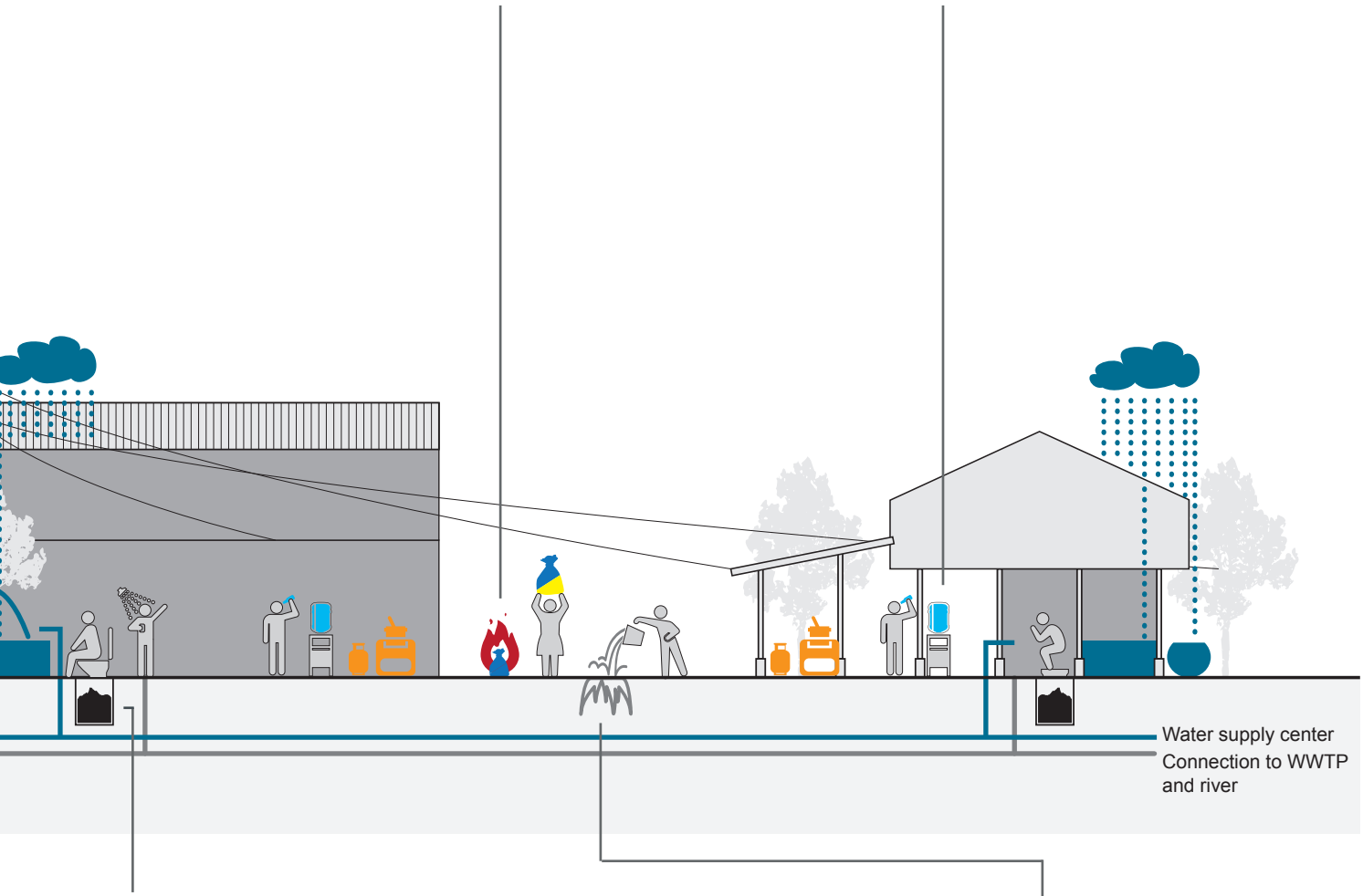
The rainwater and water from floods are collected in the central sewer system as well. The shafts in the outer city are mostly improvised by the residents and not working well since they are not enough in terms of size and amount. Because the pipes are not big enough to contain all the water during the rainy season the waste water can be pushed out of the pipes into the streets and houses. The water coming out of the pipes is even more polluted than the stromwater itself, because it's mixed with the waste water.

Waste Management - Burning

Some of the waste (such as non-valuable plastic) is burned within the urban blocks, which causes further disturbance because of bad smell and health problems. This is mostly done by the households away from the waste collection points.

Water Supply - Drinking Water

The water from the pipes connected to the central system and the rain water are sometimes used for drinking as well. In some cases, the water from both sources is also treated by filtering or boiling. Additionally the drinking water is bought in bottles or barrels, by the families which can afford it.



User Interface and Black Water

The most common toilet type is squatting pans with a pour flush system, but some households also use western style toilets. Especially for the upgraded houses, western style toilets are common. The black water is collected separated from the grey water in a tank that is emptied by a truck. Since there was no connection to the central sewage system when the houses were built, black water collection tanks were needed to be installed. Today the toilets are still not connected to the central system.

Grey Water

After the use the grey water is disposed to the central sewage system from the kitchen and the bathrooms of the houses. Sometimes it is disposed on the streets to infiltrate the ground, especially within the urban blocks. This is due to the fact that some houses do not have connection to the central sewage system.

Fig. 38: Current Infrastructure of the Outer City (Illustration and photos by the authors, *photo by Böhme 2014)

4.2.2. Outer City - Integrated Infrastructure Systems

The outer city is located between the inner city and the rural character areas. Therefore it has the benefit of being close to the central infrastructure but also having more space for the decentralized options. The density of the outer city areas are lower than the inner city, but they still preserve the urban structure and the required amount of users for some systems.

Furthermore, the expectancy of change is high in these areas which makes it easier to implement new technologies. On the other hand, the potential of infrastructural investments is low due to the nonexistence of commercial and public uses. As a result of these factors, the proposed system includes a mixture of decentralized and centralized supply systems and treatment technologies.

The overview of the material flows dealt within this system is given in the flowchart on the right. This flowchart shows the material flows that are of importance in this context and how they are connected and treated on the central and decentral level. The water supply is given on one side and the treatment and recovery of the organic resources on the other.

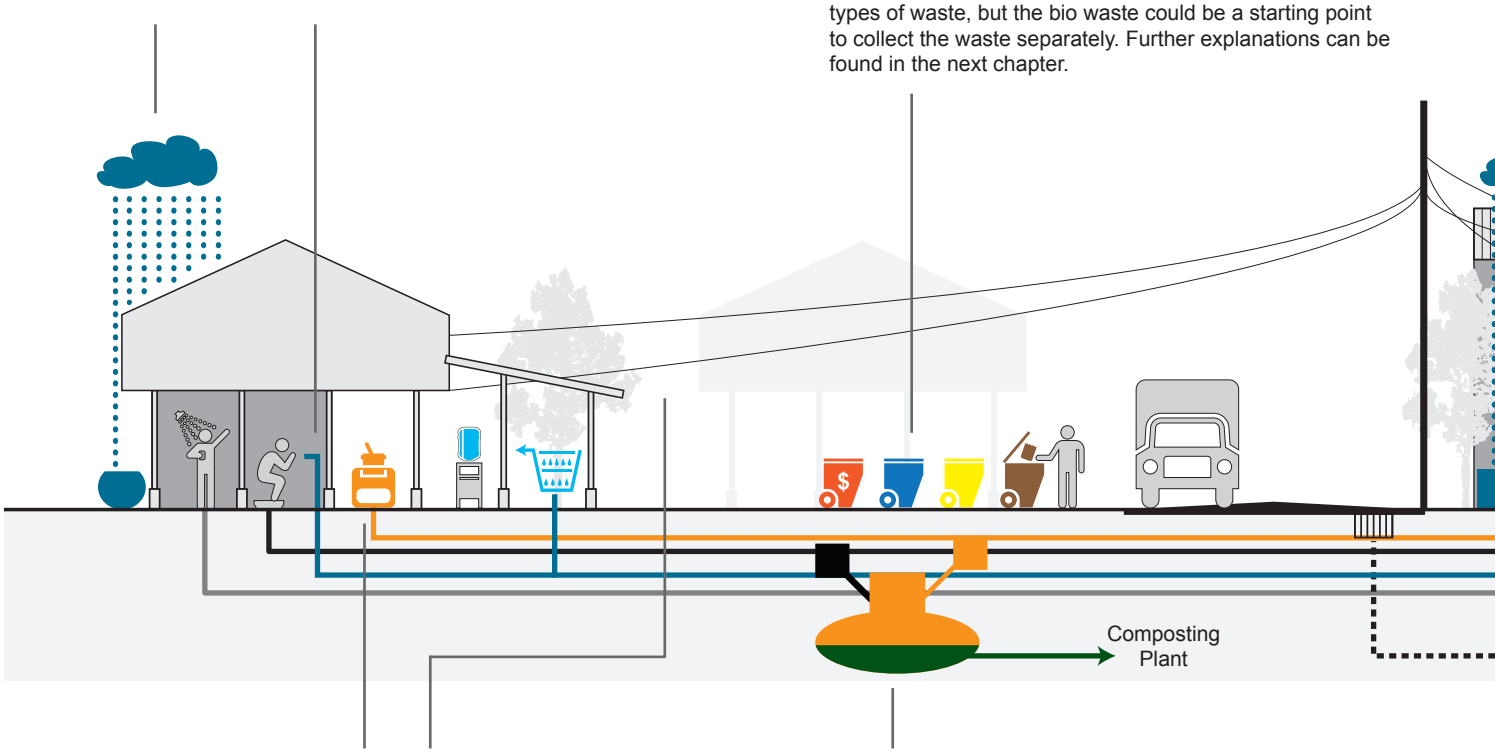
The diagram below shows examples of different improvement possibilities for the outer city.

Water Supply - Central system & Rain water

All houses should be connected to the central water supply system as it is planned already by the municipality (see Chapter 3). However, as for the inner city, the water quality needs to be improved and the security of the supply needs to be enhanced. In addition the rainwater collection should be kept while improving the storage conditions.

Waste Management

The whole outer city should be served by a waste collection system. As some houses have a bad road access, it would be good to have waste collection points. To make it easier for the collection, these points could be next to the biogas station. As a result, a common place with a road access could be found for both uses. There needs to be some education programs for the people to stop waste burning. The goal is to split all types of waste, but the bio waste could be a starting point to collect the waste separately. Further explanations can be found in the next chapter.



Energy Supply

The gas produced in the biogas plant can be used directly in households for cooking. In this way, other fossil fuel based resources can be saved. As most of the houses have electricity connection, central electricity supply is not seen as a major concern to work on. However it would be more convenient if there were less power cuts.

Black Water - Decentral Treatment

For the black water, a collection point is suggested where a group of houses is connected to one biogas plant via pipes. The biogas reactor is chosen as a treatment facility because the people have the direct benefit of the usage of gas they produce, for example for cooking. The collection in groups is favoured because it would be too expensive to build one biogas reactor for each household. Other benefits would be sharing the operational maintance and the need for less space. This also means that the community structure needs to be improved as the households share the tasks of operationand maintenance of the biogas reactors.

The sludge from the biogas reactor still contains a lot of organics. Therefore it could also be used for composting it together with the bio waste. Both need to be collected and transported by a truck, to be processed in the decentralized composting plant of the city. If the sludge is not treated by composting, it should be treated with an alternative way to sanitise it.

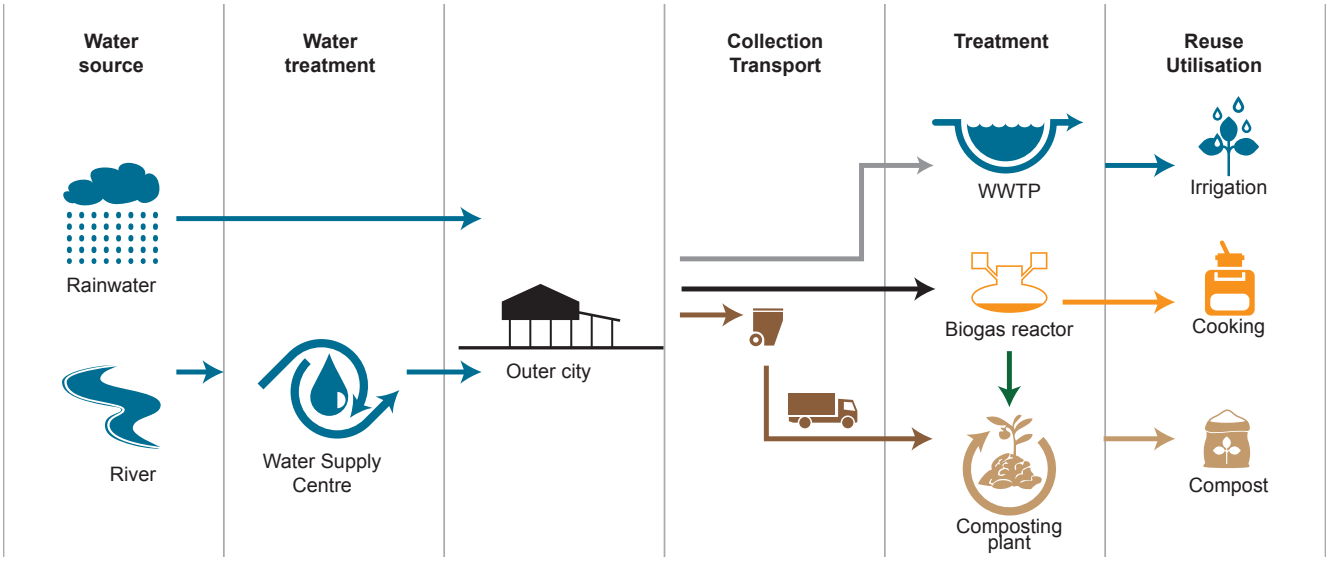
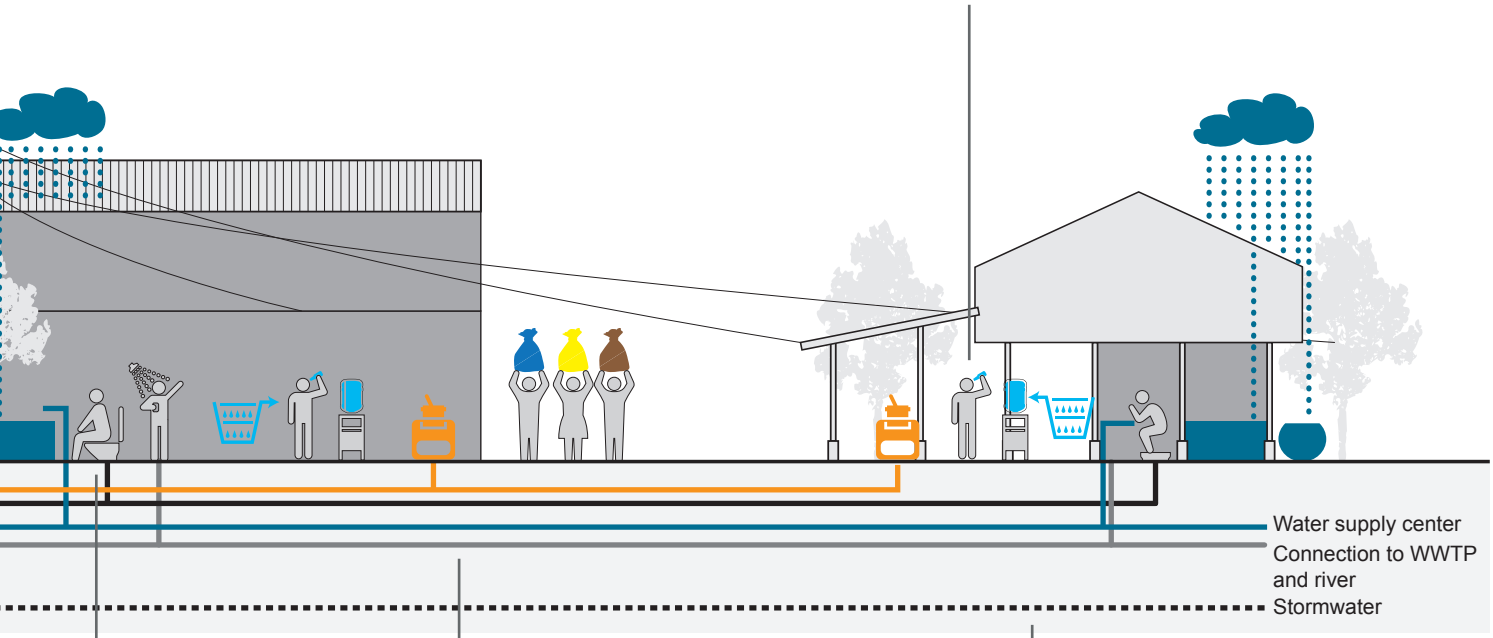


Fig. 40: Material Flow Chart of the Outer City (Illustration by the authors)

Water Supply - Drinking Water

The water supply via pipes will not have the drinking water quality. The easiest but not cheapest option is to buy barrels or bottles. However, some people might not be able to afford this. Alternatively there are a lot of options to treat water on the household level. The method which will provide one of the safest drinking water is boiling. Unfortunately this needs a lot of energy. Private households could also have filters at home where they improve the quality of the water provided by the water supply centre. More options are explained in the next chapter.



Grey Water - Central Treatment

In the outer city there is a separation of the black and grey water already. Therefore it is easy to use both resources separately. The grey water can furthermore be disposed in the central sewage system of the city. However, the waste water treatment plant needs to be improved as described further in the next chapter.

Storm Water

The storm water is a general problem that needs to be solved on the city scale. One suggestion is to have separated sewer for the collection of the storm water to reduce the amount of waste water that needs to be treated and prevent the waste water from being pushed back into the houses.

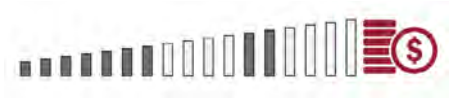
User Interface

No special toilet type is required for this black water collection system. Therefore there is no need to change the currently used interface, which is the squatting pan, and the people can keep their toilet habits.

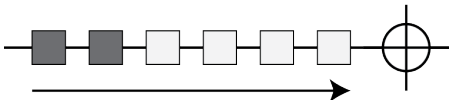
Fig. 39: Integrated Infrastructure System of the Outer City (Illustration by the authors)

4.3. Rural Character Areas

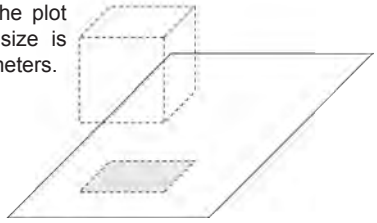
Income Level:

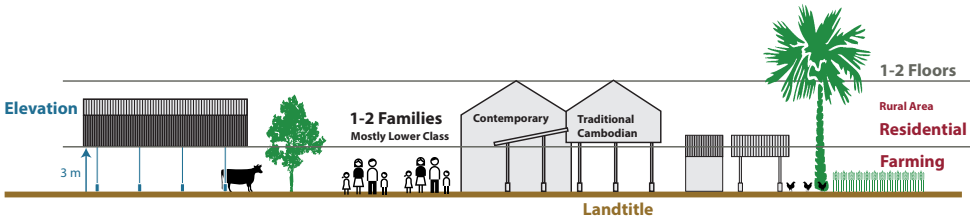


Distance to the Centre:



House/Plot Ratio:
The houses take 10 to 50 percent of the plot while the plot size is around 20x60 meters.





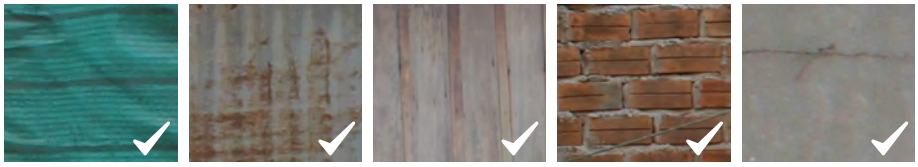
Introduction

These areas consist of rural character settlements within the boundaries of the Battambang Municipality. They are located in 4 communes. Although they are within the boundaries of the urban settlement, they carry the characteristics of the rural areas with farming, animal breeding and houses scattered in wide landscapes. The housing typology mostly consists of elevated, traditional Cambodian Houses and some contemporary structures. The income level varies from high to low, which is also seen in the building formations. These areas are mostly located far from the city centre, which causes isolation from the services.

Community Structure

The community structure in the rural areas is higher than the inner and the outer city areas. Some neighbourhoods have community funds and developments for compensating the missing central services, such as water supply. Community units have village chiefs to monitor and to represent the government, while there is also a small budget assigned to each area.

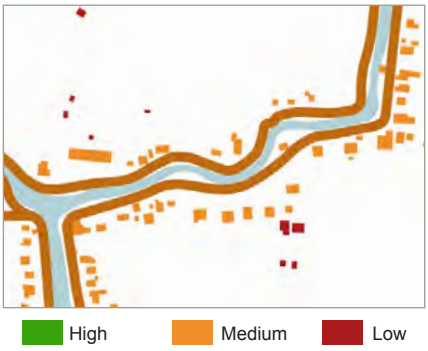
Housing Typologies



All kinds of material is used in these areas. While the high income groups have concrete or brick houses, lower income households have improvised with any material available. The dominance of the wooden structures is noticeable.

Accessibility

Accessibility of the rural character areas is low in terms of the distance to the central services. But the road access is comparatively high, since most of the houses are located along the roads. Despite the unpaved structure, the roads in these areas are mostly wide on the main axes and gets narrower deeper in the landscape.

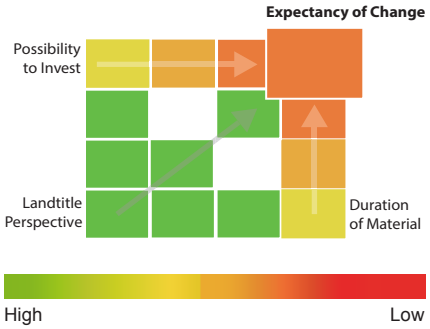


Living Conditions

In the rural areas the living conditions are mostly poor. Traditional ways to handle daily live is still working but the new challenges cannot be solved by the people themselves. Due to the low density it is more difficult to locate schools and medical care centres close. Also they have a longer way to work, and are often in self-dependence on their business or farming. To provide public service has low priority, but it harms daily life. The distance to the central services and lack of maintenance by the city are the main reasons for the low quality of life.

