makeblock

URBAN RESILIENCE

(Student’s Book)

Makeblock STEAM Education Research Center


SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS

Source: UN

Education for Sustainable Development Goals

Table: Learning Objectives for SDG 11 Sustainable Cities and Communities	
Cognitive Learning Objectives	1. The learner understands basic physical, social and psychological human needs and is able to identify how these needs are currently addressed in their own physical urban, peri-urban and rural settlements. 2. The learner is able to evaluate and compare the sustainability of their and other settlements' systems in meeting their needs particularly in the areas of food, energy, transport, water, safety, waste treatment, inclusion and accessibility, education, integration of green spaces and disaster risk reduction. 3. The learner understands the historical reasons for settlement patterns and while respecting cultural heritage, understands the need to find compromises to develop improved sustainable systems. 4. The learner knows the basic principles of sustainable planning and building, and can identify opportunities for making their own area more sustainable and inclusive. 5. The learner understands the role of local decision-makers and participatory governance and the importance of representing a sustainable voice in planning and policy for their area.
Socio-emotional Learning Objectives	1. The learner is able to use their voice, to identify and use entry points for the public in the local planning systems, to call for the investment in sustainable infrastructure, buildings and parks in their area and to debate the merits of long-term planning. 2. The learner is able to connect with and help community groups locally and online in developing a sustainable future vision of their community. 3. The learner is able to reflect on their region in the development of their own identity, understanding the roles that the natural, social and technical environments have had in building their identity and culture. 4. The learner is able to contextualize their needs within the needs of the greater surrounding ecosystems, both locally and globally, for more sustainable human settlements. 5. The learner is able to feel responsible for the environmental and social impacts of their own individual lifestyle.
Behavioural Learning Objectives	1. The learner is able to plan, implement and evaluate community-based sustainability projects. 2. The learner is able to participate in and influence decision processes about their community. 3. The learner is able to speak against/for and to organize their voice against/for decisions made for their community. 4. The learner is able to co-create an inclusive, safe, resilient and sustainable community. 5. The learner is able to promote low carbon approaches at the local level.

Source: *Education for Sustainable Development Goals: Learning Objectives*, UNESCO

Foreword

It's expected that the global population will reach 10 billion by the end of this century. As the population grows, the urbanization of society is inevitable. Issues like climate change, environment protection, as well as farming and food security will continue to cause problems and challenges facing cities and communities.

Sustainable urban development has been defined as the development of cities that meets the needs of the present toward facilitating the process of urbanization without compromising the capacity of future generations to meet their needs. One of the key strategies on urban sustainability is to develop Urban Resilience, which is discussed in and proposed by Habitat III, the United Nations Conference on Housing and Sustainable Urban Development in 2016.

Overview of the Course

Urban Resilience is the measure of the capacity of an urban system to adapt to a changing environment, attain and maintain sustainability through all natural and technological hazards as well as socio-economic-political-cultural crises.

In the light of UN's Sustainable Development Goal 11 "Make cities and human settlements inclusive, safe, resilient and sustainable", this course has been designed for anyone interested in urban development. You don't need any special experience, but it might be of interest to learners who study environmental science, geography, biology, physics, and related AP (or GCSE and IB) subject areas.

On this course, you and your peers will pretend to be investigators appointed by the United Nations Human Settlements Programme to conduct a research project on your local community. You will debate the challenges facing global urban systems and potential solutions. You will discuss Urban Resilience approaches to some of the most pressing issues in developing countries. You will learn how scientists, engineers, and researchers from different disciplines work together to solve the problems.

Course Structure

This course includes 4 modules. Module 1, *Introduction to Project-based Learning*, introduces the concept of Urban Resilience and describes key research principles in designing social innovation projects for your cities and communities. In this module, you will not only discuss possible solutions to a range of sustainable developmental issues but also identify theoretical frameworks that you could implement in projects for your cities and communities.

To help you become familiar with project management and research methods, two parallel pilot projects are provided: Module 2, *Natural Hazards and Disaster Risk Management*, and Module 3, *Technologies and Water-energy-food Nexus*. These two modules explore critical environmental issues related to natural and technological hazards as well as socio-economic-political-cultural crises in developing countries. They also inspire you to think about the impact you as a member of the communities have on real-world problems.