Expectancy of Change

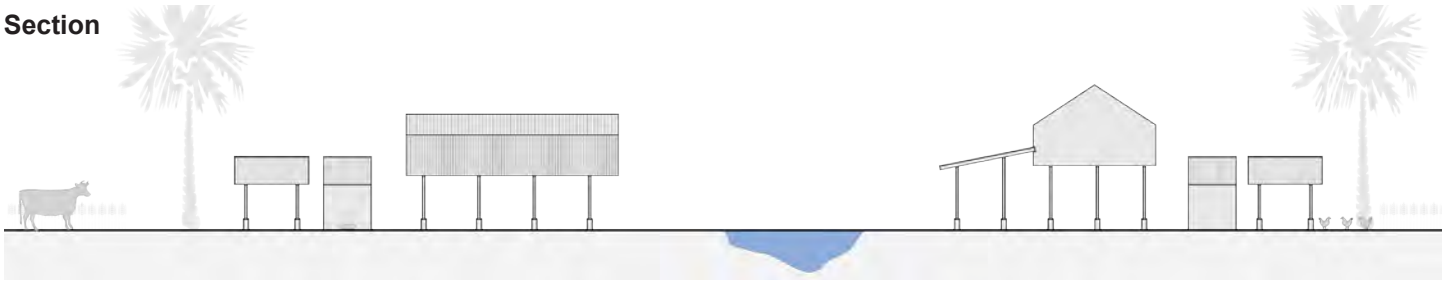
Short-term expectancy of change is low in the rural cha racter areas since the investment and the will to change is low. Almost all of the houses have a landtitle, which means no upgrading in the near future. With the development and the growth of the city, there could be a rapid urbanisation in the far future.



Urban Morphology and Density

The density is really low in these areas. Due to the farming and animal breeding, the houses require big parcels of land and as a result, they are located away from each other. There is a more dense structure along the canals and the waterways, due to the need for water. The structure gets more and more sparse away from the water and in the landscape. The areas lack central services and they do not have adequate road infrastructure.

Section



Chances and Possibilities

- These areas have high need and opportunity for decentralized systems. To connect them to the conventional infrastructure has the lowest priority, due to their afield location.
- It should already be in mind that these will become urban areas in the future.
- People‘s livelihood strategies are providing a great potential for possible systems, although improvements are required.
- There is a great potential for ‘wide scale uptake of reuse-focused sanitation solutions due to lower population densities and the location of urban agricultural activities’(Lüthi et al. 2011).
- These areas also offer ‘the potential to explore acceptance and practicability for innovations that could then be replicated’ (Lüthi et al. 2011).

Fig. 41: Urban Analysis of the Rural Character Areas (Illustration and photos by the authors)

4.3.1. Rural Character Areas - Current Situation

The areas with a rural character are the furthest away from the central systems thus the connectivity is very low. Hence the people had to find alternatives to the centralised solutions. An additional factor for the development of infrastructure is the income of the people and the amount of money they can pay. As the income in the rural areas is not so high compared to the other areas, the systems are low cost options.

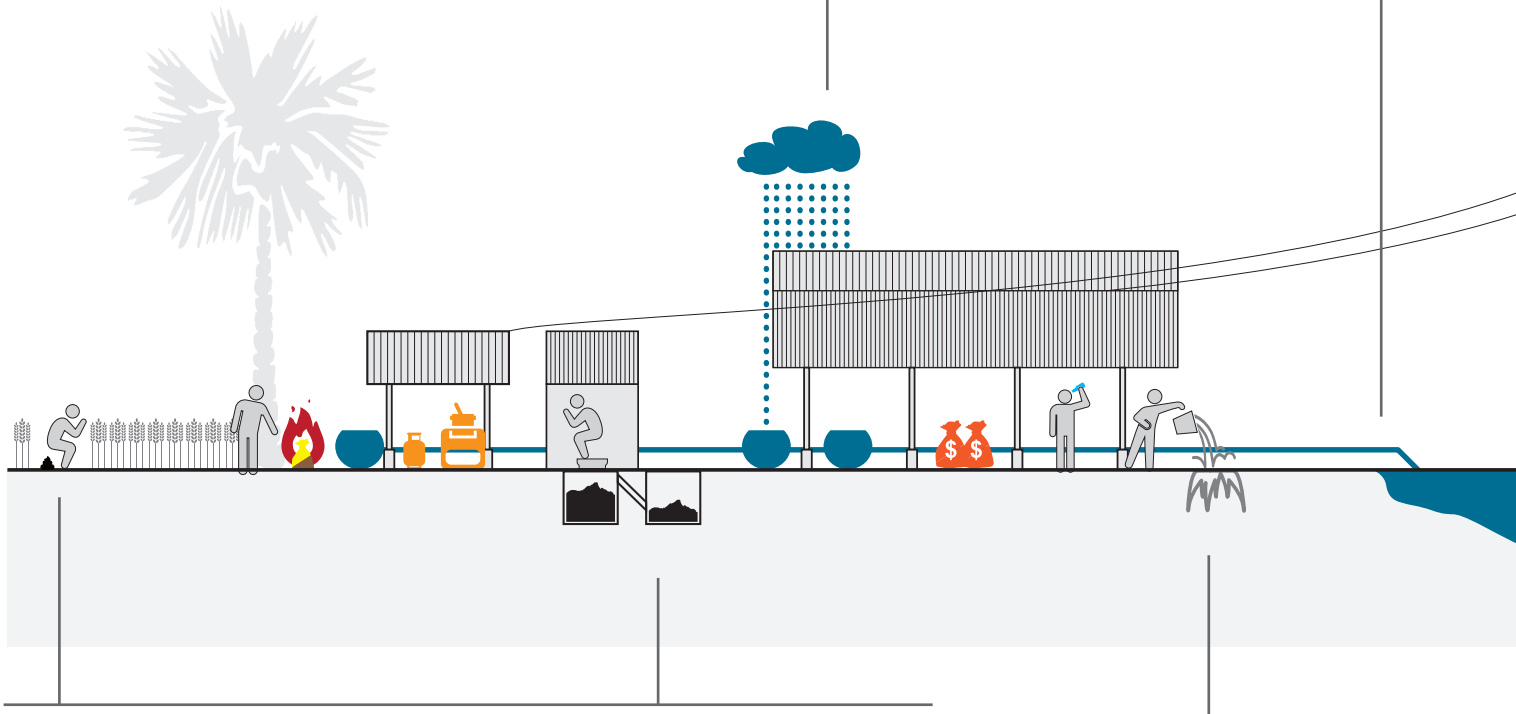
Water Supply

In these areas the main source of water is the **surface water** such as the river, canals and ponds nearby. Most of the cases, the water is pumped via a pipe system improvised by each household. Unfortunately, the water quality is really low in the ponds and canals. This quality gets even worse during the rainy season since polluted water flows are getting mixed with the water sources. The water doesn't get treated in many cases due to lack of knowledge and finances which can cause health problems. In some areas, the inhabitants have organized and funded **community water treatment centres** but it is not affordable for all income groups.

Rain water is another important and commonly used source. It is collected in traditional containers and used for all water applications, during the rainy season. Although it is not a reliable source since it doesn't rain all year long.

An alternative source, which is only used by households with higher income is the **water trucks**. The water is supplied by private companies and stored in tanks.

Special about the rural areas is that the people also need river and rainwater for irrigation.



User Interface and Black Water

The toilets are usually squatting pans with a pour flush system and two pits for collection. If there is no toilet, the people go to the field directly.

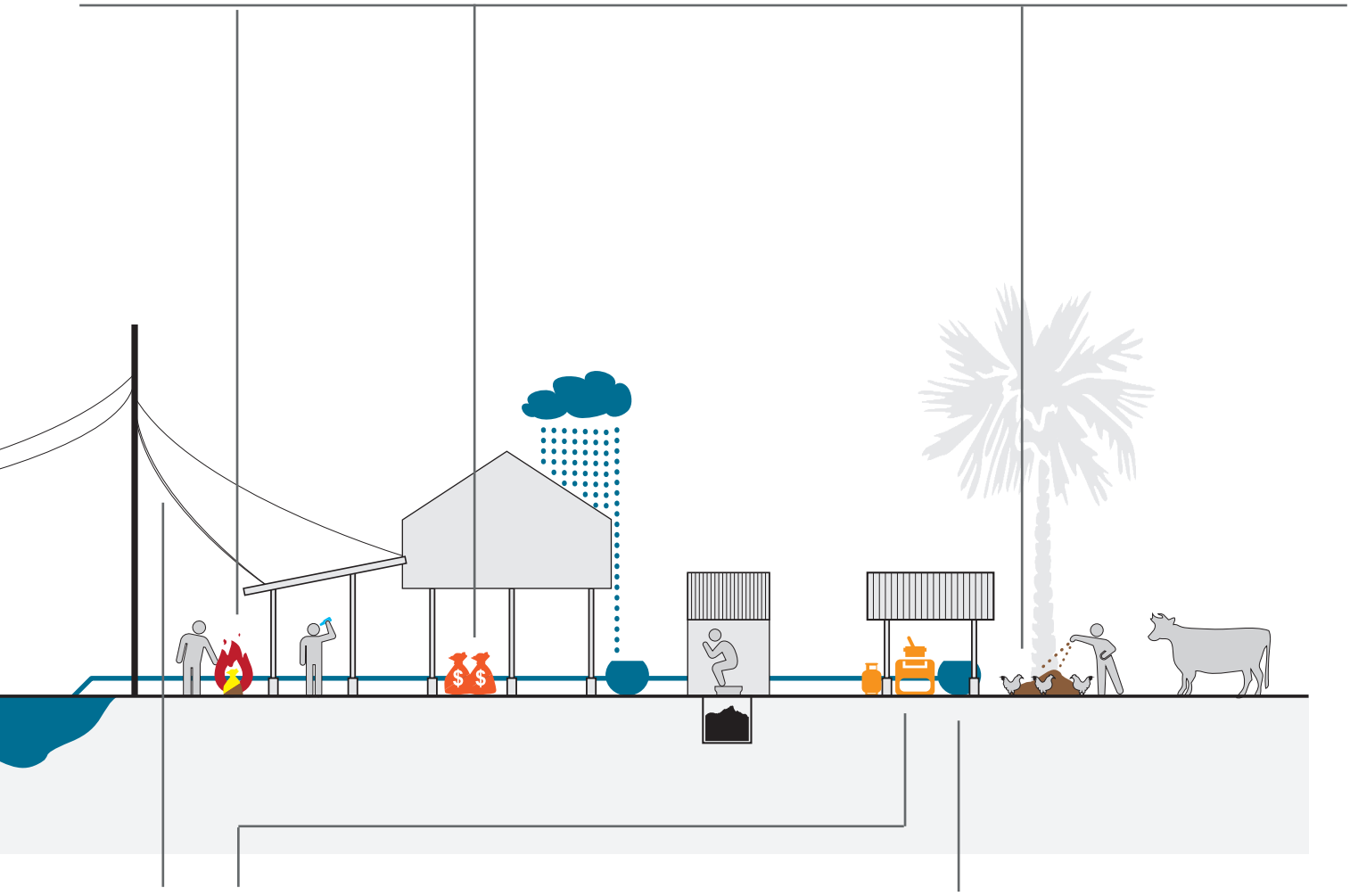
There is a variety of collection systems for black water in these areas since there is no connection to the central sewage system. In some cases the black water is collected in two pits. If one pit is filled, a pipe will lead the rest of the black water to the second pit. Some houses use single pits either with or without concrete structure. The concrete structure is important to avoid the infiltration into the soil. The pits are emptied manually or by trucks if people can afford it. If emptied manually the black water is directly applied on the fields.Untreated excreta on the field can lead to health problems because of the spreading of diseases.

Grey Water

Washing and showering is often done outside for the traditional Cambodian houses. Some of the concrete or brick buildings have their bathrooms inside. The grey water is disposed in the nature or the streets where it infiltrates the soil.

Waste Management

There is no waste collection service provided by the city administration, although by law these areas are within the boundries of the municipality. As a result people have their own ways of dealing with waste. The bio waste is separated and fed to the animals. The other wastes are burned on the street or next to the canals. The valuable waste (such as cans, bottles, metal, cardboards etc.) is set aside by the house owners which then is sold to the waste pickers. Some waste pickers collect the valuables with small vehicles (bicycles, handcarts, tuktuks etc.) and then sell it to bigger collection points.



Energy Supply

Electricity is distributed via overland cables from the central system. Burning wood is the main source used for cooking. It is replaced by electricity and gas in some households.

Water Supply - Drinking Water

While the water quality of the open water streams is not suitable for washing, it is far away from being drinkable. Unfortunately many people do not have another option for drinking water and drink the water untreated. However, some people also treat it when it is possible. The rain water is not stored in a hygenic way, that's why it is mostly not suitable as a drinking water. Additionally the drinking water is bought in bottles or barrels, by the families which can afford it.

Fig. 42: Current Infrastructure of the Rural Character Areas (Illustration and photos by the authors, *photo by Böhme 2014)

4.3.2. Rural Character Areas - Integrated Infrastructure Systems

The rural character areas have the longest distance to the existing infrastructure. Therefore, the chances of being connected to central supply in the near future are low. On the other hand, these areas have other positive attributes such as plenitude of space and self-dependence on own business or farming.Therefore, it is suitable to have on site treatment including a resource recovery on site. The products of the on site treatment, such as compost and water for irrigation, can be used on the fields directly. There are existing cases such as separation of bio waste to feed it to the animals.

In order to improve the living conditions, some alternatives need to be found for the near future. However, as the expectancy of change is high for the long term and there might be an urbanization and development process in this area, the long term plan should include the connection of rural character areas to central infrastructure, such as water supply.

The graphic on the right is giving an overview about the material flows that are dealt with in this area. The central treatments as waste collection are left out. The water supply is shown on the left side, while the decentralised treatment and reuse of the separated grey water, black water and organic waste is shown on the right.

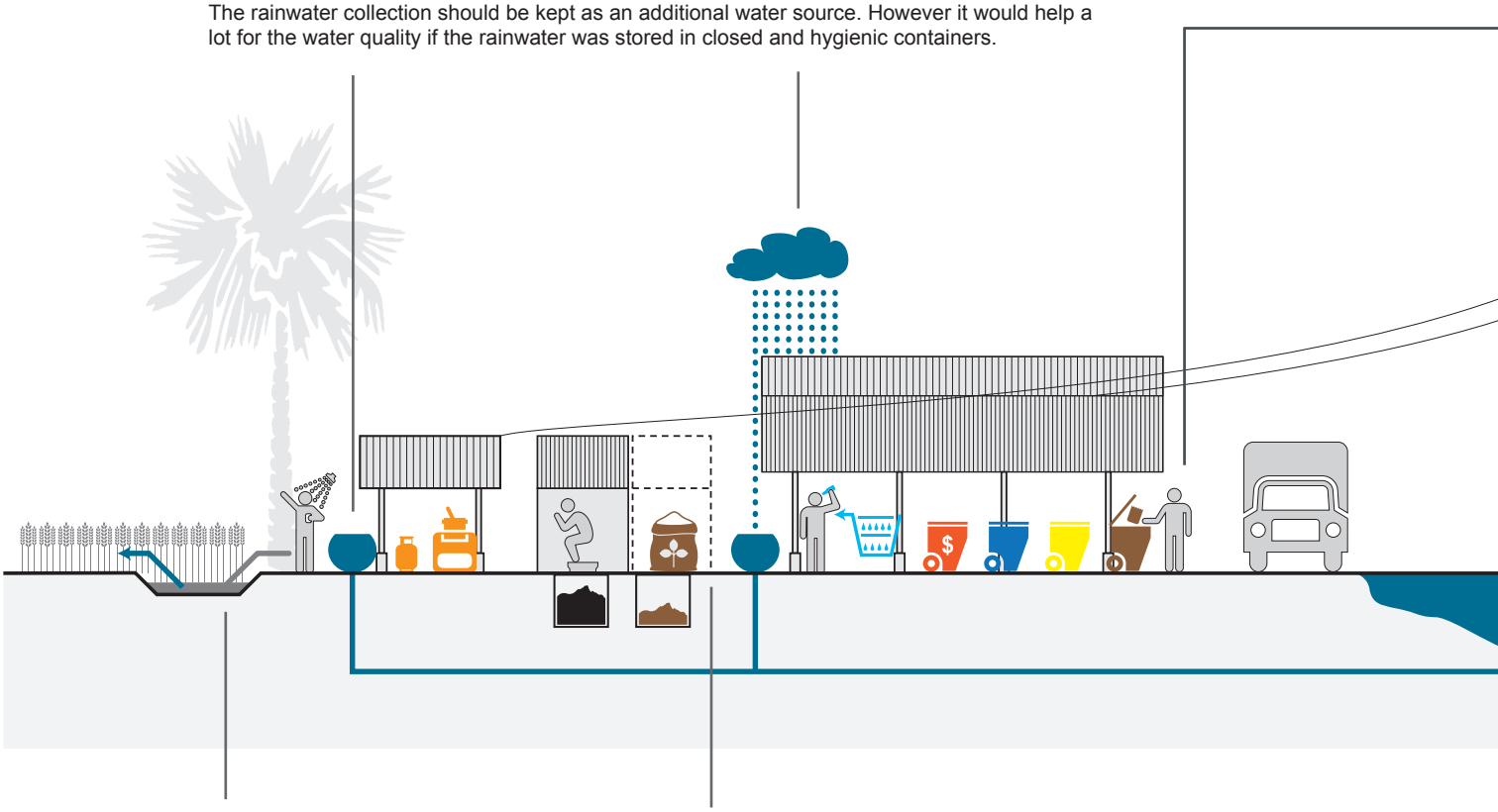
The diagram below presents an example situation, including the suggested treatment possibilities.

Water Supply

The rural character areas should be connected to the water supply centre in the long term. Till then, there needs to be some short term solutions. As the quality of the river water is even inadequate for showering, there could be a treatment of the river water on the household level to improve it to bathing water quality.

Families could have filters for the treatment. If they can't afford, it is also an option to have a community centre with a filter. Another option could be the provision of filters by the municipality.

The rainwater collection should be kept as an additional water source. However it would help a lot for the water quality if the rainwater was stored in closed and hygienic containers.



Grey Water

As there is enough space in the rural character areas, the grey water could be treated in constructed wetland. This is basically a field of plants with a gravel bed were the water is placed. These can be easily built. The water gets treated by filtering and micro-organisms. After a while, it will flow out of the wetland again and the quality is improved in a way that the water could be used for irrigation again.

Treatment of Excreta

The interface suggested for the rural character areas is the dry-composting toilet. The main benefit is the ability to apply the compost directly on the fields without any health risks, due to the treatment of composting during which the pathogens get killed. The farmers will therefore need less fertilizer and save some money. In addition, there are two pits already that can be used as an alternating pit. One of the pits is left alone for the composting process while the other pit is used and filled. The disadvantage is that the people cannot use flush water in the composting toilet and it can be very hard to change the habit of the users as they are currently using flush water. However the prospect of saving money could be a driving force.

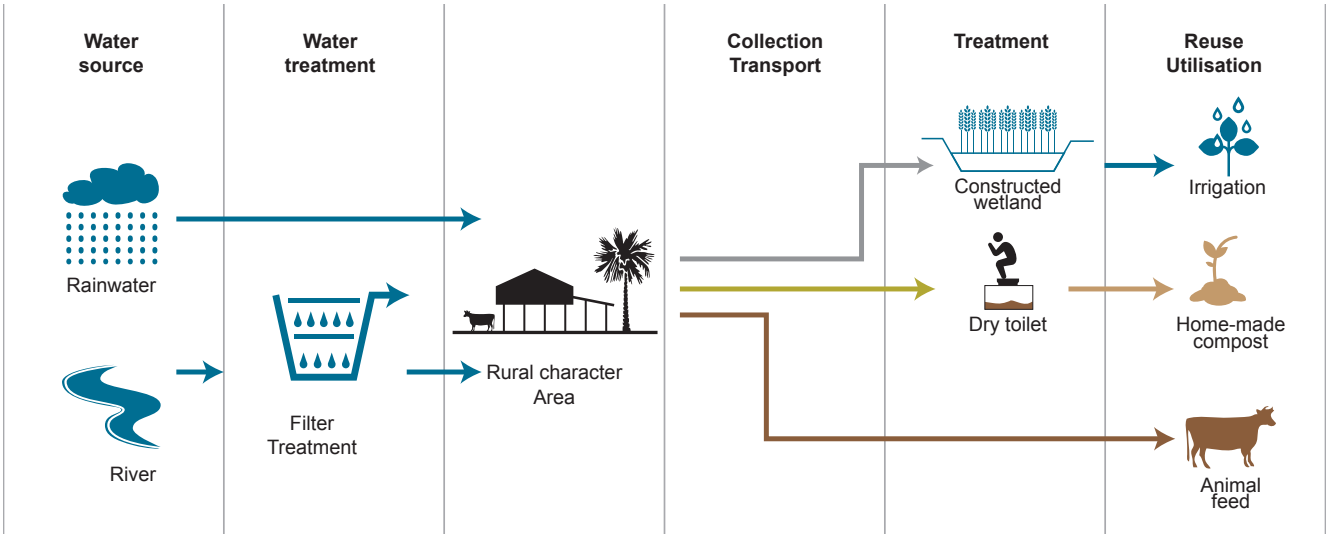


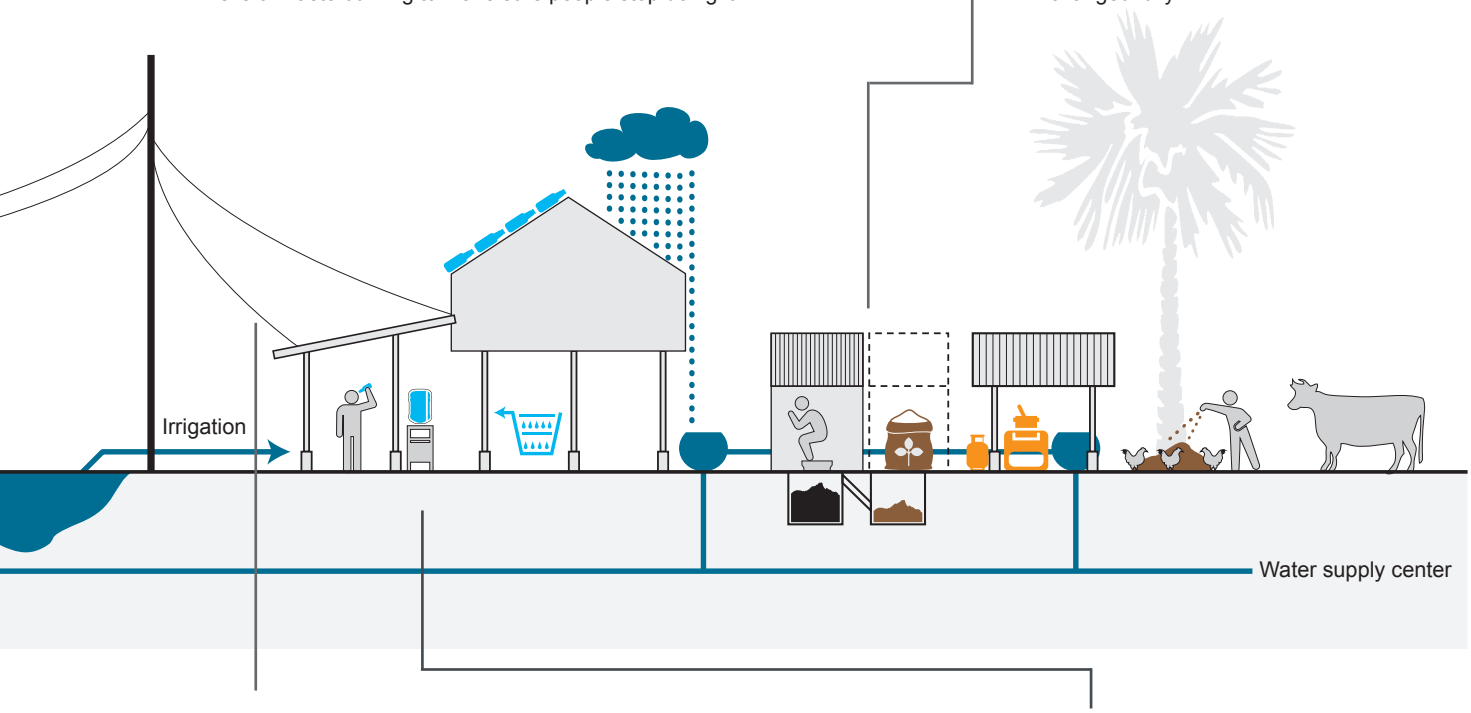
Fig. 44: Material Flow Chart of the Rural Character Areas (Illustration by the authors)

Waste Management

The bio waste is separated already to be fed to the animals. Parts of the bio waste could also be added to the composting toilets as a structural material. This will lead to an improved composting process. The valuables are picked out already which is also great for the separation of the waste. In general, the working conditions of the waste pickers could be improved. But this is something that should be done on a city scale. Rest of the waste should be picked up by CINTRI. In the rural character areas it could be useful to have some collection points to do that. It is also important that the people get an education considering the risks of waste burning to make sure people stop doing it.