The final module, *1m³ of Space in the Sustainable City*, is your capstone project. You are required to apply what you have learned to the social innovation you have planned in Module 1. To complete and deliver the project, you need to materialize your ideas on the sustainable city or community and then create a prototype. Finally, you will detail your prototype in a paper presentation in a special session of a model UN Habitat III.

Before You Start...

Prepare yourself for this learning journey by going over all the key terms used in this course in Appendix 1, *Glossary*, as well as relevant sources on the UN website or other relevant sites.

Also, get your learning resources and tools ready, such as mechanical parts and 3D design toolkits. If possible, you can carry out your learning activities in a fab lab or Makerspace.

Last but not least, keep an open mindset throughout this course. A sustainable society is vital to everyone. Every individual can and should contribute to the SDGs. Read *170 Daily Actions to Transform Our World* or *The Lazy Person's Guide to Saving the World* (both are available on the UN website), you will then realize that everyone is part of the solution to sustainable development.

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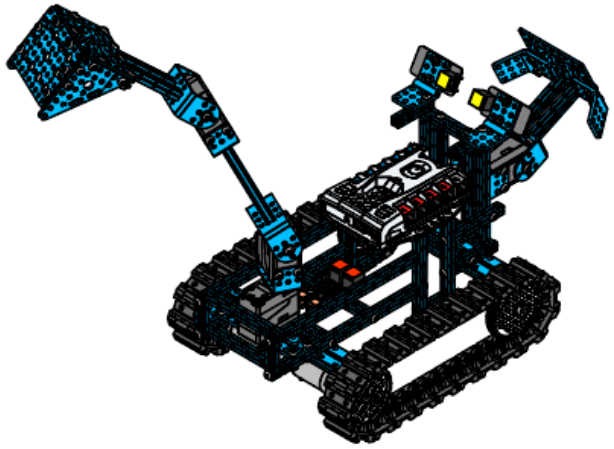
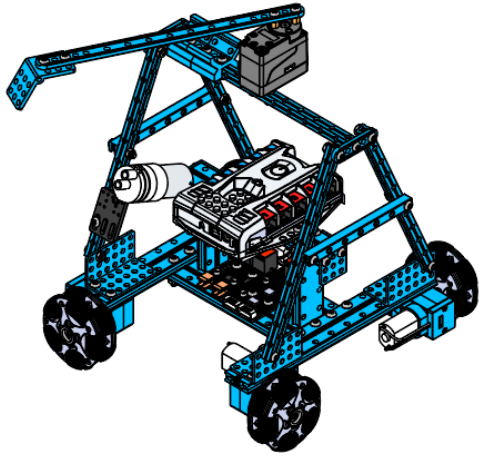
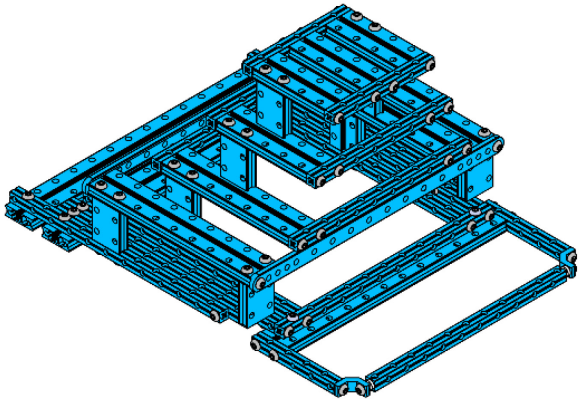
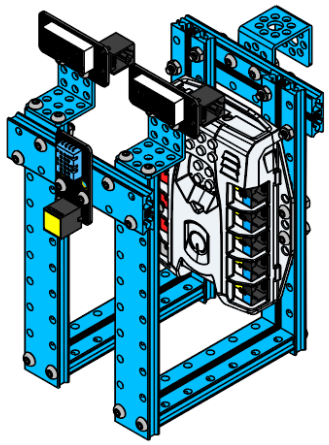
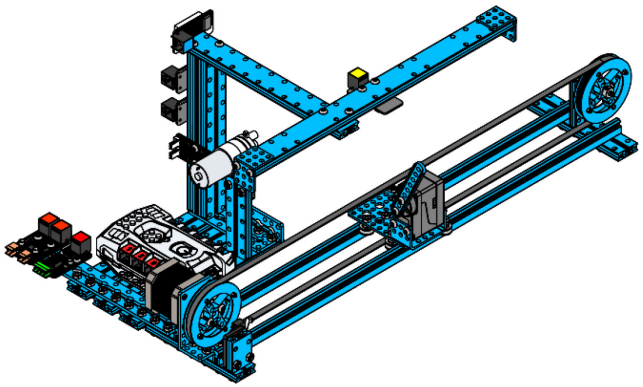
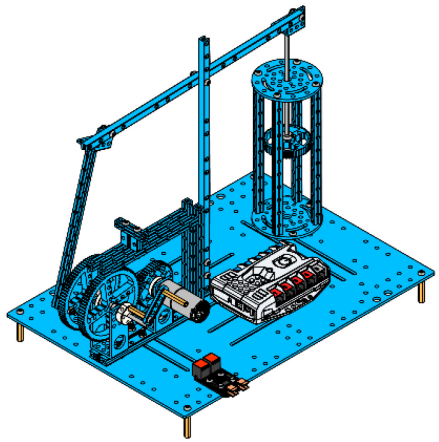
	Pilot Study A: Emergency Excavator Model	Pilot Study B: Linear Move Sprinkler Irrigation Model
Project Name and Diagram		
Key Building Parts	Continuous Track; Smart Servo Motors; 3-axis Robot Arm	Omnidirectional Wheels; Encoder Motor; Gyroscope; Rotating Shaft
Functionality Design	• Great strength and stability • Degree of freedom in the spatial mechanism • Digging and placing objects	• Great strength and stability • Degree of freedom in the plane mechanism • Inertia driven system
Applications in Industry	Tanks and excavators Selective Compliance Assembly Robot Arm (SCARA)	Center-pivot support Mobile portable device with navigation function