User Interface

The squatting pans can be kept. It is an option that the urine is separated as well to use the urine on the field. With the simple treatment step of storing the urine it becomes sanitised and can be applied on the field as a rare phosphor source. To do this the toilets would need to be changed from normal squatting pans to urine separation pans. This could be an alternative system for some cases only since the toilet habits cannot be changed fully.



Energy Supply

Like in all the other areas the security of the energy supply could be improved but the overall connection of houses to the electricity system is good.

Storm Water

There are no easy options to prevent the storm water from getting mixed with the surface water. However, if the situation in the city is improved, the storm water will be less polluted since the waste water would be separated and well treated. Therefore, the pollution of the surface water would be decreased to a certain level.

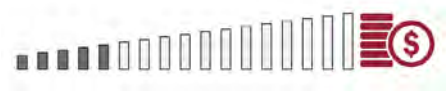
Water Supply - Drinking Water

As a lot of people cannot afford to buy drinking water, there needs to be other solutions for the rural areas. There are a lot of options of treating water on the household level to make it drinkable. One possibility which does not require any additional equipment, except the standard things that can be found in the kitchen, is the boiling. However, this takes up a lot of energy. Therefore, other treatments such as filtering or reverse osmosis would be useful. If people cannot afford, there is the same possibility as for the bathing water: to have a community supply centre or subsidies for the treatment devices. Another practical method would be UV treatment by placing water in transparent bottles on the roof.

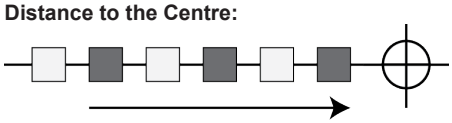
Fig. 43: Integrated Infrastructure System of the Rural Character Areas (Illustration by the authors)

4.4. Impermanent Informal Settlements

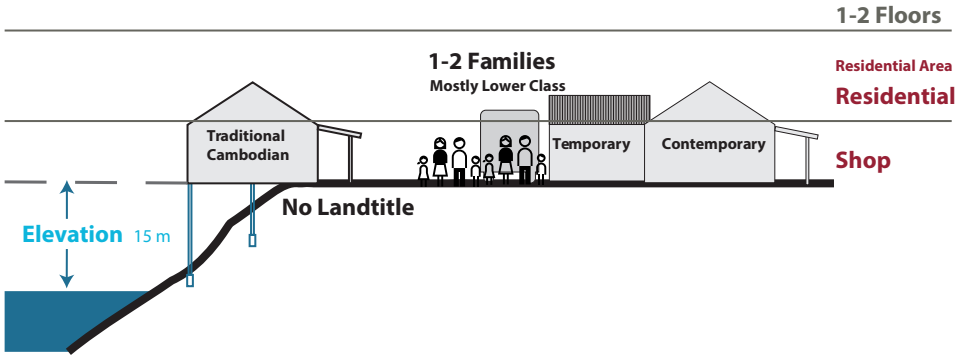
Income Level:



Distance to the Centre:



House/Plot Ratio:
Since there is no formal cadastral system and legal landtitles, it is hard to define a house/plot ratio for the informal settlements.



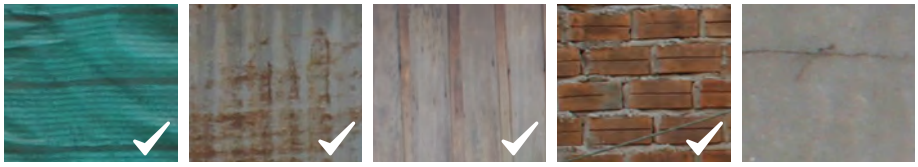
Introduction

Battambang Municipality has various solutions and policies for the informal settlements, including providing a landtitle. The typology that is defined here consists of the informal settlements with no possibility to get a title due to the fact that they are settled on high-risk, state public, state private and developing land or in pagodas. These informal settlements are planned to be relocated but still require temporary solutions to improve the living conditions. The housing typology varies, including temporary structures, traditional wooden houses and sometimes concrete buildings, shared by 1-2 families. The focus should be on the poor, since they suffer the most from the lack of infrastructure and they have the highest concern about their future of living on state public or private land.

Community Structure

The informal settlements have the strongest community structure with neighbourhood co-operations, saving groups, community centres and representatives.

Housing Typologies

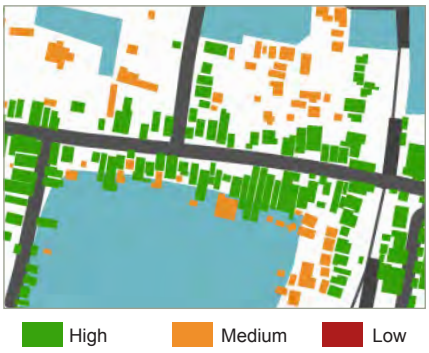


plastic | metal | wood | brick | concrete

Since it is forbidden by law to build up concrete structures, most houses are made of short-term materials like wood. Households have improvised with any material available, including plastic. Use of concrete is rare.

Accessibility

The accessibility of the informal settlements vary since they‘re scattered all around the city. The ones located in the inner city, especially along the road corridors, have a high accessibility. The accessibility gets lower when the distance to the roads gets higher. It is hard to reach to some settlements located along the railway tracks.

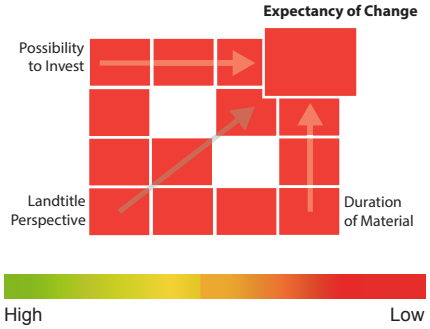


Living Conditions

The living conditions are very low in the informal settlements. These settlements are on high-risk land, which endangers the inhabitants while natural disasters, like floods, destroy the houses regularly. Public services are limited since the municipality has no legal responsibility for these areas. Providing adequate conditions for people is not possible and only some minor changes can be done to ease the problems in the short-term. Income level is another factor for the quality of life, while 66 percent of inhabitants live on one US dollar or less (Informal Settl. Survey 2009)

Expectancy of Change

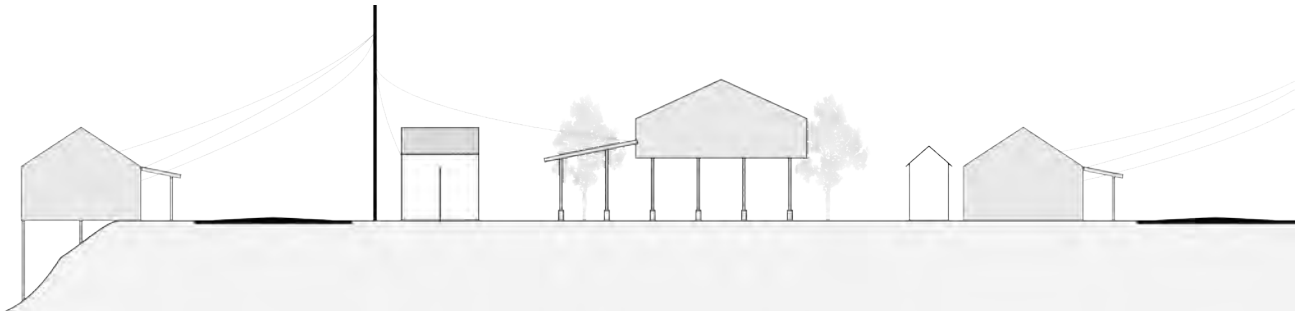
The expectancy of change is really low for the informal settlements since there won‘t be any improvement for the residents until they are relocated. Until a rapid change, which is the relocation process, the informal settlements will mostly stay as they are. Only small improvements can be done to increase the quality of life.



Urban Morphology and Density

The urban morphology of the informal settlements vary a lot. While some informal clusters are located in publicly-used land (such as the gardens of pagodas and schools), some of them create areas in the size of a neighbourhood. The common point of all of them is the unplanned urban structure. The road network does not reach to the inner areas of the informal settlements which is problematic for the accessibility and the provision of basic services. The density is high since every piece of land is used.

Section



Chances and Possibilities

- Low-budget investments with high benefits need to be implemented to serve the low-income groups
- Since the informal settlements will be relocated in the near future, short term solutions rather than big scale investments, are required.
- The lack big scale investments in infrastructure creates the opportunity to introduce new systems and technologies (Lüthi et al. 2011).
- Due to the high demand, there is a great potential to build up community structures. This can lead to commune sanitation and commune management systems.

Fig. 45: Urban Analysis of the Impermanent Informal Settlements (Illustration and photos by the authors, *photo by TWG 2010)

4.4.1. Impermanent Informal Settlements - Current Situation

Informal settlements can be found in all parts of the municipality. Therefore, the access to infrastructure and resources can vary a lot. The closer the settlement is located to the inner city, the higher is the change of having a supply. The settlement shown here is located directly at a river site. It shows examples for different infrastructure options in one diagram, which most likely wouldn't be found in this combination in the actual settlements.

Storm Water and Flooding

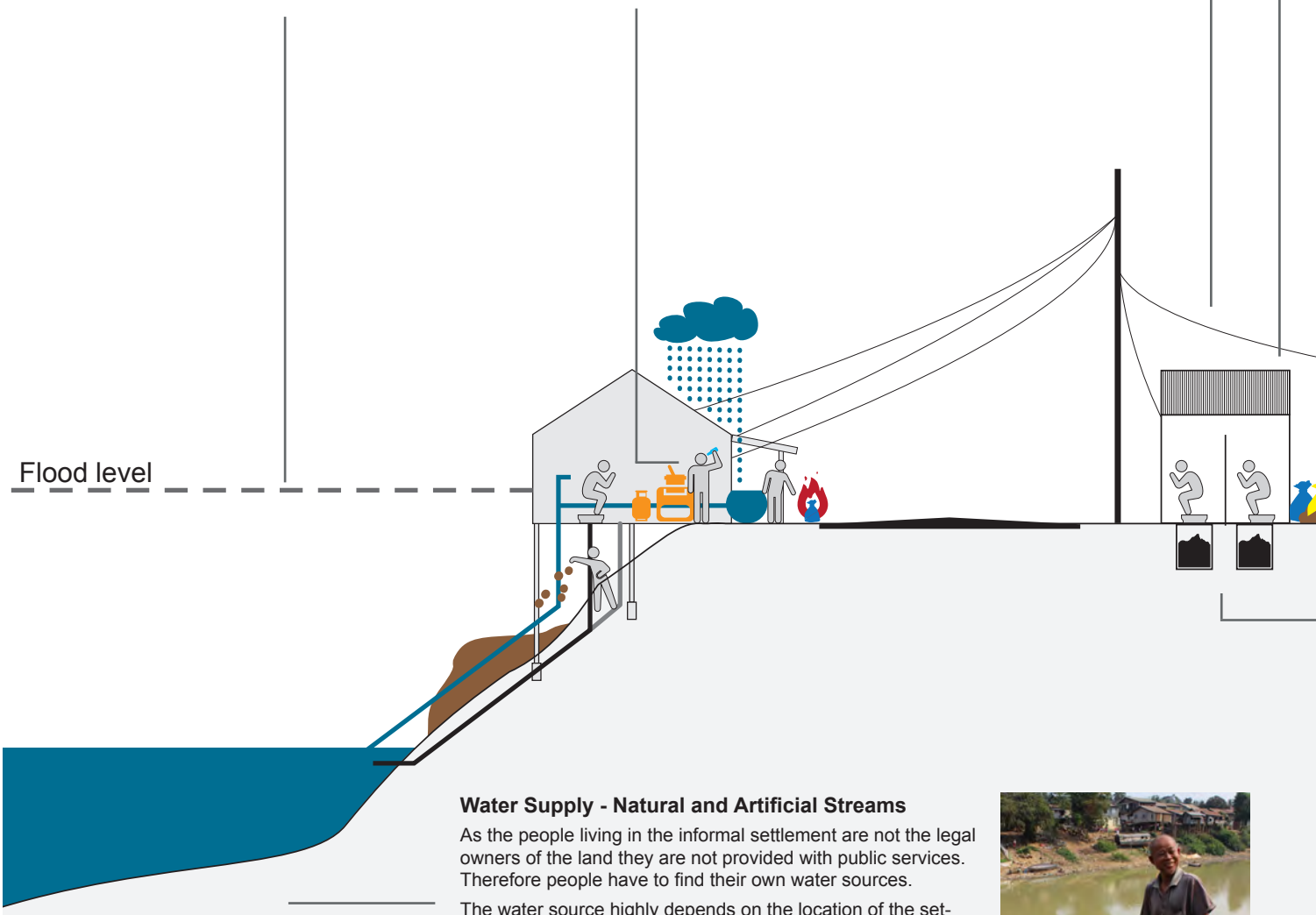
Some of the informal settlements are built in high risk areas where the houses can be flooded regularly. Although the life of the people living there is in danger, the people have no possibility to move somewhere else. The municipality is working on the relocations sites but the number of informal settlements is too high to move everybody at once. Till then there is no infrastructure to protect the people and houses against the flood.

Energy Supply

The only service provided to the majority of the households is the electricity. Over two thirds of the houses are connected to the public provided electricity (Battambang Municipality 2010). Other energy sources used are wood and gas for cooking, kerosene lamps, batteries and generators for lightning.

Water Supply - Drinking Water

Providing drinking water for the informal settlement is a major concern, as most people have no access to clean water at the moment. Due to the lack of other options, a lot of people have to drink untreated rain and river water. This leads to wide spread diseases as diarrhea. To solve this problem, some of the communities implemented decentralized water supply centres where they treat river water. However, this is not the norm. Only some people can afford to buy drinking water in bottles and barrels.



Water Supply - Natural and Artificial Streams

As the people living in the informal settlement are not the legal owners of the land they are not provided with public services. Therefore people have to find their own water sources.

The water source highly depends on the location of the settlements as some are located in high risk areas directly along the river and some have longer distances to existing water streams. Households that are close to the **river or artificial streams** will use pumps or buckets to get the water into their houses. However, there is the same problem with the treatment as in the rural character areas. Often the water doesn't get treated because of the lack of finance and knowledge which can cause health problems.

User Interface

As the informal settlement can differ a lot depending on the location, also the types of toilets can vary. Both squatting pans and western style toilets are used. There are also many people that cannot afford having their own toilet. Therefore about 17% of the residents use open defecation instead of a toilet (Battambang Municipality 2010). In some settlements there are public toilets to prevent the open defecation.

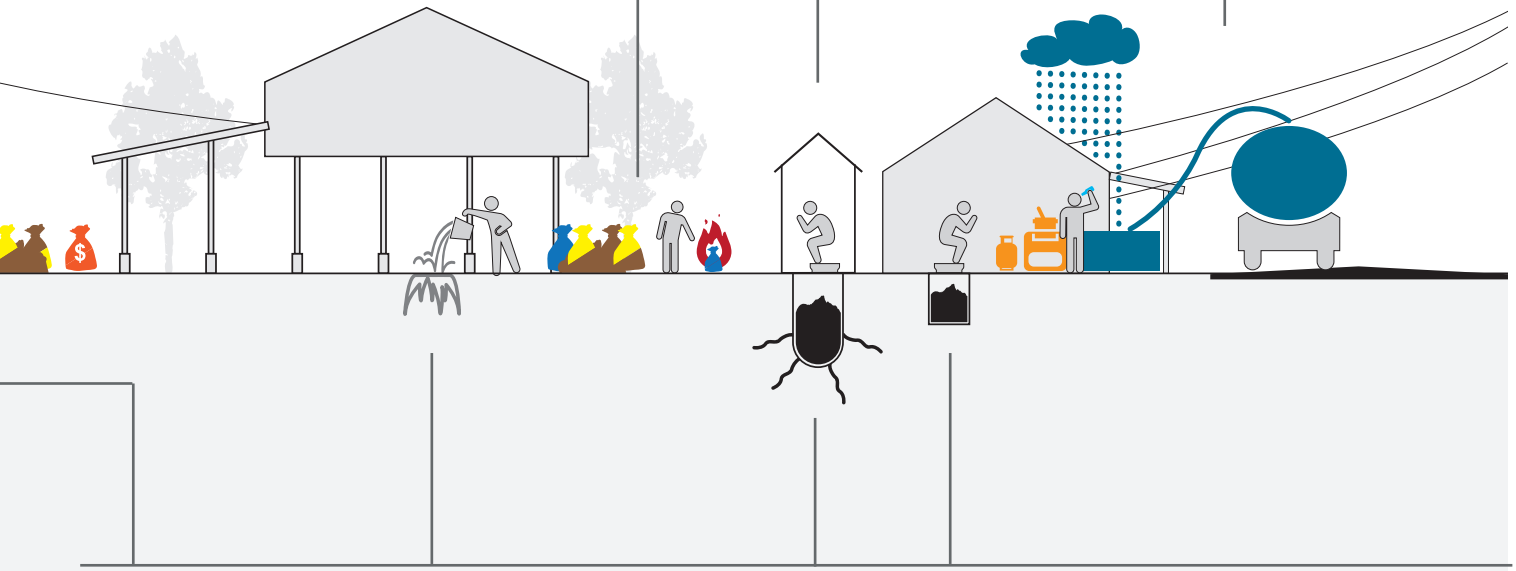
Waste Management

There is no collection of the waste organised by the municipality. Therefore the people need to find other ways of how to deal with their waste. The most commonly practice, which is used by 60%, is burning the waste. Especially in the densely populated informal settlements this causes the problem that the people get in the direct contact to the toxic fumes emitted by the burning. Furthermore the environment is polluted by the open dumping of the waste. This is practised by 15% of the inhabitants (Battambang Municipality 2010). About 13% of the people are able to have the waste collected. Often those people bring their waste to the collection points of the formal settlements.

Water Supply - Rain water & trucks

In addition to pumping water out of natural and artificial streams, households also collect **rain water**. However, this is only a continious source of water during the rainy season, as there might be no rain at all in the dry season.

If people can afford it they will also buy water from the **tanker trucks**. However in the informal settlements with no prospect to a land title this is very unlikely.



Waste Water

For the waste collection it is the same as for the water supply. The people in the informal settlements are not entitled to be provided with service; therefore less than 3% are connected to the central sewage system (Battambang Municipality 2010). Also the options for an adequate treatment are limited due to the lack of finance and space. As a result, black water is often collected in simple pits that do not always have a concrete ring to prevent the infiltration into the soil. This is the case for 60% of the toilets (Battambang Municipality 2010). They are emptied by a truck or manually or in some cases just left as they are when they are full. In areas that are located close to the river site the black water is disposed in the river directly. As the black water is not treated before, it is a high pollutant of the river. This is not only dangerous for the environment of the river but also for the people living there as they use the river water for drinking.

The grey water is mostly disposed on the streets to drain into the ground. Some people also empty it into the toilets, but this is not the case for pit latrines.

Fig. 46: Current Infrastructure of the Impermanent Informal Settlements (Illustration and photos by the authors, *photos by TWG 2010 & Böhme 2014)

4.4.2. Impermanent Informal Settlements - Integrated Infrastructure Systems

The informal settlements are located all over the city. Also the density and access to infrastructure can vary a lot. All the informal settlements with no prospect to become a land title have a low expectancy of change and there will be almost no investments made. In addition, there is not going to be an official connection to central infrastructure. Hence, it is very difficult to improve the situation for the people living there. The people will sooner or later be relocated and there is no need or sense in building a long-term infrastructure. Therefore, the technical improvements need to be short-term and cheap, as well as made of movable construction material.

The suggestions given here are aiming to ease the problems and improve living conditions in the informal settlements. No system will work perfectly as the conditions are really difficult.

The flow chart on the right is showing possibilities to deal with the resources. Only some of the existing material flows are given. The water supply is shown on the left side and waste water and bio waste on the right side. The treatment for these is both central and decentral.

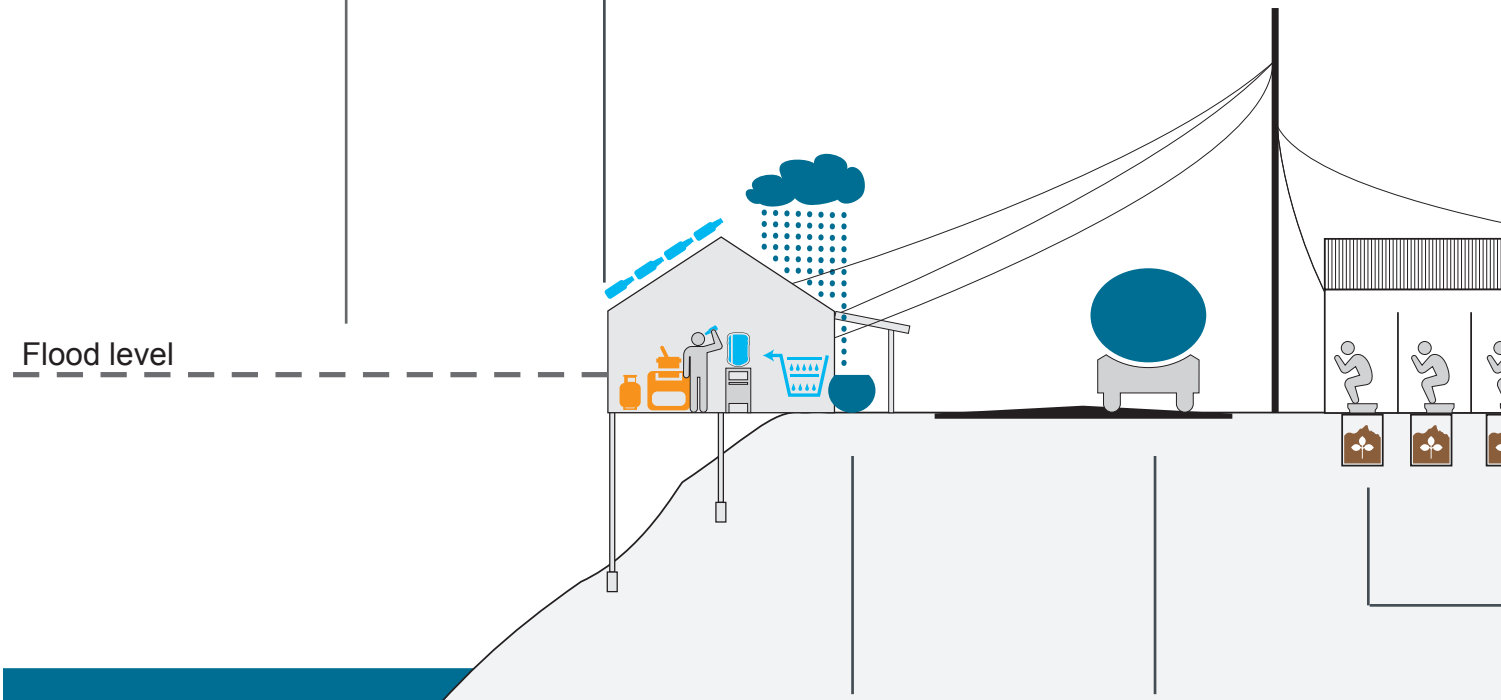
The diagram below shows examples and combinations of suggestions to improve the situation.

Storm Water and Flooding

As there is real danger for people living in the high risk flooding areas they should have a high priority to be moved somewhere else. The municipality is working on relocations sides for those people. However, the number those high risk areas is high so it will take some time until everybody is moved.

Water Supply - Drinking Water

As a lot of people cannot afford to buy drinking water there need to be alternative solutions for the informal settlements. The simplest and cheapest option would be to treat the water with UV light on the roof. This can be done by placing water in transparent bottles on the roof. Furthermore, the building of community filtering station could be enhanced. These stations could be funded or subsidised by the municipality. In this way, every household doesn't need to have its own treatment facility. There are more options for treatment which are further described in the next chapter. In general, the support for the treatment should be accompanied by education programs about the risks of drinking untreated water and the ways to treat it.



Water Supply

Improvement of the water supply is crucial for the informal settlements. The informal settlements so not have the legal right to be connected to the water supply centre. Therefore, there needs to be an alternative source. Filtered water from the river or collected rain water would be suitable for applications like washing and showering. However, not every household will be able to have their own filter treatment. Shared filters for the community could be an option there. To guarantee at least a minimum standard, the municipality could also provide water with a movable tank.

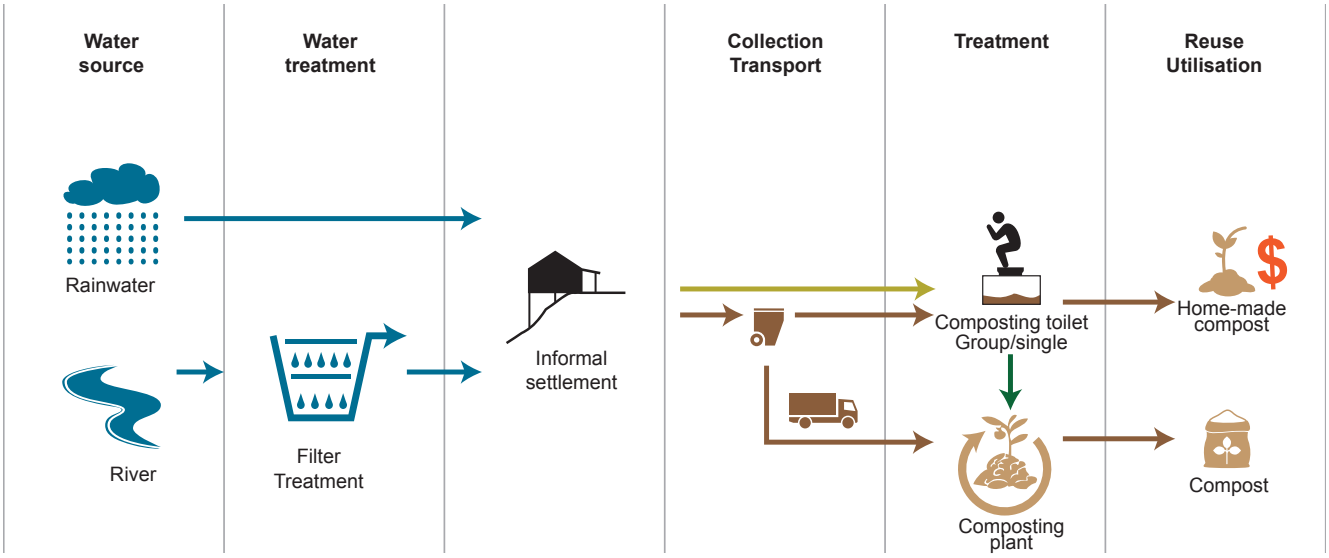


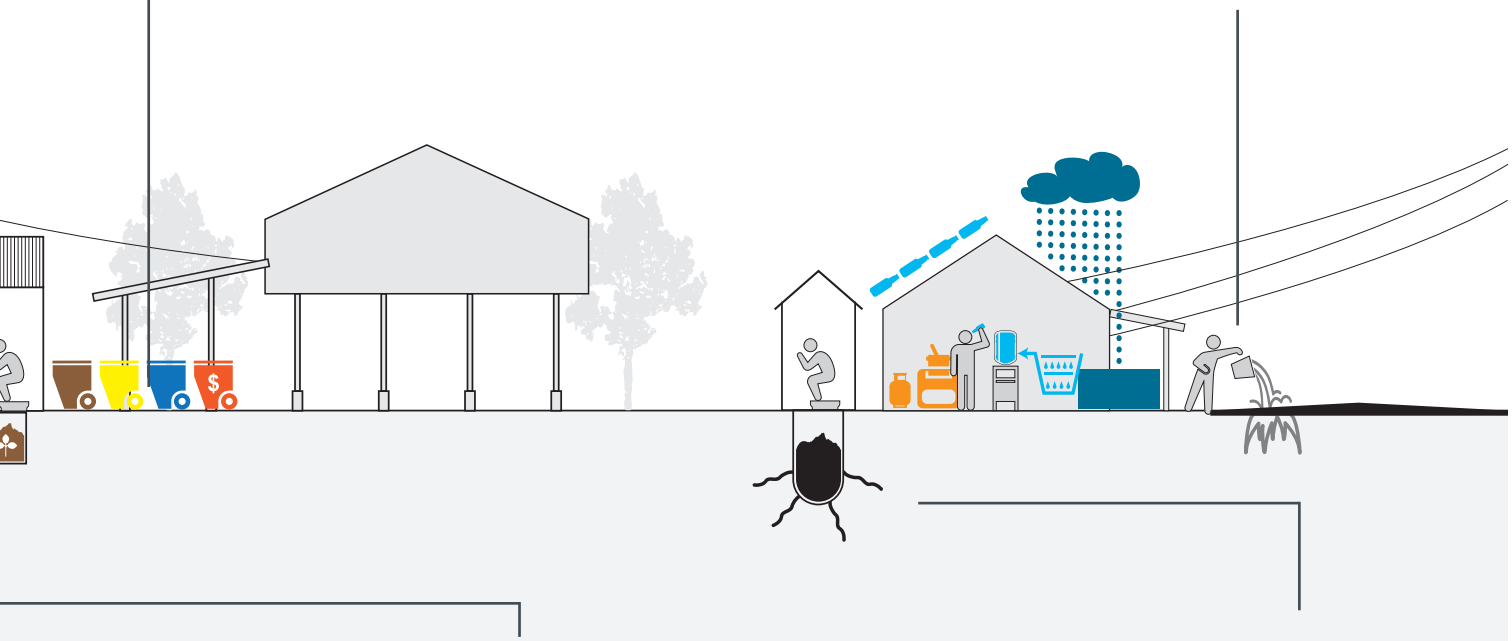
Fig. 48: Material Flow Chart of the Impermanent Informal Settlements (Illustration by the authors)

Waste Management

There won't be a complete collection service in the informal settlements. Therefore, the existing collection points would be an option to deal with the waste, as some people already bring their waste to the collection points of the surrounding areas. Some of the organic waste could be added to the composting toilets as a good structural material. It will improve the composting process. The separation of the valuables as well as the products of the composting process are also beneficial for the people, as they are able to get some money by selling them to the waste collectors and the farmers. An education programme about the environmental and health problems related to waste and waste burning is also required.

Grey Water

As the grey water is not highly polluted, the need for treatment is not high. Therefore a short term option could be simply the disposal in soakaways (holes in the ground for the infiltration of the water, often filled with gravel) or on the streets so that the possibility of water mixing with the open water streams is lower (due to evaporation and infiltration). There are other options to treat the grey water, but the treatment of the grey water is not a priority for these areas.



Treatment of Excreta

As the conditions differ from settlement to settlement, depending on their location in the city, different technical options are suggested. Community composting toilets could be a good option for the areas with some free space. The main benefits of this system are creating an alternative for having toilets in every household and the collection of the excreta resulting with profit from the compost. These are good driving factors for the people to keep the composting toilets. There would be the need of investment or subsidies from the municipality, as well as support from the NGOs. This is needed since most of the people in those settlements have economic constraints. However, community toilets can also bear safety risks. Furthermore the maintenance is an issue with public toilets. The people need to be motivated to keep the toilets clean and not to use flush water. The latter one might be the biggest challenge as it is hard to change the cultural habits. There will be the need to organize transportation manually as there is not much space inside the settlement for motorized transportation. If nothing else is possible, the pit latrine should be used as it is which a better option than the open defecation. The pits might even last long enough until the people are relocated.

User Interface

For the composting toilets and pit latrines it is possible to use squatting pans. However the use of flushing water will not be possible for the composting toilets.

Energy Supply

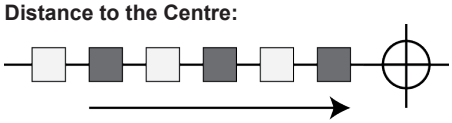
Since the households have no legal right for getting central services, the electricity system cannot be improved. Existing alternative energy sources can be supported.

Fig. 47: Integrated Infrastructure System of the Impermanent Informal Settlements (Illustration by the authors)

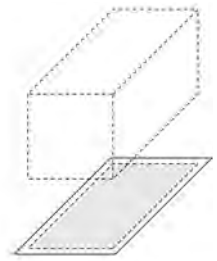
4.5. Non-Residential Buildings - Boeung Chuk Market Example

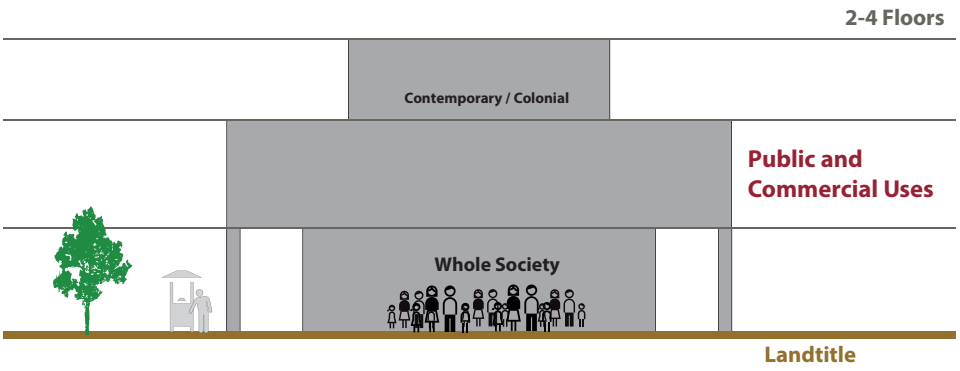
Income Level:

Distance to the Centre:



House/Plot Ratio:
The example of the market takes 100 percent of the plot while the plot size is 50x130 meters. This ratio varies in different non-residential buildings.





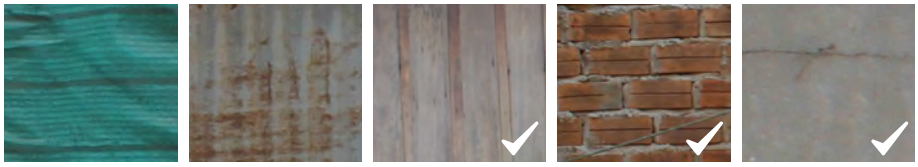
Introduction

Non-residential buildings include publicly and commercially used facilities such as schools, hospitals, markets, tourism facilities, office buildings etc. These buildings are mostly landmarks for the city and frequently used by the whole society. The users vary from high to low income groups. Since they are frequented by thousands of users daily, these buildings have 'a key role to play in awareness creation and systems exposure for piloting innovations' (Lüthi et al. 2011). The example of the Boeung Chuk Market was selected for this part since it was taken as a case study during the iReBa Workshop in Battambang.

Community Structure

Since they are used by the whole society and have a vital role for the public life of the city, non-residential buildings are good starting points for the community involvement and can be used as means for public participation.

Public Buildings

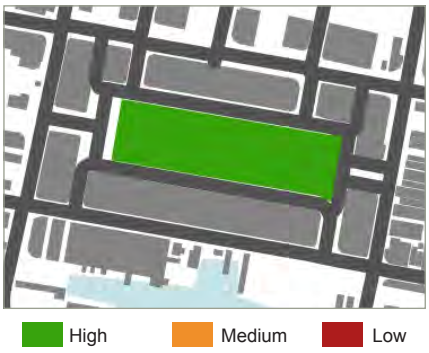


plastic | metal | wood | brick | concrete

The non-residential buildings, including the Boeung Chuk Market, are mostly constructed by durable material like concrete and brick. Wood is also used in some traditional structures, like pagodas and some schools.

Accessibility

Accessibility of the non-residential buildings is mostly high since they are well-served by the central systems, including road infrastructure. While some are located in important junctions and the inner city, the ones further from the central areas still have a well-connected location. This is a plus since they ought to be accessible for everyone.

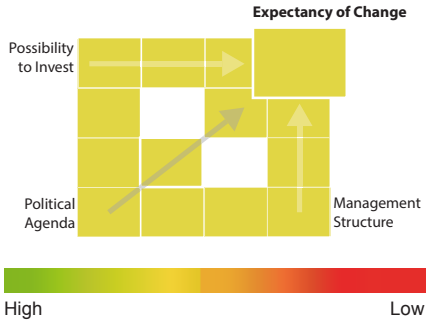


Living and Working Environment

Non-residential buildings like schools, markets or offices can become a role model for a good living environment. Public buildings can also compensate missing infrastructure and serve the poor. The hygiene conditions should be good because of the high infection risk related to the high frequency, although often it´s not properly organised. The improvement of the living and working environment in the non-residential buildings would improve the conditions in the whole city since they are role models for all and used frequently by almost everyone.

Expectancy of Change

The expectancy of change is medium for the non-residential buildings due to three factors: possibility to invest, political agenda and management structure. Although there is a big potential, these tools are not being used efficiently. With the help of the political agenda, possibility to invest and the management structure can be improved.



Urban Morphology and Density

The non-residential buildings are scattered all around the city while their common attribute is shaping the area that they are located. As for the example of the market, the public buildings become the main hub for the activities surrounding them. The market is a commercial entity, as well as a meeting point and a socialization place. The public uses also create a potential for the area to develop further. The existence of a public building enhances the improvement of the area it is located in.

Section

Chances and Possibilities

- Due to the high amount of users, non-residential buildings offer the opportunity to implement new ideas and systems which could not be implemented at home.
- These buildings are highly frequented thus they can be used to educate people and to introduce new systems to the citizens.
- Schools can play a special role in changing the habits of the society and to make the future generation aware of environ mental problems as well as the causes.
- Non-residential buildings can also be used for pilot projects regarding financing and management structures (Lüthi et al. 2011).

Fig. 49: Urban Analysis of the Non-Residential Buildings (Illustration and photos by the authors)

4.5.1. Non- Residential Buildings: Boeung Chuk Market - Current Situation

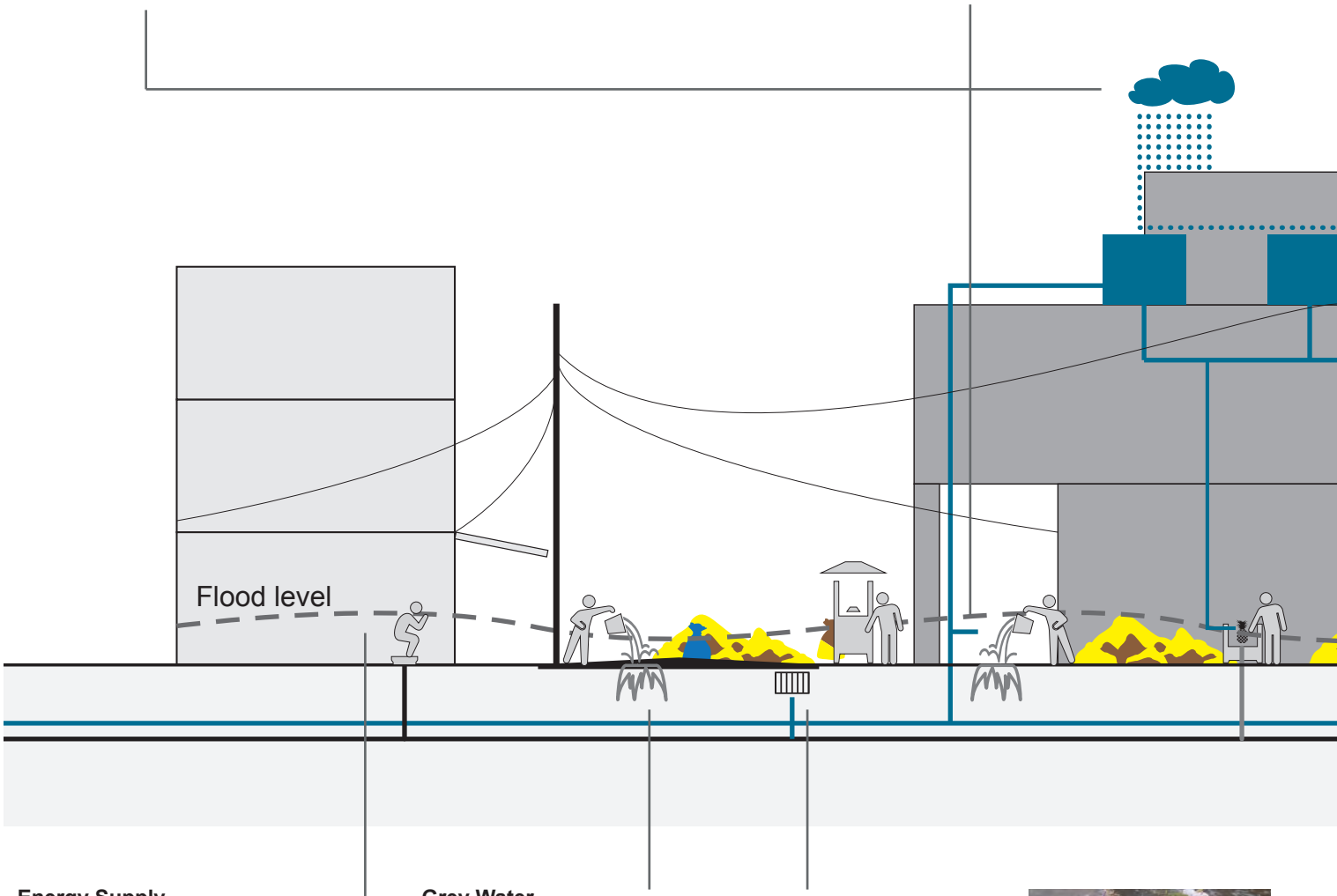
The infrastructure provided for the non-residential buildings is highly dependent on the location. Buildings in the inner city will generally have a better connection than the ones located in the outer city. The Boeung Chuk Market, which was taken as an example, is located in the inner city and has an overall good supply. Furthermore it is already a part of a project from COMPED which deals with the separation of bio waste and the promotion and process of composting (COMPED 2013).

Water Supply

As the market is located in the inner city part it is connected to the water supply centre. The second water source is the collection of rainwater which is collected on the roof in gutters and stored in tanks on the roof. Together with the storage in the basement it the tanks have a total volume of 4.000l. These tanks can be also filled with the water from the central supply system. Hence there is never a water shortage in the market, even when the supply by the pipe is interrupted for a while.

Water Distribution

In general, the shops do not have a water connection directly in their shops. In total there are 3 distribution points in the market which are mainly located on the ground floor. Additionally, the toilets on both the ground level and the first floor do have water connection. Thus the shop owners have to carry the water needed in buckets to the shops. For an amount of 20 litres they need to pay 100R.



Energy Supply

Boeung Chuk market, as well as most of the public buildings, have connection to the central electricity supply centre. Electricity is distributed via overland cables from the central system.

Grey Water

There is no disposal system for grey water inside the building, not even wash basins for washing the hands in the toilets. Therefore the people have to bring the grey water from the shops outside where it is disposed on the streets into the shafts connected to the sewer system. However, the shafts and pipes are often blocked by piles of waste so that the water stays on the street. The cost of cleaning the pipes is 10$ per meter which is quite high, according to the market owner.