Project Name and Diagram	**Extension I: Drainage and Flood Control System** 	**Extension II: Information System for Locust Forecasting** 
Key Building Parts	Stepped Retaining Walls	Humiture Sensor
Functionality Design	• Slowing down the influx of surface runoff • Water cycle	• Collecting weather data
Applications in Industry	Stepped drainage channels Sponge Cities	Weather forecast and alert Big Data, "Internet + Agriculture"

	Extension III: Automated Traveling Sprinkler Model	Extension IV: Bicycle-powered Water Pump Model
Project Name and Design		
Key Building Parts	V-slot Guide Rail; Belt-drive Transmission Mechanism	Gear and Rod; Crankshaft and Connecting Rod
Functionality Design	• Fixed-distance-based movement • Reciprocal linear motion	• Conversion between reciprocal and rotary motion
Applications in Industry	Conveyor belts Assembly lines	Well pumps Drive mechanism of bikes

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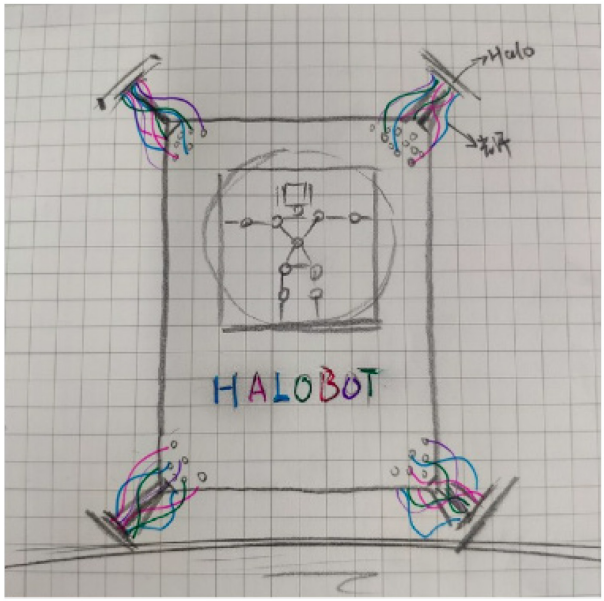
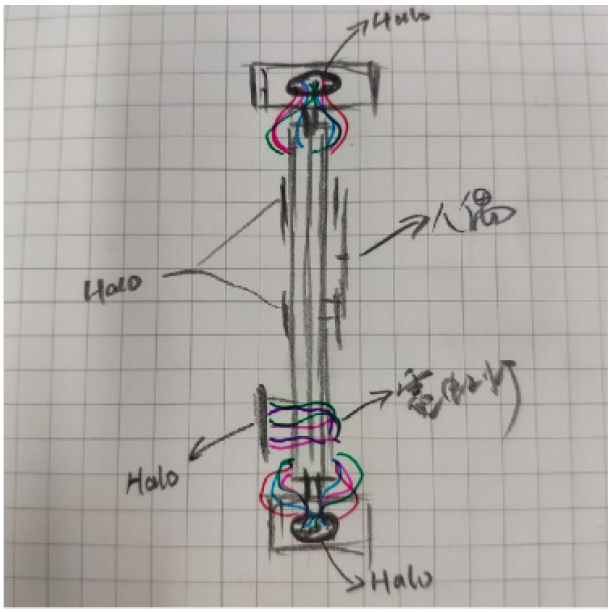
Learning Materials Checklist

Before the journey, make sure you have the tools and materials below:

- ☐ The Student's Book of *Urban Resilience*
- ☐ The prototype design assembly instructions attached to *Urban Resilience*
- ☐ Makeblock Makerspace Kit and the relevant software
- ☐ An engineering notebook for you to write down your ideas and notes





Note: Writing engineering notes along the way is a good approach to help you manage your projects. You can write down your ideas, draft your designs and draw project roadmaps on the engineering notes.

The Model UN Habitat III

Start your learning journey in this course by organizing a model UN Habitat III with your peers and course instructors. In this model conference, you and other delegates should comply with the procedures and rules of the real UN conferences.

If this is not your first model UN conference, perform as how you did before. If this is your first model UN experience, refer to Appendix II for detailed information about the procedures and rules.

In Task 1-1, draft your speech for the position paper. A position paper consists of three parts: Topic Background (related to urban issues and development), Past International Action, and Country Policy.

Task 1-1 Write a position paper for the Model UN Habitat III

In Task 1-2, write an opening speech draft based on the position paper. Opening speeches are the most important documentation to convey your ideas and opinions.

Task 1-2　Write an opening speech for the Model UN Habitat III

INTRODUCTION TO PROJECT-BASED LEARNING

Overview

The model Habitat III conference enabled you to gain a basic understanding of the importance of sustainable urban development and to identify the most pressing problems and challenges facing the world. Today, 3.5 billion people live in cities, and the number will continue to grow. Many cities and communities have to face growth challenges including poverty, migration, education and healthcare services, climate change, natural resource exploration, environmental protection, disaster resistance during urbanization.

Invited by the "United Nations Human Settlements Programme (UN-Habitat)", you and other investigators will carry out a study centering on the sustainable urban developmental issue related to the community where you live. Based on the research outputs, demonstrate your visions of sustainable urban development, and deliver a social innovation project for your community.

Intended Learning Outcomes

- ☐ Prepare a blank notebook where you can write down your engineering notes.
- ☐ Interpret the concept, practical implications, and value of Urban Resilience.
- ☐ Develop your community profile.
- ☐ Identify your initial research question relating to Urban Resilience.
- ☐ Read through the theoretical tools and conceptual framework included in this course.

Keywords

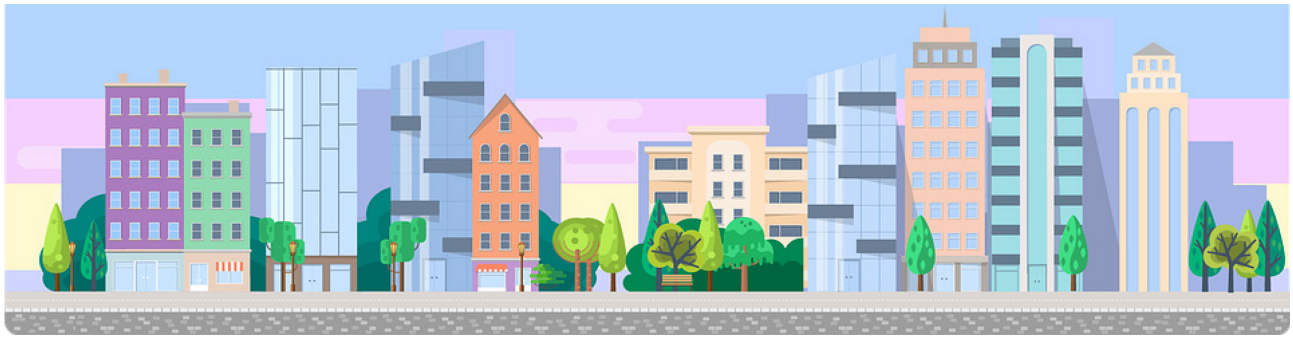
Capstone Project; Community Profile; Pilot Project; Resilient City; Sustainable City; Urban Hazards; Urban Resilience; Urban Systems Model Approach