Storm Water

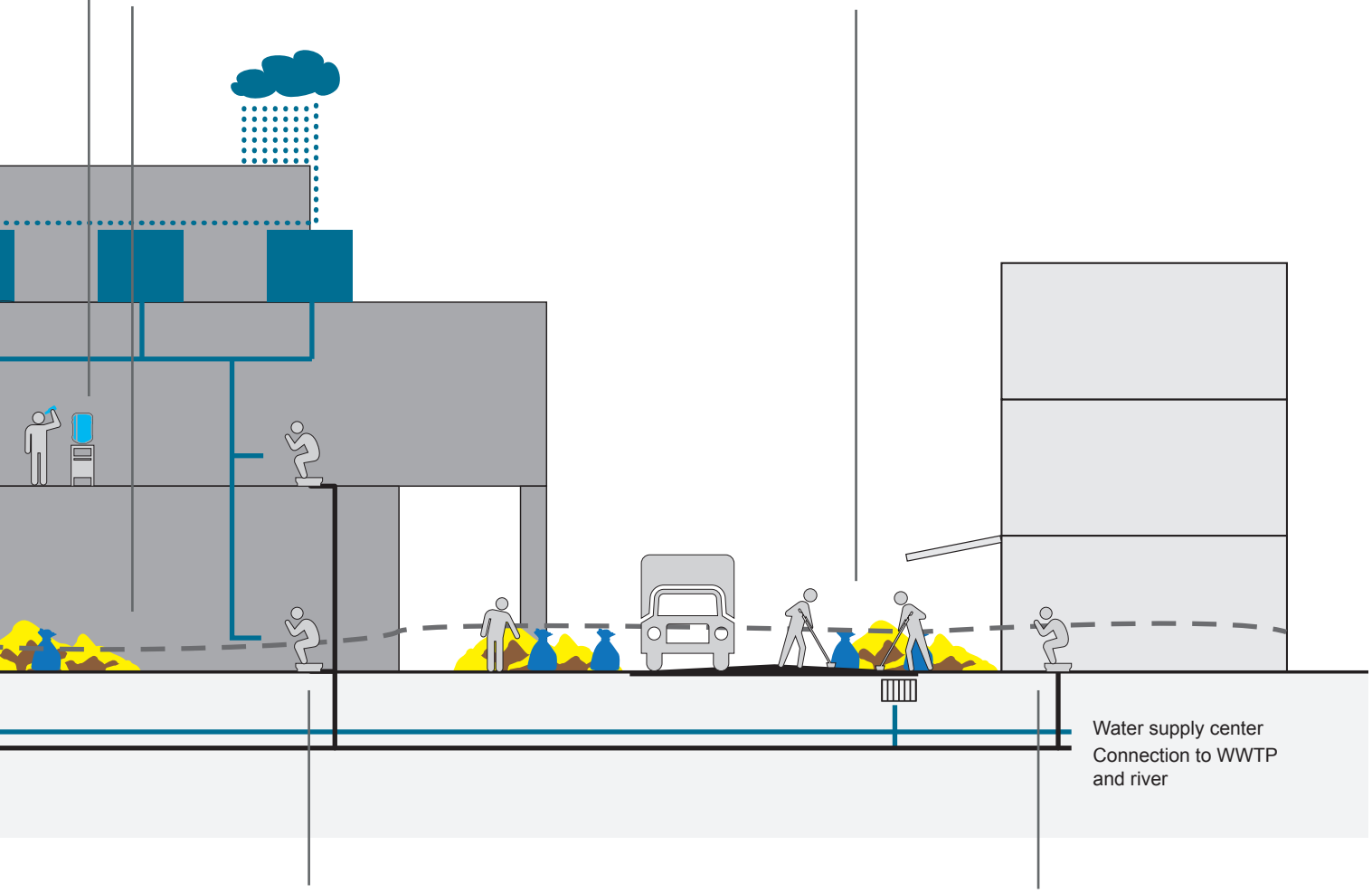
The market is located in an area that is flooded every year. The area used to be a lake that was filled with sand and nowadays it is still lower than the surrounding area. Therefore the water is coming in through the pipes from the river during rainy season. The water is highly polluted as it is mixed with the waste water from the market. In 2013 the water level was 30 cm above ground and the market was closed for 10 days as no customers were coming to the flooded building.

Water Supply - Drinking Water

There is no supply of drinking water directly in the market. Therefore, the shop owners have to buy bottled drinking water themselves.

Waste Management

The waste is collected by the NGO named COMPED as a part of a project working on the separation of bio waste. Inside the market there are a few small bins, but they are not suitable for the amount of waste that is produced. The shop owners throw their waste just somewhere on the street, sometimes packed in plastic bags or loose. In addition, there are no designated collection areas hence the waste is all over the streets and is even more spread by vehicles running over it. This is not only problematic for the collection, it is also very disturbing for customers and disadvantageous for the attraction of people visiting the market. The streets then get swept by the waste collectors. They collect the waste in waste bins with wheels which are emptied into the trucks. The trucks bring the waste to the composting centre where the bio waste is separated. This is done manually by spreading the waste on the floor and picking out the unwanted parts as the plastic. The bio waste is then used for the composting. Everything except the bio waste is brought to the dumpsite right next to the composting centre. The waste is collected three times a day at the market.



User Interface and Black Water

The Boeung Chuk Market has 9 toilets in total which are owned by a private company. The user interface is always a squatting pan with a pour flushing system. To use the toilets costs between 300R for the older ones on the first floor and 500R for the newer ones on the ground floor. Often the shop owners also use toilets of the surrounding houses where they have to pay about 500R as well. The toilets are connected to the sewer system directly, hence the black water is going to the central treatment.

Fig. 50: Current Infrastructure of the Non-Residential Buildings (Illustration and photos by the authors)

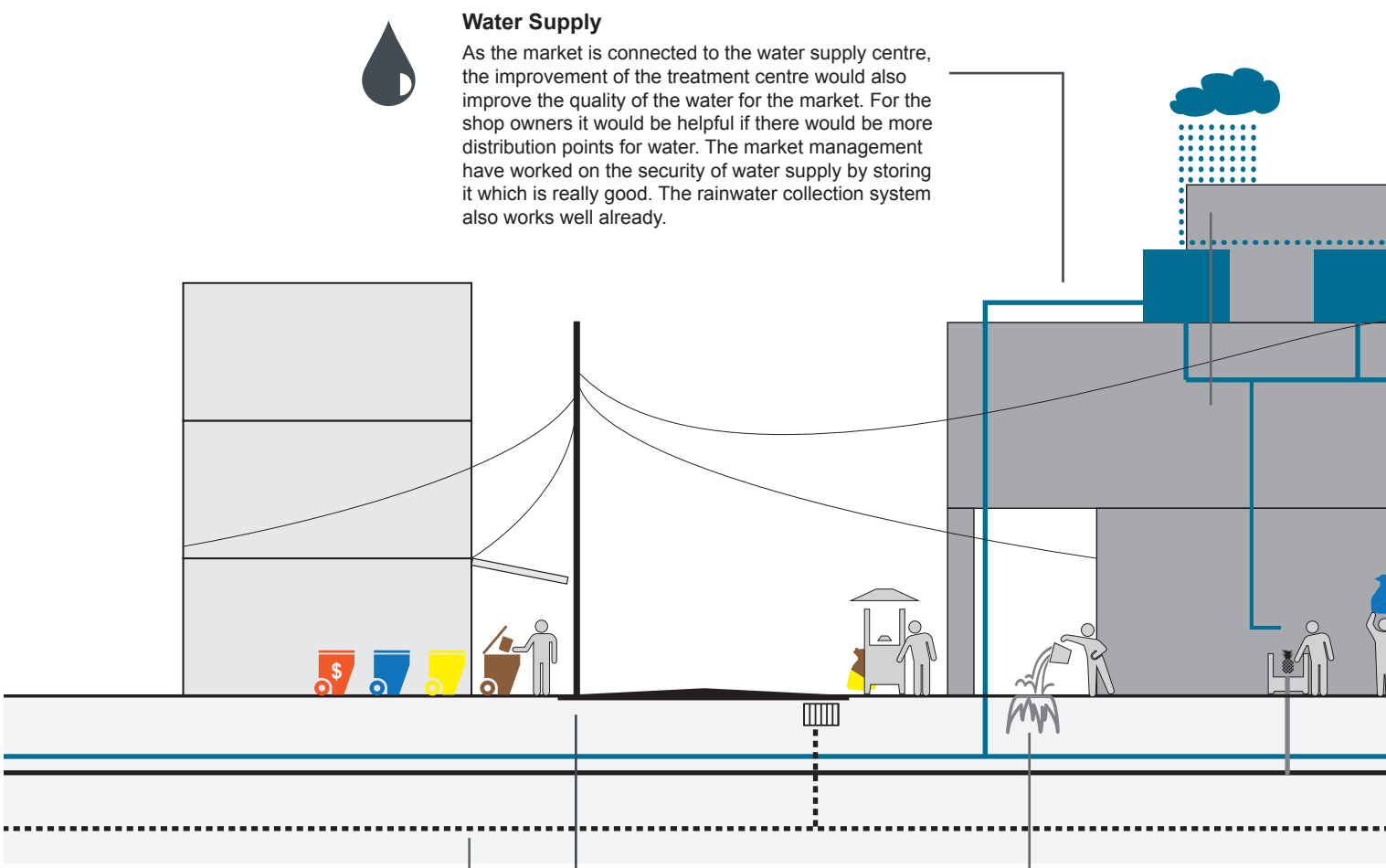
4.5.2. Non- Residential Buildings: Boeung Chuk Market - Infrastructure Systems

The infrastructure used in non-governmental buildings depends on the infrastructure used in the area they are located in. What is also important is the space that is available around the buildings. Buildings located in the city centre should be connected to the central water supply and central waste water treatment. If there are buildings with enough space, it could be an option that they get their own biogas plant or their own drinking water treatment facility. In the case of schools and universities, the implementation could also be supported by the education of the students and pupils. This is the case at the University of Battambang, where they have their own drinking water treatment. Therefore, non-residential buildings are also a good starting point to introduce innovative technologies.

In the case of the Boeung Chuk Market, the improvement of the infrastructure should be similar to the inner city areas. As there is not much space in and around the market, it will be the best to keep the connection to the central infrastructure.

The flowchart on the right shows some of the material flows of the market. It includes the water supply on the left side and the waste water and bio waste on the right side, with the central treatments.

The diagram below shows the market with a variety of improvement possibilities.



Water Supply

As the market is connected to the water supply centre, the improvement of the treatment centre would also improve the quality of the water for the market. For the shop owners it would be helpful if there would be more distribution points for water. The market management have worked on the security of water supply by storing it which is really good. The rainwater collection system also works well already.

Storm Water

The implementation of a second sewer system for the storm water would be beneficial for the market. It would also prevent the highly polluted water from being pushed out of the pipes during the rainy season. Until then, the installation of non-return valves could help to prevent occurrence of the latter scenario.

Energy Supply

As for the rest of the inner city the energy supply can be improved in terms of the supply security. This would be especially helpful for shops that need the electricity for their work.

Grey Water

The shafts have the primary importance for the disposal of the grey water on the street. Hence, solving the blockage problem of the shaft would improve the situation a lot. Disposal of the waste into the containers could solve the problem easily. Additionally, there could be grids added to the shaft to keep the waste out of the canal system which is expensive to clean. In general, the disposal of the grey water is no problem as the water will still go into the central sewage system. However, it would be more convenient for the shop owners to have collections points inside the market as well. Regarding the waste water from the meat shops, it would be more hygienic to prevent the water to be spilled on the street. An optional implementation would be for the waste water of the hair dressers, which is not highly polluted. This water could easily be reused for flushing the toilet, as the water is collected in buckets already.

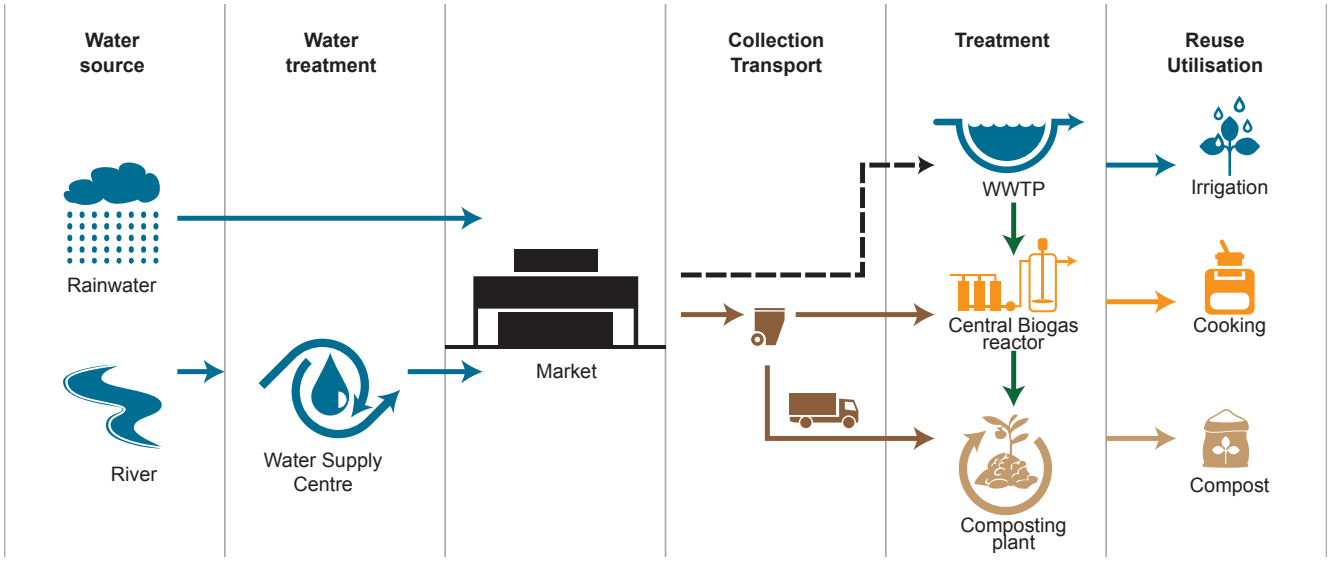
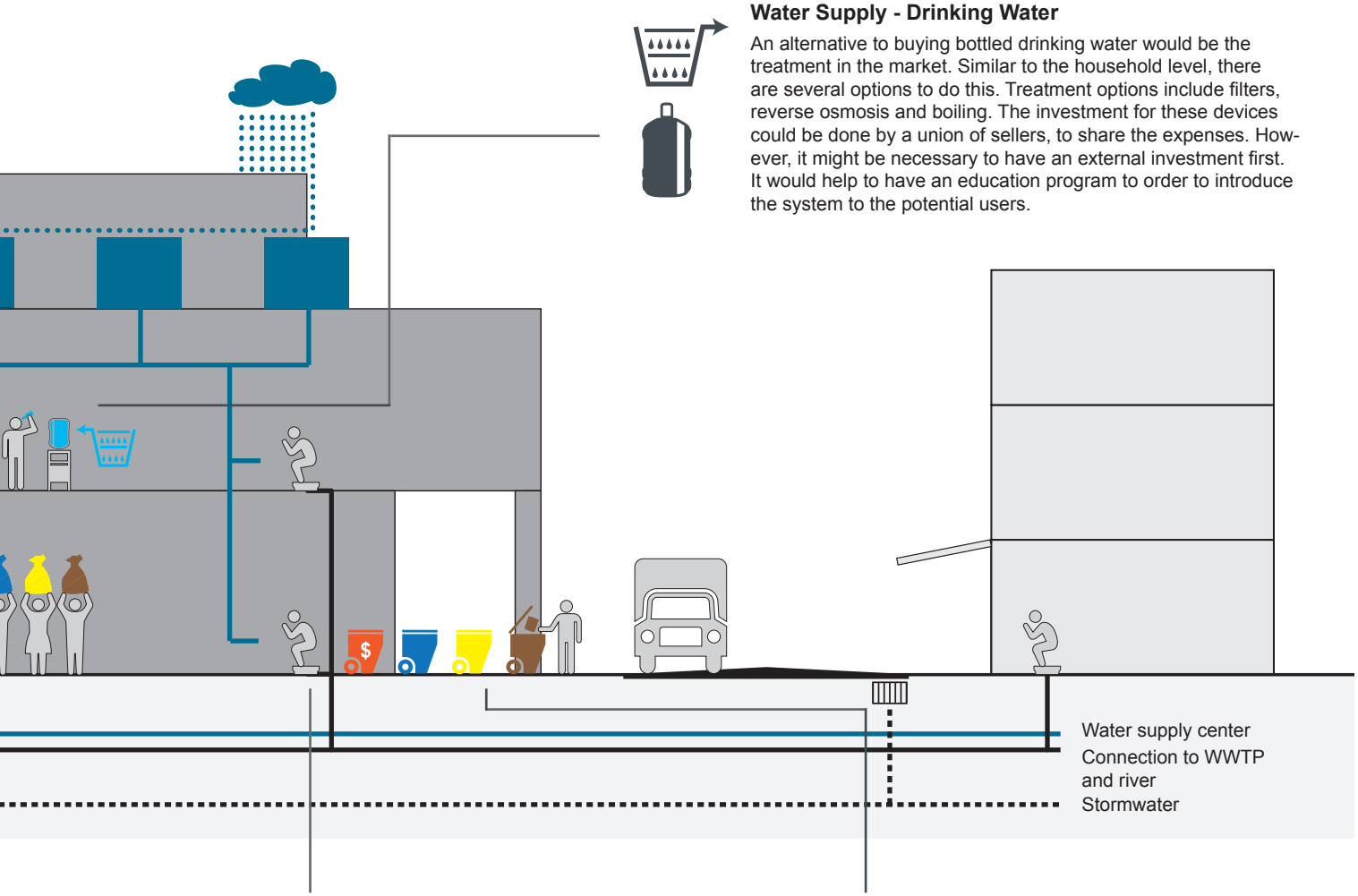


Fig. 52: Material Flow Chart of the Non-Residential Buildings (Illustration by the authors)

Water Supply - Drinking Water

An alternative to buying bottled drinking water would be the treatment in the market. Similar to the household level, there are several options to do this. Treatment options include filters, reverse osmosis and boiling. The investment for these devices could be done by a union of sellers, to share the expenses. However, it might be necessary to have an external investment first. It would help to have an education program to order to introduce the system to the potential users.



User Interface and Black Water

It is useful to keep the style of toilets as people are used to them. The amount of toilets could be increased to be able to service all the people in the market. The black water treatment of the market is managed by the central treatment system of the inner city. However, it is also an option to have a biogas plant in the market for a decentral treatment. The toilets could be connected to it as there is only black water running in the pipes. The waste water and the leftovers from the meat section could be added as well. The benefit of having the on-site treatment is that the biogas produced could be either used directly or sold. Unfortunately there might be not enough free space at this specific market.

Waste Management

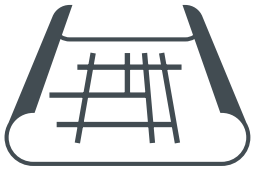
The waste collection at the market could be improved regarding different aspects. For the collection of the waste, it would be helpful to have designated areas. There could be containers at these locations for the shop owners to throw their waste. However, these containers need to be big enough to hold the huge amounts of waste produced by the market. The goal of separating the waste directly at the market, which is part of the current projects, should be kept. However, some further education and information about the project could be useful to motivate the shop owners to separate their waste.

Fig. 51: Integrated Infrastructure System of the Non-Residential Buildings (Illustration by the authors)

4.6. Planned Urban Development Areas

Planning Process

According to the population projection, population growth of Battambang is 2,5% per year. This has to be considered in the future master plan. This will provide the frame to regulate and manage the city in a better way. There are new development corridors planned in the existing master plan which will include planned urban development areas. These areas give a great chance to implement innovative natural resource management in detail, from the beginning. These new development areas are going to be designed and planned on predefined land.



The first step to consider is the preparation of a detailed development plan. Planning authorities have the responsibility to organize and manage the process. The open market dynamics should not shape the city development. The goal to create the best living conditions for everyone should lead the process. The current and future demands should be considered in the long term, after defining the critical mass. The development of the quarters can be done step by step, but they need to be planned together.

These new development areas should be on unused land. If there are existing residents, they should also profit from the new developments. These people should be integrated in urban developments, instead of being displaced. The planned areas have the opportunity to be effectively organised and redesigned, providing every inhabitant a land title.

An integral development plan should be developed, where the streets and buildings are planned together with the infrastructure from the beginning. Despite of the importance of the technical infrastructure, services such as schools and medical care, as well as daily food supplies, need to be provided in the same area. Recreational and public areas should be integrated in proportion to the area. A mix-used area goes in line with sustainability.

Design and orientation of the building can support the optimal infrastructure concept. The new houses have the chance to rethink the current construction system. The production and transportation should consume little energy. Research should be done in order to find environmental friendly materials and the value of local material options, which could be renewable, recycled and made of non-toxic components. The households, as the main consumers of energy, should reduce consumption and value the resources by designing buildings according to their own conditions and supplies. Building low energy buildings could also improve the future life quality of the people.

The community structure should be strengthened from the beginning. It is easier to address people that are already organized and could settle directly without any future conflict. If further investment or improvement is needed, households can establish saving groups. Implementing new technologies requires education about correct usage, as well as periodic maintenance.

Infrastructural Options

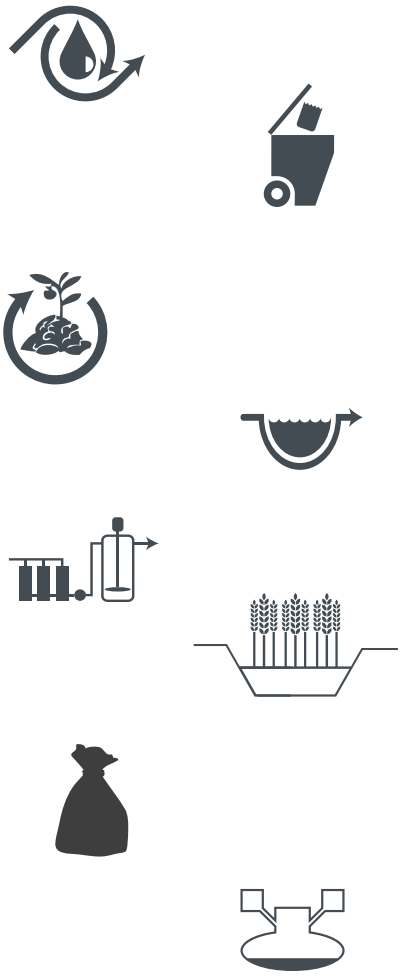
The planned infrastructure for the planned urban areas has to fit into the context of the proposed concept for the rest of the city. The great advantage is that the spatial and the infrastructure planning can be combined and that there are no limitations according to the existing infrastructure. As a result, access to roads can be guaranteed. Nevertheless, factors like cultural habits and income level have to be considered like in the other typologies of Battambang.

Centralized Treatment

The centralized treatment steps that are common for most part of the city can also be used for the planned urban areas. Like there is the separated waste collection for organic and non-organic waste and the further recycling and disposal of it, either in the central biogas or composting plant or the sanitary landfill. Furthermore the water supply with bathing water can be done by the waterworks and the storm water management has to be planned for the whole city anyway. It should be guaranteed that the new planned urban areas are not located within flooding areas.

Decentralized Treatment

For the waste water there are several options according to distance to fields and available space. One possibility would be to build a ‘resource recovery point’ like in the outer city, so that the blackwater could be separated from the greywater and then treated in a biogas reactor. In this way, people could use the biogas directly. This point could also be used to collect the waste so that the collection trucks do not have to bring together the waste from each household. If there is enough space available, the greywater could be treated in a decentralized way, for example in a constructed wetland to save the resources for transporting it to the central WWTP. Another option can be to divert the urine from the faeces, if fields are nearby where the stored urine could be used as fertilizer. If this is the case, a vacuum system could be feasible.