Sustainable Cities and Communities: From a Vision to Reality

The adoption of the *New Urban Agenda* is one of the key outcomes in the United Nations Conference on Housing and Sustainable Urban Development (Habitat III). Principles related to urban sustainability, such as urban planning, construction, development, management, and renewal, are also mentioned at the Habitat III. The *New Urban Agenda* highlights the relationship between healthy urbanization and development, and elaborates on Sustainable Development Goal 11, "Make cities and human settlements inclusive, safe, resilient and sustainable."

Below is the vision shared in the *New Urban Agenda*:

> *We share a vision of cities for all, referring to the equal use and enjoyment of cities and human settlements, seeking to promote inclusivity and ensure that all inhabitants, of present and future generations, without discrimination of any kind, are able to inhabit and produce just, safe, healthy, accessible, affordable, resilient and sustainable cities and human settlements to foster prosperity and quality of life for all.*
>
> *We aim to achieve cities and human settlements where all persons are able to enjoy equal rights and opportunities, [...].*
>
> (UN, 2017: 5, Item 11 and Item 12)



Urban Hazards and Crises

There are three main types of urban hazards: natural hazards, technological hazards, and socio-economic-political-cultural crises. Categorize the hazards listed in Task 1-3 (a), and write your answer in Task 1-3 (b).

Task 1-3 (a) Classification of urban hazards

Transport Accident	Drought	Housing Crisis
Water Systems Breakdown	Radiation	Explosion
Extreme Temperature	Wildfire	War
Chemical Spill	Insect Infestation	Social Conflict
Epidemic	Pandemic	Earthquake
Food Shortage	Terrorism	Racial Segregation
ICT System Breakdown	Flood	Water Shortage
Energy Systems Breakdown	Poisoning	Immigration Crisis
Massacre	Energy Crisis	Volcano
Excessive Unemployment	Gas Leak	Temperature
Corruption	Storm	Oil Spill
Political Conflict	Fire	Trade War
Business Discontinuity	Collapse	Mass Movement
Education Systems Breakdown	Cold War	Economic Crisis

Task 1-3 (b) Classification of urban hazards

Natural Hazards	Technological Hazards	Socio-economic-political-cultural Crises

Urban Resilience

To implement the blueprint and initiatives proposed in the *New Urban Agenda* and solve the problems in urban development, Habitat III brought up a significant concept: Urban Resilience.

Urban Resilience derives from the resilience in psychology. Resilience refers to the ability of an individual to adapt in the face of adversity, trauma, tragedy, threats or significant sources of stress, such as parents' divorce and failure in the college entrance exam.

Urban Resilience is the capability of allowing an urban system to maintain its continuity as well as to positively adapt and transform towards sustainability during natural hazards, technological hazards, as well as socio-economic-political-cultural crises. Urban Resilience can be developed across functional, spatial, physical and organizational scales.

Figure 1-1 Features of a resilient city

As shown in Figure 1-1, an urban system with great resilience, like a springy ball, is able to recover from external stress, be it natural or man-made stresses, and diminish the damage to the internal system while consuming less time or fewer resources.

Designing a Sustainable Community of the Future

The "UN-Habitat" invited you and your team members to research the potential problems facing your community. You need to design social innovation projects for the sustainable development of your community.

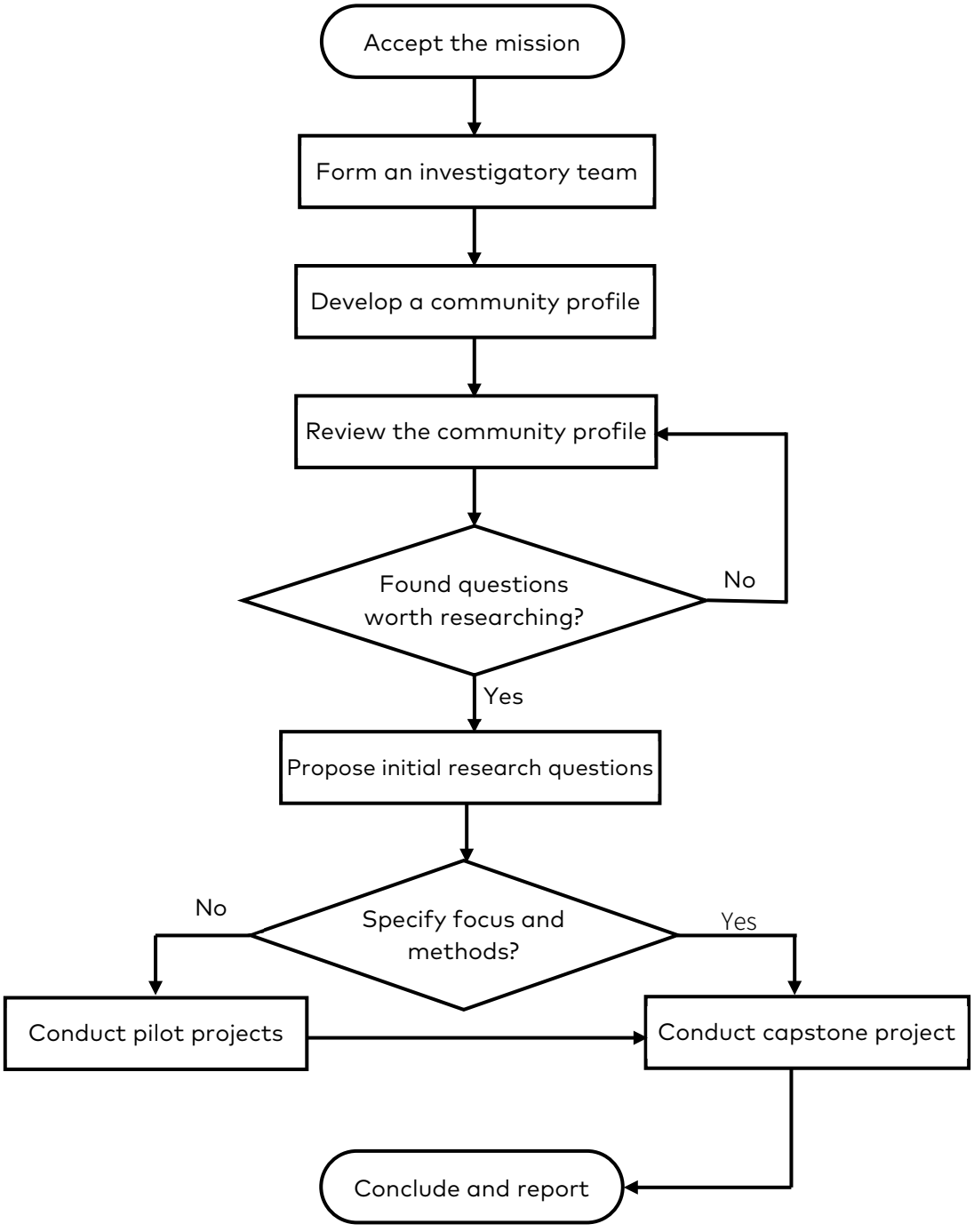


Figure 1-2 Workflow of completing this course

Accept the Mission: *1m³ of Space in the Sustainable City*

You are commissioned by the "UN-Habitat" to deliver a project, *1m³ of Space in the Sustainable City*.

"1m³ of Space in the Sustainable City", literally, depicts a tiny area that might be hard to notice in a complex urban system, like a drop in the ocean. However, there are thousands of ways to make use of this tiny space.

Where can we find $1m^3$ of space? In the gap between neighboring houses, on the traffic island in a busy road, at the trash pile around a corner of the community, or the tranquil flower bed in downtown. It may appear useless, but just a potted plant or a chair can make a big difference to this tiny space.

Figure 1-3 Montane Mansion, Hong Kong

Figure 1-4 Train Street, Hanoi

Figure 1-5 Bosco Verticale, Milan

Figure 1-6 Gardens by the Bay, Singapore

Take another look at the community or city where you live. Consider how you would interpret and apply the concept of "1m^{3}of space" to make your community more sustainable and livable.