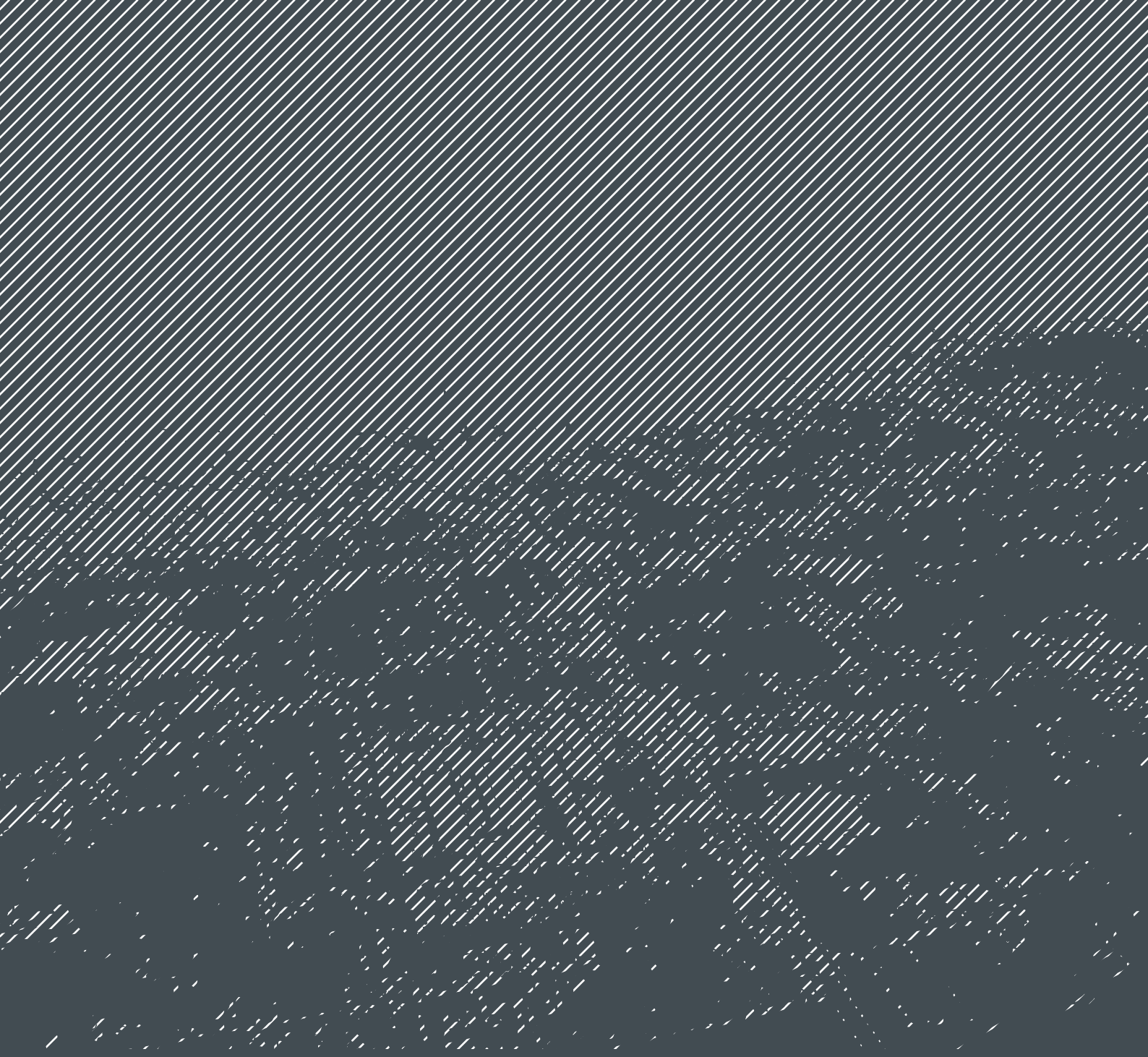
4.7. Conclusion

All six typologies in the city have different conditions and therefore different chances. The city centre has a central infrastructure already whereas there is a lack of provision in the rural character areas and the informal settlements. This different starting situation also bears different weaknesses, threats, chances and possibilities for each area. The inner city has the benefit of having a sewage system already, but on the other hand this is also a limiting factor for the implementation of new sustainable sanitation systems. Furthermore, free spaces are rare which leads to the need of having centralised infrastructure. For the rural character areas it is the other way around. There is only limited existing supply and infrastructure but there is a lot of space and potential to implement new sustainable systems. Hence it is suggested to keep central systems in the inner city but to start supporting decentralized technologies in the outer parts of the city. Nevertheless there is also a need for infrastructure on the city level which is further described in the next chapter.

Overall the focus on all areas is to recover the resources in the system. The main technologies chosen for the recovery of the biological material are the biogas production and the composting both on central and decentral levels.

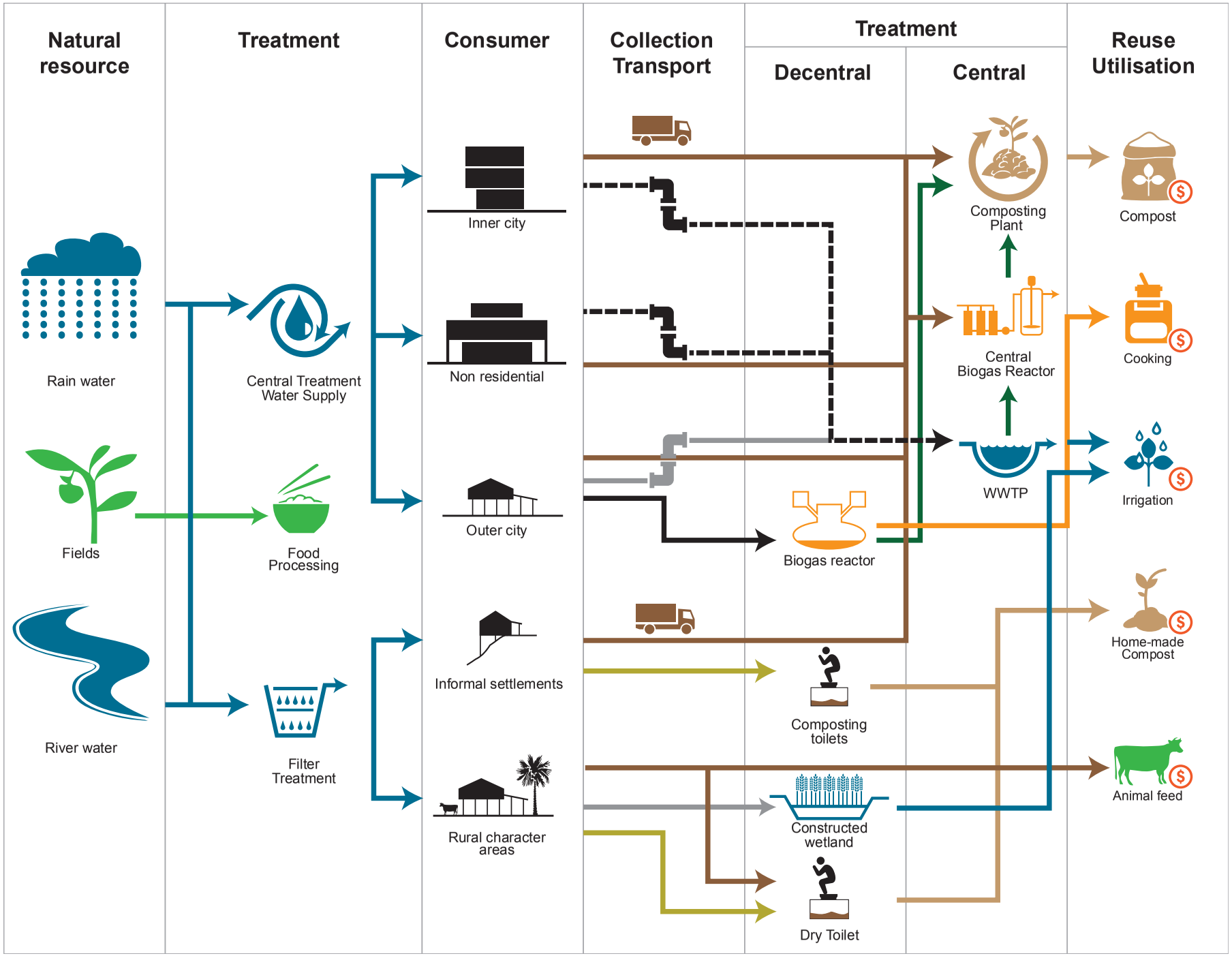
How all the systems for the different typologies work together in the city with a holistic concept is explained in the next chapter. Furthermore the benefits of the proposed systems are discussed as well as its weaknesses and threats.

Fig. 53: Planned Urban Development Areas (Illustration and photos by the authors)



Chapter 5:

Overall concept and future outlook


Natural resource
Treatment
Consumer
Collection Transport
Treatment
Decentral
Central
Reuse Utilisation
Rain water
Fields
River water
Central Treatment Water Supply
Food Processing
Filter Treatment
Inner city
Non residential
Outer city
Informal settlements
Rural character areas
Composting Plant
Central Biogas Reactor
WWTP
Biogas reactor
Composting toilets
Constructed wetland
Dry Toilet
Compost
Cooking
Irrigation
Home-made Compost
Animal feed
Non-drinkable water
Food supply
Organic waste
Mixed-waste water
Grey water
Black water
Excreta
Sludge
Compost
Gas
Valuable

5. Overall Concept and Future Outlook

From the different parts of the city, now the focus is back on the city of Battambang. In this chapter, it will be examined, how all the systems for the different typologies work together in a functional integrated infrastructure system. Furthermore the benefits of having such an integrated infrastructure system on a city-scale are discussed as well as its weaknesses and threats. In the end further steps are examined that have to be taken to come to an action plan for implementation.

5.1. Overall Concept

The overall concept for Battambang on a city-scale has the goal to include the different typologies of the city together in one system. For this purpose, decentralised and central parts of the integrated infrastructure systems are combined to one overall concept. This is an important step, because in some characteristic city fragments decentralised techniques are suggested, in some central systems are more effective or feasible.

The detailed systems for each typology was explained in the chapter before, so that this section is focusing on the connection between the systems, the centralised components and how the different fragments work together for an overall, functioning resource recovery system for Battambang.

Certainly, this overall concept should not be seen like a fixed suggested solution, but a flexible frame. Whenever it is necessary to plan or build a new structure, it can be adapted within this loose and flexible frame. Also a combination of components of different parts of the city is possible.

5.1.1.Systematic Approach

To show the different parts of the overall concept the material flows of the single areas are combined in one flow chart. The systematic is kept to distinguish between resource, consumer, collection/ transport, treatment and possible reuses. To make it easier to read and to arrange it clearly, the domestic waste is illustrated in a separate diagram.

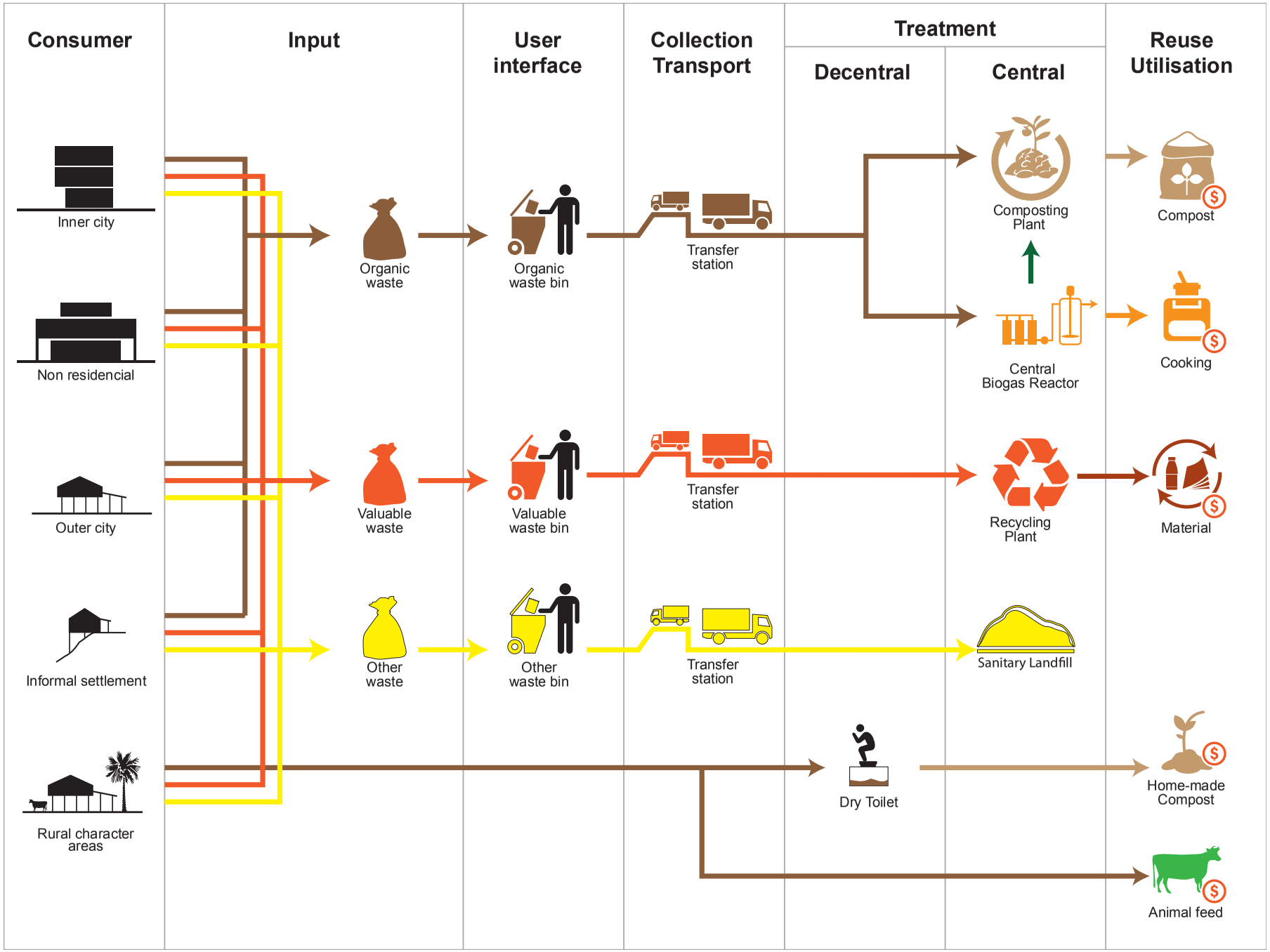
On the left site we can see the basic resources like drinking and bathing water that come originally from the river or the rain and the food from the fields, woods or animal breeding. To make this resources usable for the consumer, there is some kind of treatment necessary, for example a clarification of the river- and rain water and a food processing for the eatable resources.

In the middle there is the consumer, which stands for the people living in Battambang. The concept is focusing on improving the living conditions of these people. To show the different urban typologies and their influence on the system, the consumer section is divided into the characteristic houses standing for each area. The new planned urban areas are not shown as they can be integrated in the concept and do not have limitations like the other parts. The output of this section are the converted inputs like blackwater, organic waste, greywater.

For being able to reuse the resources, a collection and transportation and afterwards a treatment is necessary. The collection and transportation can exist of pipes or collection trucks. It is clear that the users or consumers have to contribute in this section the most, because they are responsible to bring the waste to a collection point for an example. As a result, this is a critical point to pay attention on. Additionally, a good organisation for a central collection is needed.

When the resources made this step and arrive at the different treatment plants, it is differentiated between central and decentralised treatment. However, the level of decentralisation of the treatment can differ. There is the household-level for the drying and the composting toilet, the small clusters for the clarification in the constructed wetland, the neighbourhood level or even quarter level for the biogas plant in the outer city. For the central treatment plants like the waste water treatment plant, the biogas plant, the sanitary landfill and the composting plant further planning, improvement and financing is needed. Nevertheless, as a result of this whole process there are several options to reuse the valuable residues like compost, water for irrigation, biogas for cooking or energy supply. They make the process worth the required effort and profitable.

Fig. 54:
Overall Concept Diagram (Illustration by the authors)


Consumer
Input
User interface
Collection Transport
Treatment
Decentral
Central
Reuse Utilisation
Inner city
Non residencial
Outer city
Informal settlement
Rural character areas
Organic waste
Valuable waste
Other waste
Organic waste bin
Valuable waste bin
Other waste bin
Transfer station
Transfer station
Transfer station
Composting Plant
Central Biogas Reactor
Recycling Plant
Sanitary Landfill
Dry Toilet
Compost
Cooking
Material
Home-made Compost
Animal feed
Organic waste
Valuable waste
Other waste
Compost
Sludge
Gas
Recovered materials
Food supply

The diagram for the domestic waste flow refers to the same systematic like the other material flow system except for the resource part, because it is so various. This diagram is less complex as the different streams are not as inter-connected and the separation of the waste streams is the crucial part. Therefore, the waste is divided into the organic waste that is also dealt with in the other diagram, the valuable waste that can be a resource of money or recycled materials and the rest of the domestic waste that has to go to a sanitary landfill that then has to be built. By keeping this structure, also a step-by-step implementation of a waste-separation can be established.

Nevertheless, the consumer has to contribute and throw the waste in a special bin. There is the option of having bins per household or also having them on collection points for the denser areas, so that the people would have to bring it there manually. Either from the households or the collection points the waste has to be collected and transported by trucks. To minimize transportation distances, transfer stations could be a possibility. The trucks bring the organic waste to the composting or the biogas plant as it was described in the other diagram. At the moment there is just the option to sell the valuable waste to Thailand as there are no recycling plants in Cambodia. For a future outlook it can be good to build recycling plants for different materials like paper, glass or plastic. As a result, these materials could be reused again instead of buying them. The non-valuable waste has to be disposed on a landfill, but it should not have negative outcomes for the environment and the human beings. For that purpose a sanitary landfill has to be constructed to catch the leachate and the gas emissions.

5.1.2. Connection Between Different Typologies and Components

It is important that the system is not just consisting of a collection of components, but is a collaborating system. This is why this paragraph focuses on how this collaborations looks like and how the systems of the different parts of the city are connected.

First of all, there are the spatial linkages. Although characteristic typologies could be found throughout the city, they do not have clear boundaries between each other. Hence, it is not possible to distinguish them. The city is more like a colourful mosaic of various pieces. As an example it is the case that an informal settlement mostly lies within the outer city areas. Consequently, the systems for each area are not separated spatially from each other.

To pay tribute to the spatial interrelations and to make the system work, there are the infrastructural connections. Referring to the infrastructure systems, there is no part of the city that is completely autarkic.

First of all, there are the transportation components like the pipes or the central collection of waste that are shared by most parts of the city. The central sewage system is used by the inner city and the non-residential buildings that lie within it and the collection of the greywater from the outer city.

Afterwards the treatment steps follow. The residues of one treatment step are dealt with in another (central) treatment step. For an example the activated sludge of the WWTP is transported to the biogas plant and the digestate from here is after-treated on the composting site. To this composting site also other residues are conveyed like the organic waste or the digestate of the decentralized biogas plant in the outer city. The arriving organic waste has to be shared amongst the central biogas plant and the composting facility, so here a lively cooperation and consultation is needed. The process water that is a result of dewatering the digestates of the biogas plants before being able to co-compost it together with the organic waste, can be brought back to the waste water treatment plant to clean it.

Finally, the recyclables are re-entering the city on the resource site. They serve the whole city by providing water for irrigation, compost, heat and energy.

As a consequence it is necessary to broaden the perspective on the whole city while planning the infrastructure for one part. This is why there is a necessity to have an infrastructure concept for the entire city and also to solve the problems like organization and financing on a city-scale.

Fig. 55:
Waste Flow Diagram (Illustration by the authors)

5.1.3. Central Treatment Systems

As the decentralised treatment steps were examined step by step in the previous chapter, the focus is now on the central treatment facilities. Some have to be improved or extended, some have to be built from scratch. To get the residues to the treatment plants, first of all the collection and transportation step is necessary which is also centralised for some material flows. Then there are some central treatment plants, which are a part of the proposed infrastructure system. Overall there has to be a management and organisation to make the system work. This is also the case for the stormwater management.

Canal system: To improve the canal system the pipes for the wastewater have to be connected properly so that there is no leakage and the blockages caused by waste have to be removed. Furthermore the pipes need to have a slope in the direction the water is supposed to flow.

Collection of waste: To treat the bio waste in the composting or biogas plant it needs to be separated and collected. However, the collection should be optimized regarding to different aspects. There are two options. One option would be to separate the waste already in the households and then have a separate collection with different trucks that pick up the waste from each household. In this case the bio waste could go directly to the central composting site.

The separated collection at the households should be implemented step by step. As a first step the isolated collection of the bio waste could be a start to get the people used to the separation process. After a while also the paper and plastic could be collected separately as it was suggested for some Ger-Settlements Bag7 in Darkhan, Mongolia (Böhm et al. 2013). Until then the bio waste can be separated at the composting site, as labour is cheap anyway like it is done at the moment.

On the other hand it might be easier for the collection process to have collection points if the collection points are marked more clearly and there is some kind of collecting system the people can throw their waste into. Like this there would be also less visual pollution which is especially good in the representative inner city.

If the informal sector continues to collect the valuables the situation for them could be improved. The waste collectors need clothes for protection and also vehicles would be helpful. In the long term planning it can be useful to keep the valuable inside Cambodia as this will also keep the money there and not transporting it to Thailand as it is the case at the moment.

Sanitary landfill: For the deposition of the non-recyclable waste the landfill needs to be optimized. By sorting out the bio waste the emission of the landfill will be already reduced. However, there needs to be some protection against leachate getting into the environment. One option would be to find a new location were there could be some basement with a leachate collection system. As there is a lot of precipitation it is also important to cover the landfill after closing it.

Wastewater treatment plant: The functionality of the WWTP can be enhanced by having a better maintenance and operation, the sludge for an example should be removed on a regular basis. Also the equipment can be improved, which is planned already by installing new pumps. However, the dimensions and the treatment methods of the existing WWTP have to be evaluated to achieve the required quality for the effluent and to be able to deal with the arriving wastewater amount. It is already planned to build one more WWTP on the eastern side of the river to also serve these people.

Biogas plant: To shorten transport distances, the biogas plant could be built close to the WWTP. By doing so the process water from dewatering the digestate could also be directly treated in the WWTP again. As the dewatered digestate is supposed to be co-composted together with the bio waste of the city, the capacity of the composting station needs to be increased.

Composting plant: The existing composting plant could be enlarged as it is close to the WWTP and therefore also to the biogas plant, which minimizes the transportation distances. An advantage of enlarging the existing composting plant would be that there is already stuff to run the plant that can advise further workers. Nevertheless, if there is no land available anymore to expand the existing plant, a new location would have to be found, also keeping the transportation distances in mind.

Water supply: The city is in general provided with water from the water supply centre. There are different factors that could be worked on. One thing is the quality. The water coming from the water supply centre should have bathing water quality. First of all, there needs to be regular inspections to achieve this goal. When the quality is known, the technical treatment methods can be adapted and supplemented in a way that the requirements are fulfilled. Even after, the quality of the water should be checked regularly. There is an existing programme funded by a Japanese agency, working on the improvement the water supply in the central areas. Measuring instruments will also be provided, so the quality checks can be the starting point for an improvement process.