Step 1: Form an Investigatory Team

If you want to lead an investigatory team, recruit 3 to 5 investigators. The investigation team should be no more than 6 members.

If you find another team's research question interesting, and they are recruiting members, ask the team leader whether you can join the team.

If you play the role of the project lead, you need to propose the research topic before recruiting members. A research topic does not mean a specific research question but includes keywords or key phrases that can represent the questions. For instance, if you are interested in disaster risk management, but unsure about what kind of aspect you want to address, you could narrow down to the keywords by discussing with your members.

Fill in the form below after you set up your team, and introduce to each other, talking about your interests in subject areas and sustainable issues.

Task 1-4 Investigatory team information card

Topic	
Name	**Skills, subjects or areas of interest, sustainable development issues of interests, etc.**

Step 2: Develop a Community Profile

A social innovation project is a design activity that is centered on humans and their needs. Before you define your research question, you need to take the characteristics of your community into account and be prepared to apply your prior experience to your projects. After that, you have to materialize your ideas through text, images, and videos to generate a city or community profile.

A community profile is a comprehensive description of the needs of community members and resources within the community. It requires the active involvement of the community for developing an action plan to improve life quality. Generating a community profile is a process where you need to collect, select, analyze information related to the social and human attributes of the community, and extract words or tags that could depict the community.

Creating a community profile is a key step to your research. The purpose of a community profile is to enable you to understand the community as a whole.

A city contains various regions and communities, between which there may be significant differences. If noticeable regional differences exist in your city, then focus on one specific region or community to conduct the observation.

First of all, based on the chosen research question of your investigation team, collect information and data, like geographic position, climate, cultural heritage, population, population density, population distribution, and transport network.

If you are unclear about what information to collect, create a mind map and list as many ideas as possible on the notebook, and select the key ones from the list.

You also need to know where to collect reliable and authentic information.

There are many ways to collect information: search online, visit city galleries, cultural centers, and museums, or if necessary, consult your teachers, librarians, parents or other professionals.

Second, in Task 1-5, filter the collected information, and categorize and tag the information.

In the left column of Task 1-5, write down the collected information. If you have collected information about the geographic position, then you may write down: in which direction your community lies in your city, neighboring cities, city size, etc.

In the right column of Task 1-5, abstract the information in the left column, specify what characteristics that the information is about, and tag the information.

Task 1-5 takes Tung Chung, an area of Hong Kong, as an example. You can analyze your community following this example.

Alternatively, you can also try reverse thinking, deducting what information and data you need from the perspective of analysis.

Figure 1-7　Tung Chung, Hong Kong

Figure 1-8　Sham Shui Po, Hong Kong

Task 1-5 Sample and open code my community or city

Background Information	What Characteristics of My Community It Depicts
Example: *Tung Chung is a new town on the northern coast of Lantau Island, an offshore island of Hong Kong which you will drive by if you go to Hong Kong via Hong Kong-Zhuhai-Macau Bridge. Tung Chung is close to Hong Kong International Airport, which is on the island of Chek Lap Kok. Tung Chung is connected to other places of Hong Kong via cross-sea bridges, underwater tunnels, and mass transit railway system.*	**Example:** (tag + description) ***Transport Hub:*** *Tung Chung is close to two crucial transport networks of the Guangdong-Hong Kong-Macau Greater Bay Area, Hong Kong-Zhuhai-Macau Bridge and Hong Kong International Airport. It plays a vital role in resource allocation in and out of the bay area with its convenient air, sea, land transportation.*

At last, concisely describe your community profile and write it down in Task 1-6. When you write your community profile, be objective and cite relevant statistics. The description should not be more than 420 words.

A well-done community profile could spark readers' imagination and impression of the community that you describe. When you write the profile, put yourself in the reader's position, assuming you are an officer from the UN-Habitat, or a delegate from the Habitat III, or someone unfamiliar with the community you live in. Think about how to help the reader quickly build up an understanding of your community and identify the problems.

Task 1-6 Develop a community profile

Step 3: Review the Profile and Propose Research Questions

Whether your project is innovative depends on what research question you choose. A carefully-chosen research question will give you a good start towards a successful social innovation project.