The water coming from the tap doesn't need to have drinking quality, due to various reasons. On one hand, only a small amount of water from the tap is actually used for drinking. There are many other uses as washing, showering and flushing, where water doesn't need to be potable. On the other hand, producing water with drinking quality takes up a lot of energy which would be a waste if the water is not used for drinking purposes.

As a result, there should be a direct supply just for drinking water. One option would be to improve the existing delivery system for water containers. Tanks or containers have the benefit compared to bottles that there is less waste involved. A first option could be a more central approach, involving the city administration. This could be done by regular inspections, to make sure that the water is potable. In addition, the water needs to be affordable so it might be necessary to have some subvention so that also people with a low income have access to drinking water.

Another option would be a more decentralised approach, such as the promotion of filtering at home. The benefits would be that the people are able to make sure that the water is treated, and that there is only a one time investment for the filter. There are a lot of options of how to treat water on the household level. One is the treatment with filters or reverse osmosis. For this kind of treatment there needs to be a one term investment, which might already be too high in a lot of cases. The cheapest option would be to clarify the water in transparent bottle by placing them on the roof. This is then a natural UV light treatment. The boiling of water is also a possibility to make it safe to drink, that almost all households will have the equipment for that at home. Another possibility is using pills for the treatment, however they are expensive. Therefore it is not widely used. Rainwater is comparatively clean. However, it needs to be stored in a hygienic place to keep the quality until the water is used.

Stormwater management: The storm water itself is a big problem and not dealt with in detail. To deal with the high amount of precipitation during the rainy season, a second sewer system for the storm water would be beneficial. On the one hand the treatment of the water gets easier as the storm water doesn't get mixed with the waste water and hence there are less pollutants in it. On the other hand there will simply be less waste water to treat in the waste water treatment plant. Therefore also the sewer system for the waste water can be smaller which will make it easier for the water to run through the pipes during dry season when there is no additional storm water. Another benefit is that during the floods the storm water can't push the waste water out of the pipes into the houses again. However, this is a long-term solution as it will take some time to build the drainage. As a short-term improvement the installation of non-return valves could help in areas that are flooded because water is pushing in from the river.

5.2. Benefits and Chances

5.2.1. Direct Benefits

The resources that can be reused because of the implementation of this resource recovery concept can serve the whole city. As the direct benefits are the first thing the people that are part of the system can recognize, it is very important that these benefits are of great advantage for them. They can be the motivation to continue working on an improvement of the situation. If they are not profitable enough for the inhabitants and they do not see the positive outcome, they will not further contribute to the system by collecting and separating waste or by changing habits to use dry toilets, for an example. However, this system has a lot of direct benefits for the people.

The direct benefits of the resource recovery concept can be listed as:

Organic waste is already used as **animal feed** in the rural character areas. So there is no need for buying special food which saves money and it is also a contribution to foodstuff.

Compost is made in a big scale on the central composting plant or at home in the rural character areas and the informal settlements. From there it can be used directly on the surrounding fields, where it can serve to increase the amount of food that can be harvested and in the same process decrease the amount of artificial fertilizer needed. As a result it leads to save money or is a source of revenues if it is sold by the inhabitants of the informal settlements to farmers nearby. On the central composting plant the selling of the produced compost also has to help to finance the operation and maintenance of the plant.

Biogas is also produced in different scales. In the decentralised way in the outer city the biogas can be used directly via pipes for cooking in the households that contribute to the biogas plant. It still has to be examined how much gas can be produced and how to store it. In the big scale production of biogas, it could also be used to gain electricity as Cambodia is dependent of imports from Thailand in this sector.

Till now **materials** cannot be recycled in Cambodia as there are no recycling plants. This is the reason why they have to be sold to Thailand. Consequently, in the nearby future the inhabitants of Battambang can just make money out of the valuable waste. In the long-term recycling plants would be nice to produce paper out of used paper, produce glass out of melted glass or shredder plastic to use it for other purpose.

Water clarified in the WWTP or a constructed wetland can be used to irrigate the surrounding fields without harming the environment. Especially in the dry season a storage would be useful, it can also exist of a pond. If the water is used for irrigation it also contributes to gain foodstuff and increase the harvesting. Another option, also depending on the location of the treatment, is the refill of natural sources like the river. After the implementation of the concept, the refill is done with clarified water that is no longer harmful for the environment and the ecology of the water streams. Additionally, it has a positive effect on the water supply and the storm water management if the river water gets cleaner in the long-term which will be examined further in the next section.

Money is earned from selling valuables. As the interviews in the informal settlements showed, for most of the people the most urgent problem is the economic situation. Consequently, saving and earning money is the most attractive benefit for a majority of the people because it is also the most obvious one. On the one hand money for fertilizer, energy supply, for example gas to cook, and water for irrigation can be saved, on the other hand money is earned by selling valuable waste to waste sector or compost to farmers.

With the installation of sanitation systems the health situation will be greatly improved, which again will enhance the **living conditions** of the people.

5.2.2. Long-term Benefits

In addition to the obvious resources that are gained through the implementation of such an infrastructure concept, there are further benefits for the development of the city of Battambang according to the life of the inhabitants, the protection of the environment and further social and economic outcomes. Keeping this in mind, for realising the goal of a sustainable development in Battambang as also formulated in the Battambang Masterplan, natural resource management is crucial.

According to the growth of population the amount of consumption and waste increases as well. Thus to realize growth in Battambang waste- and water management has to be organized as well. The province is directly dependent on natural resources for their livelihoods.

> *"The growth of cities and its implications for resource consumption and climate change is already showing to be the single largest influence on global development in this century." (Lüthi et al. 2011, p.27)*

Thus it is of great advantage for Battambang to reduce the resource consumption due to the reuse of primary resources, like compost or water for irrigation. As a result, these resources are not lost and it counteracts the shortage of nutrients. Phosphor for example is a really rare but crucial one, but it can be reused through compost of excreta. Additionally, when the waste is recycled there is less space and effort needed for a sanitary landfill.

In order to overcome the problems of the serious discrepancy between city growths on the one hand and the provision of adequate supply and disposal infrastructure, the design and implementation of semi centralized treatment units are essential. To widen just one central supply and disposal system requires the necessity to install for example longer and larger pipes or dumping sites, as well as stronger pumps or longer transportation routes. This would require a greater demand of energy, increased costs for the authority and longer planning times. It does not seem to be reasonable to integrate only one system in fast-growing urban areas because they do not allow flexible adaptation to dynamically changing structures.

Various and small-scale systems are less endangered in terms of external influences. Even in case of a complete system failure as result of natural disasters, the impact on civil life is lower and does mostly not affect the whole city. In addition, affected decentralised systems can be repaired in shorter periods of time. And the implementation does not afford one major investment; the supply can be developed quarter by quarter. The users of these decentralised treatment steps can be involved directly in the decision making process, because the planning is still easy to understand and the people even have to contribute to the system by separating the waste or dealing with the operation and maintenance of a decentralised biogas plant, for an example. Through this involvement, the community structure can be empowered and the gap between the government on the one hand and the citizens can be closed or minimized. To achieve this goal an information campaign to advise the people is necessary.

Nevertheless the backbone for public service supply is the conventional system, which were integrated when French colonialist developed Battambang. Until now, most of the inhabitants in the inner and outer city are depended on e.g. central water supply, and in consequence an improved waterworks for Battambang would improve the water quality for most of the households immediately.

An improved water quality is directly related to a better health condition of the inhabitants. Other positive effects of a waste water and waste management on a healthy living of the people are the save discharge of the excreta into a system without leakages and without direct contact with the humans or through food or water. Thus illnesses like diarrhoea and other related diseases can be reduced which has various positive effects. Additionally to a better system a hygiene program is necessary as washing the hands with soap can already reduce a great amount of diseases. Additionally a good design of toilets can make the usage of these toilets a lot safer, especially for children. It is also a question of dignity when the people are not forced to practise open defecation anymore, as it is still sometimes practised in the informal settlements and the rural character areas. In general the quality of life for the citizens of Battambang can be improved by an integrated waste and wastewater management concept.

Also in plans like the Environmental Management Plan of Battambang (CAM: Greater Mekong Subregion Corridor Towns Development Project Battambang Subproject) the goal is to prevent natural pollution. Battambang is in an urbanization and industrialisation process, but live still depends on the agricultural sector, which should not be negatively affected. Rice farming and fishing guarantee the subsistence of

people in Battambang Province. By not discharging untreated wastewater directly into the surrounding fields or water streams an eutrophication of these water streams can be prevented and the supply of food is a lot safer. By building a sanitary landfill and giving alternatives to burn the waste, climate-effective emissions can be reduced and the quality of air can be improved which again has a positive outcome for the health of the people. As the environment is also the basis for future natural resources, long-term effects can be assumed. For an example, if waste water is no longer discharged into the Sangker River, also the water supply can be improved due to the fact that the waterworks take the water for the water supply out of the river.

In this case it is also obvious that money can be saved that would be necessary to clarify the polluted environment like the river. If the environment is not polluted anymore you do not have to clean it. Money can also be saved for then unnecessary medicine and doctor visits as diarrhoea can be reduced. This has further advantages for the household savings as the people can go to work or to school when they are healthy, which can increase the income level and the productivity of the city and thus increase the taxes gained for the government.

As the concept has to be decided together by different groups with different background on an interdisciplinary basis, there is a planning reliability for future decision making. This can be a location factor for further investments and increase the attractiveness for investors. As a result jobs can be created which is also the case for the environmental sector as skilled stuff is needed to plan, operate and maintain the integrated infrastructure system. And finally, a clean, green environment will also have a positive outcome on the tourism sector.

All in all, you can say that the resource management concept has not only the benefit of recovering resource compared to conventional sewage systems, it even has vastly more far-reaching effects.

5.3. Weaknesses and Threats

The given concept for the city of Battambang is made in a very general way and needs to be improved with further work and analyses. Finding the perfect one fits all solution for a whole city is simply not possible. Therefore, the system contains some weaknesses and has some gaps that will be described in this chapter.

The team, working on the concept, contained students from urbanism, engineering, local students, experts from the municipality and the NGO COMPED. All these participants were giving valuable input to the project. But it would have been really useful to also have experts from economics, agriculture and the law to include more input of these professions and to adapt the system also to their needs and requirements. The municipality, stakeholders and the community of Battambang need to contribute to the system and need to have the willingness to change the existing situation. If this is missing the whole system would not work in the end.

The municipality, stakeholders and the community of Battambang need to contribute to the system and need to have the willingness to change the existing situation. If this willingness is missing the whole system will not work in the end.

The important fact of participation of the local community could not be covered in detail, but is crucial for such a systematic approach. It is mainly based on the local students but to clarify the acceptance of the whole system, more work with local communities and stakeholders would be necessary. Especially where people need to change their existing habits. That is for an example the case in the rural character areas where the concept includes dry toilets as user interface; due to the fact that the local habit of anal cleansing with water stays in conflict with the concept of dry toilets.

Also the separated collection of waste is necessary for the implementation of the proposed system. It is not clear if people are willing to separate their waste or if the private company CINTRI can overtake this task. This is, like the conflict with the dry toilets, an unanswered question that needs further analyses.
The analysis that was done for the project based on field trips, literature studies and group work with the local students and stakeholders. This is of cause not enough for a comprehensive analysis and might be not representative for the whole community of Battambang.

Another important problem that was found in Battambang is the flooding during the rainy season. The problems that are related to flooding are diverse and effecting large parts of the city and peoples daily life. Since the project was focused on resource recovery this major problem was not covered in the proposed system. Nevertheless, further work on this issue should be done in the future to improve people's life conditions and because it affects also the integrated infrastructure system in an intensive way.
The implementation of the concept in general would need a lot more work. A detailed implementation plan for the concept is missing so far, although it is unbearable for a successful implementation of the project. Points like financing, affordability or the organisational structure were not covered fully during the project. It is important to have a well-organized structure for all facilities, services and maintenance. This would include the separated collection of solid waste and the collection of black water and sludge. It needs to be analysed if this can be done by a private company or if the city of Battambang should take care of this task. Detailed technical design work is necessary to adapt the system to all local conditions. This includes also the transportation, analyses of local construction material and available construction sites. Financing the concept and the affordability for the people are close related. It requires further work to find a way to finance the concept without overtaxing the local community. The diverse levels of services in the different application areas as well as different income levels and the profit made out of the gained products need to be considered thereby.

It is planned to use the existing sewage canals in the inner city after maintenance for the collection of wastewater. It needs to be analysed if maintenance of the existing system is possible or useful. Therefore a comparison of costs would be necessary to find out if it is better to maintain or replace the old canals. The size of the canals is an important factor as well. It would make no sense to maintain them if they are too small for the planned amount of wastewater. In general you can say that an economic cost-benefit assessment has to be done for the entire system.

The situation after a successful implementation may not be satisfying in all parts of the city, especially in the informal settlements. Due to the dense structure of the settlements and the fact they will never get the land title, the project was planning short time improvements. These are including shared facilities, which have some major disadvantages and limitation. "Badly managed sanitation facilities can be expensive, unhygienic and largely inaccessible, which is a particular problem for women and children who need a safe place to use, especially at night. To address this, public sanitation blocks must be well-managed and open 24 hours a day (de Albuquerque)". Due to this, the distance to facilities should be reduced to a minimum and the maintenance should be supervised in a suitable way to keep the usage of shared facilities save. Nevertheless, shared or public toilets would improve the situation in the informal settlements.

Also the maintenance of decentralized facilities, like the biogas digesters, which are planned for the outer city, can be critical. They need to be maintained well to keep them running and to avoid problems with the gas production. Running a biogas digester is not an easy task but community members who are educated by experts should be able to do that in the future. Another problem can be the removal of the sludge that is left over in the digesters. This requires access roads for vacuum trucks for every planed facility, which can be problematic in some areas. "The collection of material flows and the transport to the treatment facilities is one of the major challenges due to not existing plot boundaries and the strong limited space in large areas of the city (Seyfarth, 2013)".

This can be problematic especially in the rainy season when road conditions are becoming worse in cases of heavy rainfalls. The removal of the sludge by hand is not appropriate, due to the fact that the sludge is not stabilized and sanitised. Composting at the local composting plant is planed for the sludge from the centralized and decentralized biogas plants. The local composting plant needs to be improved to process the increased amount of organic matter and the sludge that is collected in the city. Suitable technologies should be applied therefore.

The development of the city of Battambang was not analysed in detail. But it is estimated that the city will grow in the future and that the number of inhabitants will increase. The future demand for infrastructure needs to be analysed in a more detailed way. The system that is given is flexible and adaptable, but it will reach its capacity on a certain point in the future. Therefore it needs to be analysed where these limits are and how the system can be extended in the future.

5.4. Next Steps and Future Outlook

This chapter will inform about steps that would be necessary in the future to implement the proposed holistic concept for the city of Battambang.

5.4.1. Raising Awareness and Education

The proposed concept is complex and would need several requirements to be implemented. First of all, the acceptance of the different technical components at the household level needs to be proved. This is a major requirement due to the fact that the citizens of Battambang need to deal with the changes and accept them. The participation of the people can increase the acceptance of the whole concept and can help to adapt the systems to local requirements wherever necessary. (Eawag 2005)

The participation of the citizens for this project is based on the local students and can be improved by working with communities and stakeholders on-site. This work should include basic education and raise people's awareness according to environmental problems. People need to understand how environmental problems and bad habits are effecting their daily life. Education on this topic can start in schools or can be done with help of information events in small communities. Also posters, flyers, radio or TV can be used to educate people and reach as much people as possible. This education will help to point out the advantages of the new system while showing how it improves the current situation. The concept for each area needs to be presented to the local community members.

Therefore simple schematic drawings of the planned system as well as small-scale applications of the systems can be used to demonstrate how the system works and how to use it. (Schirmer 2014) That can help to reduce doubts of the potential users and to raise the demand for the planned systems. The potential benefit and limitations of the proposed technical system need to be pointed out in a clear and detailed way.

5.4.2. Implementing New Technologies and Maintenance

The proposed holistic concept contains small technical components like composting toilets as well as large and expensive ones like the central biogas plant. Further analysis is necessary to decide which components of the holistic concept should be set up first. This is amongst others dependent on the number of peoples that are effected, financial resources and defined priority areas. Also the connection between different technical components needs to be considered before setting up different technical components.

Implementing such a complex system would also need specialized staff on-side that cares for the implementation and later on, on the maintenance of the system and its different components. Maintenance will be needed especially for the larger components like the biogas plant, the composting plant, the WWTP and all connections in between.

They could also be responsible for people's questions and can constantly support the local community members that are running decentralized biogas plants or composting toilets. The local specialists should be supported in a suitable way until they are able to run the complete system by themselves

5.4.3. Detailed Design

The designed systems are planned for each area with a special focus on the local conditions, requirements and existing material flows. Nevertheless, further planning is needed for the implementation due to the fact that the given systems are just general. Detailed dimensions and designs need to be found in further planning processes and together with local community members. Wishes and concerns of the local people should be considered to find best suitable design options. The participation in the design process would again lead to a higher acceptance of the whole system. (Eawag 2005)

Existing infrastructure can be considered while designing detailed solutions on-site. But the system should be kept flexible due to the fact that the typology of Battambang changes constantly. The WWTP is a good example therefore; it was planned in the colonial times and for the number of people that were

living in Battambang that time. These days the number of people living in Battambang has increased but the WWTP was not adapted to the rising amount of wastewater. Changes like this should be considered in the design process and the system components should be kept flexible and extendable.

5.4.4. Legal Framework

Another important factor is the legal framework. A sound and well-organized system would be necessary for the implementation. The legal framework itself should include suitable minimum standards for the level of service and regulations for the implementation e.g. forbid unimproved pit latrines or illegal disposal of wastewater.(Eawag 2005) Some of these requirements are already implemented in the existing law but they are not enforced in a suitable way. The legal framework should also regulate responsibilities and accountabilities for the implementation and the following maintenance and services.

The high level of corruption in Cambodia is a major problem and a risk for the implementation of such a project. Money that is planned or donated for such a project should also be used within the project. The fight against corruption should be one of the major future tasks for Cambodia.

Finally, the implementation process should be planned with an interdisciplinary approach to consider all requirements of the different professions and to pay tribute to the linkages between them. By doing so, further disciplines like agriculture, economy and law can be included.

5.5. Conclusion

The systems of the six typologies were brought together in one overall concept that was visualised in a material flow system. It was examined how the different systems of the typologies contribute to one working system and that there are several relations. As a result, an organisation and planning for this has to be done on a city-scale by including several disciplines and professions as well as the community itself. By doing so, various benefits can be achieved, like the resources that can be recovered, but also long-term benefits according to social, economic, environmental and administrative factors. However, by having such a concept the benefits cannot be guaranteed as several factors can risk a successful implementation. Additionally, the project has its limitation and there is still much further work and analysis needed. Moreover, an implementation strategy or an action plan is necessary which could be part of further cooperation and projects.

CHAPTER 6:
REFLECTION AND REVIEW

6. Reflection and Review

The reflection of the workshop itself as well as the whole project is divided into different sections like the cooperation between the students, interdisciplinary work, timeframe, task, method, limitations and positive outcomes.

6.1. Co-operation between Students

Generally speaking the cooperation between students from BUW and UBB worked out very well and satisfying.
Due to different language skills and levels of knowledge there where some difficulties at the beginning of the workshop and it took some time to get the workshop really started and till everyone recognised that he or she can give valuable input to the project. This situation improved during the workshop. Different backgrounds of the students such as urbanism, environmental engineering and nuclear engineering were enriching but also challenging at the same time. It could have been useful if the Cambodian students had lectures before the start of the workshop as well as the students from Bauhaus-University.

However, both the students from BUW and UBB were able to learn and profit from each other. The students from BUW could provide working methods, basic technical and planning knowledge; the students from UBB had a very good knowledge about the area and its problems, even the problems that are not that obvious e.g. corruption or mismanagement in some sectors. Also arranging meetings with stakeholders and organising fieldtrips was quite uncomplicated with the help of the Cambodian participants.

The University of Battambang itself supported the project in a suitable way by providing premises and giving the opportunity to run the project at their University.

6.2. Interdisciplinary Work

To come to an overall concept for the city of Battambang, interdisciplinary work between urbanism and environmental engineering was needed. It turned out that combining both professions is not uncomplicated. Different ways of thinking and working where discovered during the project. Due to the different backgrounds, sometimes misunderstandings occurred between the students. Though, the group went through it very fast and the interdisciplinary work was an enrichment for both professions. Further the iReBa project profited from it and the experiences made will be useful for further projects and the working life.

To create an overall concept for a city like Battambang, many circumstances and factors need to be considered. One of these aspects is that a city has different areas with different needs and requirements. Finding and defining these areas was an important step during the project, which could be done in a correct scientific way by the urbanism-students. This helped to divide the city into smaller units for the engineers to work on the technical infrastructure. With the help of criteria that were predefined together, the students from urbanism were able to collect important data for the work of the engineer students. It appeared that not only existing technical infrastructure needs to be considered but also the settlement structure, for an example.

Visualisation was an important part of the project, too. Posters were made during the workshop and the final presentation was designed in a way that it was easy to understand even for people that did not take part in the workshop. This part might not sound so important but it helped a lot during the workshop. And it turned out that the students of urbanism have a good understanding how to simplify complicated structures or situations and convert it into easily understandable graphics.

The interdisciplinary aspect of this project was valuable although the way to combine both professions could have been planned earlier in advance and more detailed by the students, as well as the support for the students from urbanism can be improved in following projects by having constant support from a supervisor.

6.3. Timeframe

The work in Cambodia was not always on time according to the schedule that was prepared in Germany due to the fact that some planned contents were taking more time than expected. The complex situation in Battambang made additional fieldtrips and group work necessary which were important for the on-going working process. One example for this, is the excursion to the market and the further analysis of it which took a lot of time during the first week of the workshop. Also the connection between different topics and workshop days was sometimes not managed in a sufficient way and took some additional time as well.

However, two weeks were a tight time frame for the amount of work that was related to the project including research on-site, the planning and the workshop itself and the presentation of results. Extending the workshop period to three weeks or moving the presentation to Germany and handing over the official project report to present the result to the Cambodian stakeholders would have been an alternative. Additionally, the date of the workshop between two semesters was difficult to organise for the students, because this is something that is not designated in the study plan and caused some formal trouble. Following projects would be easier to manage if the timeframe for the work is agreed with all important stakeholders.

6.4. The Task

The vast and complex task for the project was a challenge for all participants and at the same time a great chance to expand the theoretical knowledge in a practical manner and to learn about the situation in Cambodia. It was easy to see that projects like iReBa can be enriching and that it is necessary to share information between different cultures and professions. The task was formulated in a way that the working process and the outcome was not precisely defined. That was giving the chance for the students to form the working process and to fulfil the requirements with their own understanding of the task. However, the supervisors of the group had an idea of the wanted outcome in mind that was not always fitting to the on-going working process. This led to discussions about the different expectations of the supervisors and the students. Nevertheless, in the end the group was coming to a result that was satisfying for all participants and that seemed to combine several expectations.

6.5. The Method

The eight-step method that was used by the group turned out to be the right approach to deal with the complex topic. But it needs to be said that these steps are part of the outcome of the project and that it was not clearly defined from the beginning how to manage the project. This can be improved in following projects with the help of the defined steps. That would help to work in a more focused way on the defined task and to save time instead of searching for the next possible and necessary steps.

6.6. Limitations

Due to the short timeframe some limitations were given. There was no time to visit a representative number of households for analysing the different typologies in the city. Also the acceptance of the designed technical systems was not proved although this would be very important before the implementation. Also a detailed analyse of the existing infrastructure was not possible, but it would be essential to give recommendations for maintenance, operation and improvements.

6.7. Positive Outcomes

The project and especially the workshop were quite intensive and they took its toll on all participants. However, through this work everyone gained new knowledge and made enriching, positive experiences. The most formative aspect was the inspiring group work between the different cultures and study fields. As a result, intercultural and interdisciplinary projects should be accelerated in the future.

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Appendix

Appendix 1: Summary of the Workshop in Battambang

The workshop was officially started on Monday, 3.3.2014 in Cambodia at UBB. At the beginning of the workshop, all students and persons in charge met the first time. And after a short introduction of everyone the work started with some group work and a lecture given by Mr Stäudel to the Cambodian students.

A field trip took place the second day to learn about the area and its local conditions. Therefore, the group went to the local dumping site located in the outskirt of the city. The group found out that the dumping site has a poor design and is in a bad condition. Also waste picking people were seen which were working under bad conditions on the dumping site. Nearby, the compost plant and the Social-Center of COMPED were visited by the group. Mr Bora who is running the compost plant gave a short introduction in composting and told the group about existing problems. Overall, it was seen that the composting plant is working well although plastic is sorted out by hand. Especially the students of UBB learned a lot about composting and the dumping site because most of them had never seen or thought about what happens to their waste after collection.

Later, the local wastewater treatment plant (WWTP) was visited. It turned out that the WWTP consists of three treatment ponds which were all in a bad condition and undersized for the amount of wastewater that is flowing to it. Later on the group went to an informal settlement and a relocation site to learn about the people living in informal settlements as well as their living conditions and major problems. After the field trip the group met again at the University to discuss the impressions of the day.

In the end, it turned out that an example was required, to understand the existing material flows into, within and out of the city. Therefore the “Boeung Chuk“ market was chosen. The group picked that market because this place was well known by the students and all citizens; it is a landmark within the city of Battambang and combines all kinds of material flows. Additionally, the group wanted to learn about the existing cooperation between COMPED and the market.

With the help of the Cambodian participants a meeting with the market owner and a visit of the market was arranged for the next day. Therefore the group split up into smaller groups with different topics to prepare questions for the next day. Those were discussed and answered by the very friendly and open minded market owner and the group during the meeting the next day. An employee of the market guided the group through the lively market after it. During this tour the group took the opportunity to ask some questions to the sellers and to see some problems in reality.

The rest of this day and the day after were used to evaluate the meeting, summarize the problems discovered, analyse the stakeholders of the market and to simplify the situation for a better understanding of the existing material flows. The last day of the week was used to define on which area or problem the group should continue to work on. The group concluded that the market is just one spot in the city, which was good to work on for an understanding of the situation and to get everybody in the group on the same level of knowledge and way of thinking.

The group then decided to focus on different areas in the city and to create possible technical systems to use valuable resources in those areas. Therefore different groups were formed, one with special focus on the areas in the city and another one focusing on possible technical systems for each area. The first one went on an additional field trip to each of the defined areas together with students living there. They where collecting information that was needed for planning technical systems and to define the areas in more detail. Criteria, which were prepared together, were used therefor.

The group, which worked on technical systems, focused on existing resources and infrastructure and ways to use them in a suitable and affordable way. After the information was collected different technical options were discussed and the areas were defined. This way of working turned out to be the most efficient approach to deal with all the problems and to find a holistic concept in the end. At the end of the second day of week two, the concept became more and more clear and during the following days, the outcome of both groups was combined and the final presentation set up.

The final presentation was then on the last day of the workshop. The audience consisted of students and persons in charge from UBB, members of GIZ and people from the municipality of Battambang. Different presenters from BUW and UBB supported by Mr. Bora and Mr.Samnang who helped translating the presentation into Khmer language presented the results. Members of GIZ, the municipality and the market under the moderation of Mr.Stäudel from BUW held a penal discussion where questions of the audience were discussed.

Appendix 2: List of Possible Infrastructure System Components

Input	User Interface	Input/output	Collection and Storage/treatment	Input/output	Conveyance	(Semi) -centralised treatment	Input/output	Use and /or disposal
Sanitation								
Faeces	Urine diverting toilet	Urine	Single pit	Effluent	Human powered empting transport	Anaerobic filter	Treated sludge	Fill and cover/ arborloo
Urine	Urinal	Faeces	Single ventilated improved pit	Compost/Eco humus	Motorized empting and transport	Waste stabilisation pond	Compost	Application of urine
Excreta	Pour flush toilet	Yellow water	Double ventilated improved pit	Treated sludge	Simplified sewers	Aerated pond	Biogas	Application of dehydrated faeces
Grey water	Cistern flush toilet	Brown water	Fossa Alterna	Dried faeces	Solids-free sewer	Free-water surface constructed wet land	Digested residue	Application of compost/eco-humus
Rain water	Urine diverting toilet	Black water	Twin pits for pour flush	Stored urine	Conventional gravity sewer	Horizontal subsurface flow constructed wetland	Effluent	Irrigation
Storm water	Vacuum toilet	Excreta	Dehydration for vaults	Faeces sludge	Transfer station (underground holding tank)	Vertical flow constructed wet land		Soak pit
Anal cleansing water	Dry toilet		Composting camber		Sewer discharge station	Trickling filter		Leach field
Flush water			Septic tank		Jerry can/tank	Up flow anaerobic sludge blanked reactor		Aqua culture ponds
Dry cleansing material			Anaerobic baffled reactor			Activated sludge		Floating plant (macrophyte) pond
			Anaerobic filter			Sedimentation/thickening pond		Water disposal-groundwater recharge
			Anaerobic biogas reactor			Unplanted drying beds		Land application of sludge
			Urine storage tank/container			Planted drying beds		Surface disposal
						Co-composting		
						Anaerobic biogas reactor		
						Anaerobic baffled reactor		
						Conventional WWTP		
Waste								
Food	Separating bin	Mixed waste	Compost pile	Compost	House collection	Burning/incinerator	Shredded waste	Application of metal
Paper	Non separating bin	Separated waste (all combinations possible)	Burning	Ashes	Collection on collection point	Composting plant	Compacted waste	Application of plastic
Plastic	non		Sweeping and container	Mixed waste		Sorting	Melted waste	Application of glas
Metal			Open dumping/burying	Separate waste		Mechanical treatment (shredder, compactor, separator)	Sorted Waste	Sanitary landfill
Textile						Melting		Application of glas
Glass								Application of paper
Wood and dry matter								Application of wood
Others								
Plastic bottles								
Cans								
Toxic waste								
Dangerous waste								

Fig. A.1: Table of possible Infrastructure System Components (Illustration by the authors based on CLUES 2011)

Criteria/ Urban Typology	Inner City	Outer City	Rural Character Areas	Impermanent Informal Settlements
Accessibility				
Road Material and Type	Concrete Main Roads and Side Streets, Earth Footpath	Concrete Main Roads, Earth Side Path	Concrete Main Road, Dirt Road, Side Path, Dead Ends	Dirt Roads and Paths, Dead Ends
Road Accessibility of the House	High	High on the main road, Low inside the block (can be reached by tuktuk, motorbike, bike and foot)	Low	High
Water				
Type of Water (Water supply Centre, River Water, Truck, Shops (Bottle, Barrels etc), Rainwater)	Water Supply Centre, sometimes supported by Rainwater, Shops, Water supply by Trucks - storage on the rooftop and buying barrels	Water Supply Centre on the main road, and some inside the block (with smaller pipes), treated Rain Water in rainy season	River water, Rainwater, Water supply by trucks, Decentralise water supply (treated river water)	River water, Rainwater, Water supply by trucks, Decentralise water supply (treated river water
Drinking	Treated river water in barrels, Sometimes boilled Rain and River water	Water Supply Centre, sometimes supported by filtered Rainwater, Shops, Water supply by Trucks - buying barrels	River water, Rainwater (with no treatment or boiled or filtered), Water in barrels	River water, Rainwater, decentralise water supply centre (treated river water) at community centre
Cooking	Mostly from the Water Supply Centre	Water Supply Centre	River water, Rainwater	River water, Rainwater
Cleaning	Water Supply Centre (sometimes Rainwater)	Rain water in rainy season, Water supply centre in dry season, River water	River water, Rainwater	River water, Rainwater
Shower	Water Supply Centre	Rain water in rainy season, Water supply centre in dry season	River water, Rainwater	River water, Rainwater
Toilet	Water Supply Centre (Sometimes Rainwater)	Rain water in rainy season, Water supply centre in dry season	River water, Rainwater	River water, Rainwater
Irrigation	None	None	River water, Rainwater	Mostly None
Connection to Electricity	Yes	Yes	Yes	Yes
Type of Toilet	Western style and squatting pan with pour flush or flush	Squatting pan with pour flush and latrine	Squatting pan with pour flush and pit latrine, open space	Public toilets, squatting pan or western style with pour flush and pit latrine, open spaces
Disposal of Black water	Honey suckers and Sewage system	Honey sucker, on the road pit latrine	Excreta from the toilet taken into the field by themselves or Honeysuckers	Honey sucker, drain away to the ground
Disposal of Grey water	Sewage system	Sewage system, Street	Nature and Streets	Street to drain away to the ground, flushing in the toilet
Waste				
Composition of Waste	All mixed	All mixed	Mostly organic, some plastic and metal	Mostly plastic and organic waste
Collection of Waste	CINTRI, Informal Waste Management Sector	CINTRI, Informal Waste Sector (with Collection Point)	Informal Waste Sector (Waste pickers collecting valuables)	Informal Waste Sector (Waste pickers collecting valuables)
Separation of Waste (Organic waste Other Valuables (Can, Bottles, Metal) Plastic**)**	Only for Valuables	Only for Valuables, few collection of organics for animals	Mostly organic for animals, valuables, burning plastic	Only for Valuables
Usage of Organic waste	None or rare	Sometimes reuse of Organic Waste for animals	Animal food	None
Alternative Ways of Disposal	Plastic Burning	Plastic Burning	Plastic Burning, feed animals	Plastic Burning, open space
Energy source for cooking	Gas, Electricity ?	Wood, Electricity	Wood	Wood, Gas, Electricity

Criteria/ Urban Typology	Inner City	Outer City	Rural Character Areas	Impermanent Informal Settlements
Typology (Elevation, Material, Style, Dimension…)				
Elevation	None	Mostly elevated	Mostly elevated (wooden structure on concrete or wood columns), No elevation in concrete houses	Mostly elevated
Height	Mostly 2 to 4 storeys, up to 10	Mostly 1- 2 storeys	Mostly 1-2 storeys	Mostly 2 to 4 storeys, up to 10
Material	Mostly concrete	Wood, Concrete, Bricks, Metal	mostly wood, concrete, bricks, metal, rarely mud	mostly wood, concrete, bricks, metal, rarely mud, plastic,
Style	Colonial, Modern Khmer and contemporary	Traditional Cambodian House, contemporary concrete houses	Traditional Cambodian House, contemporary concrete houses	Traditional Cambodian House
Dimension	5-7 meters to 10 meters	7-10 meters	7-10 meters	5-7 meters to 10 meters (for example these with shops)
Plot size	Same with building dimensions	9-10 meters	20-60 meters	5-7 meters to 10 meters
Ratio of build up area and land	100%	80%	10-50 %	80-100%
Socio - Economic				
Number of Families	1 to 5	1 to 2	1 to 2	1 to 4
Occupation	Varies, Mostly high and middle class (pal working in the municipality, trading hubs)	Varies, Mostly middle class (Doctors, Teachers, Small Business …)	Varies, Lower class (ppl handcrafts, farmer sellers on the market)	Various (Construction Labours, Sellers, Waiter, Teacher Government Officer, Military)
Usage	Mixed-use Area	Mostly residential, few vendors	Rural (residential with farming)	Mostly residential, few vendors
Land Title	Yes	Yes	Yes	No
Expectancy of Change	Low except empty plots	Low in terms of plot sizes, high in terms of material (from wooden to concrete structures)	Low	High in terms of relocation, low in terms of material
General Topic				
Community Structure	Village Chief / Commune Chief / District Governor / Province Governor	Village Chief / Commune Chief / District Governor / Province Governor	Village Chief to monitor and to represent the government, Neighbourhood Help	Village Chief / Commune Chief / District Governor / Province Governor (in addition: Community Centre, Saving Groups, Neighbourhood Cooperation, Unified Structure)
Availability of Construction Materials	Mostly concrete or brick	Wood, Concrete, Bricks, Metal	Wood, concrete, bricks, metal, mud, other natural materials	Wood, concrete, bricks, metal, mud, other natural materials, plastic

Fig. A.2: Urban Typologies Information Sheets (Illustration by the authors)

International student cooperation project **"Integrated Resources Management Battambang (iReBa)"** between the University of Battambang and the Bauhaus-Universität Weimar

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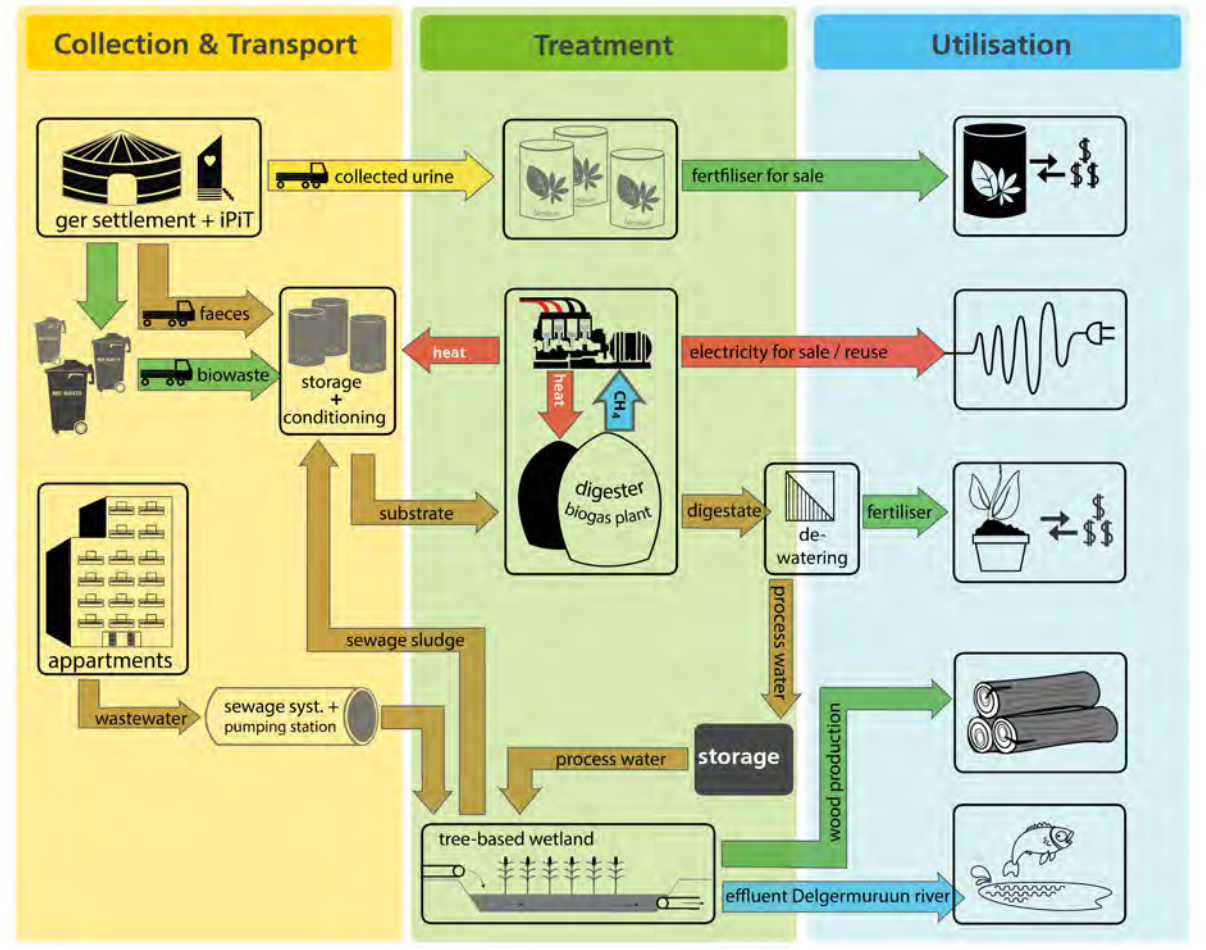
Introduction

Within the frame of the "Internationaler Ideenfonds (International Fonds for Ideas)" of the Bauhaus-Universität Weimar (BUW), the chair of Urban Water Management and Sanitation and the Institute for European Urbanism applied for funding of an international und interdisciplinary cooperation with representatives and students of the University of Battambang (UBB), Cambodia.

Within this interdisciplinary and international project, the involved students from different faculties will learn how to combine urban planning and integrated infrastructure development in a practical manner and create value added sustainable urban resource management system (Londong et al. 2013; Stäudel et al. 2012).

The main goal is to bring together sustainable and resource-economic based urban water management and waste management with modern urban planning. The results shall be a practical contribution for the further development of the city of Battambang. (Stäudel 2006)

Furthermore this interdisciplinary approach should be a contribution to the fight against poverty, because it intends to integrate the special local socio-economic framework (income situation, illiteracy, unemployment and poverty in the informal settlements) in Battambang.



Example for a resource-based urban water management system: *Integrated sanitation system for a city in Mongolia*

Cooperation

The project will enhance the cooperation between the Bauhaus-Universität Weimar and the University of Battambang in order to build up a network between Cambodian and German researcher and students. This cooperation is also the basis for the common propose of research projects in South East Asia and a sustainable collaboration.

This project shall also encourage the German and Cambodian students to get in touch and exchange ideas. The students get the chance to strengthen their scientific education on an international level. The practical cooperation of the students from both countries will enhance their intercultural understanding and open the possibility for a deepened exchange of knowledge in the future.

Furthermore the project may improve the attractiveness of both involved universities for national and international students in the field of environmental engineering, urban planning and other related professions.

Starting situation

Battambang is the second largest city in Cambodia. The existing infrastructure for wastewater disposal of the city centre is partially existing since the colonial period. But since this period the area of the city increased several times, mostly uncontrolled without considering modern urban planning. Unsafe pit latrines pollute the groundwater and are flooded during the rainy season.

Less than 70% of the inhabitants are connected to the central drinking water supply or have access to toilets. With increasing distance to the city centre the access to adequate infrastructure decreases. Waste collection, recycling and disposal of solid waste are further challenges for the city.

While struggling with a lack of adequate infrastructure, at the same time the city has an important economic potential in Cambodia, as it is located on one of the main roads in the country and Southeast Asia.

With the second largest university of the country, Battambang is a centre of science and education in Cambodia and has access to the educated elite. The social and economic situation of the city is more balanced than in the capital Phnom Penh.

Consequently, a network with local representatives of science, administration, economy and organisation of development is much easier to establish than in Phnom Penh.

Good contacts with local stakeholders and especially with the UBB are already established due to a long lasting cooperation in several pilot projects between BUW, the Thüringisch-Kambodschanische Gesellschaft e.V. (TKG) (Thuringian-Cambodian Association) and UBB in Battambang.

Project presentation

The Chair of Urban Water Management and Sanitation under Prof. Dr.-Ing. J. Londong received some funding for the establishment of a cooperation between BUW and UBB. The here presented project offers a good possibility for the intensive beginning of the cooperation between the 2 universities.

The project consists of 2 parts:

One theoretical part in Cambodia and Germany respectively and a second practical part in Battambang, Cambodia:

In the theoretical part the students will learn the basic knowledge of resource-based urban water management and resource management systems in mutual learning sessions. The students will work in groups on general and specific topics and prepared for their field trip / cooperation to and in Battambang. Consultations with the lecturers are part of the preparation.
In the practical 2nd part of the project the students and scientists from Germany and Cambodia will develop an overall concepts for resources management for the city of Battambang.

Students as well as the lecturers and scientists will get opportunity to deepen and to extend their scientific knowledge and to adapt it to the specific context. Due to the interdisciplinary format of this project and the intercultural exchange between Cambodian and German students, all involved persons will benefit greatly on the professional and the personal level respectively.

One main focus of the project is the practical relevance of the learning content and the results to be achieved. Missing data has to be collected in a practical manner and brought together in a holistic concept for the city of Battambang.

This involves excursions to local stakeholders, interviews with residents in different urban settings and visits to related projects (e.g. composting plant, social waste management centre, wastewater treatment plants, informal settlements etc.) and organisations in order to get a full understanding of the local situation. Common leisure activities and trips to the surroundings of Battambang are part of the project as well.

The staff member from BUW (1 Professor, 2 Scientists) get to know their Cambodian colleagues in Battambang. As a result this will create a good base for further scientific cooperation, student exchange and common research projects.

Purposed Results

The goal is to reach the following results of the project:

- Development of an model-like overall concept for water/wastewater with focus on resource recovering and with specific treatment of organic matter
- Medium-term solidified contact with UBB
- Common German-Cambodian publications
- Final papers for students
- Enhancement of teaching at BUW in Germany and at UBB in Cambodia
- master credits for students (environmental engineering and urbanism)
- Basis for application for international funds in the region Southeast Asia

Course pre-requisites for attending

- good English language skills
- master students of the degree program of civil engineering, engineering, management, urban planning (Bauhaus-Universität Weimar)
- master student of faculty of engineering, XXXXXXXXXXX (Royal University of Battambang)
- application procedure with CV and letter of motivation and oral test
- maximum attendees: 8 Cambodian students and 8 German students.

Academic validation

For the German students, the project is offered as a regular "study project" for master students of degree programs civil engineering, environmental engineering and urbanism with 12 credits.

For the Cambodian students, the project is offered as a XXXXXXXXXX for master students of degree programs XXXXXXXXXXXXX with XXXX credits.

Literature:

Londong, Jörg, Jürgen Stäudel, Christian Bruski, Grit Rost, and Matthias Hartmann. 2013. "Integrated Sanitation System : From Disposal to Reuse – The Case of Darkhan, Mongolia." *Submitted to Water Resources Management*: 12.

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Further information:

Royal University of Battambang: http://www.ubb.edu.kh

Bauhaus-Universität Weimar: www.uni-weimar.de

Professorship Urban Water Management and Sanitation:
http://www.uni-weimar.de/Bauing/siwawi/home/_home-eng.htm

Integrated sanitation systems: www.ipit.eu

Thuringian-Cambodian Association: www.tkgev.org

Cambodian Waste Management Organisation (COMPED): www.comped-cam.org