With your community profile and prior experience, write down two to three research question options in accordance with the research area you chose.

It takes time, a week or even longer, to identify a research question, and you need to consider many constraints, such as time, place and space, human and material resources, to evaluate whether your project is feasible under the limitation. Therefore, leave enough time for your team to analyze the information and consider the feasibility of your research proposal.

Before you make the final decision, think about the following questions:

(1) What are the project goals? Why is your project important?

(2) In what ways does your social innovation project strengthen the degree of Urban Resilience of your community?

Think thoroughly before writing down your initial research question. No more than 30 words.

Step 4: Specify Research Methods and Theoretical Frameworks

After identifying a tentative research question, you need to find a theoretical framework to support your research and help analyze the question. The suggested theoretical framework in this course is the Urban Systems Model.

Proposed by the UN-Habitat, Urban Systems Model Approach aims to illustrate the relationship between shocks and stresses that urban systems might suffer and Urban Resilience. To be more specific, that is the relationship between the three major types of hazards and the four scales of resilience.

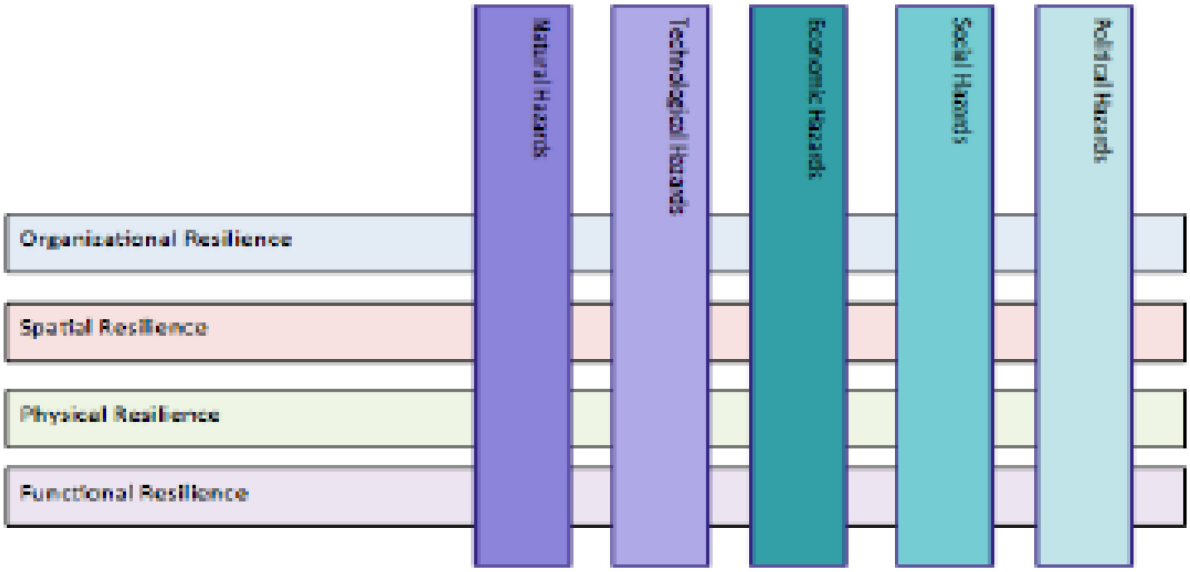


Figure 1-9 Urban Systems Model Approach

(Source: "*Urban Resilience*", Habitat III Issue Paper, 2015)

A city is a complex dynamic system that continuously adapts to all sorts of stresses and shocks. Cities are vulnerable to the disruption or breakdown of the individual or multiple parts of the urban system. Resilience strategies call for an understanding of the inherent relationship, with the view that cities cannot be resilient in isolation. Building resilience requires not only attention to the risk and immediate impacts of a shock on the affected area, but also highlights effective strategies to reduce loss and resolve crises in the long run.

Revisit the tags and community profile described in Tasks 1-5 and 1-6 and the identified problems. Use the Urban Systems Model Approach to re-categorize the collected information. Write down your findings and anticipated community issues in Task 1-7 by category.

Task 1-7 Analyze my community or city in the light of Urban Systems Model Approach

	Natural Hazards	Technological Hazards	Socio-economic-political-cultural Hazards
Functional			
Spatial			
Physical			
Organizational			

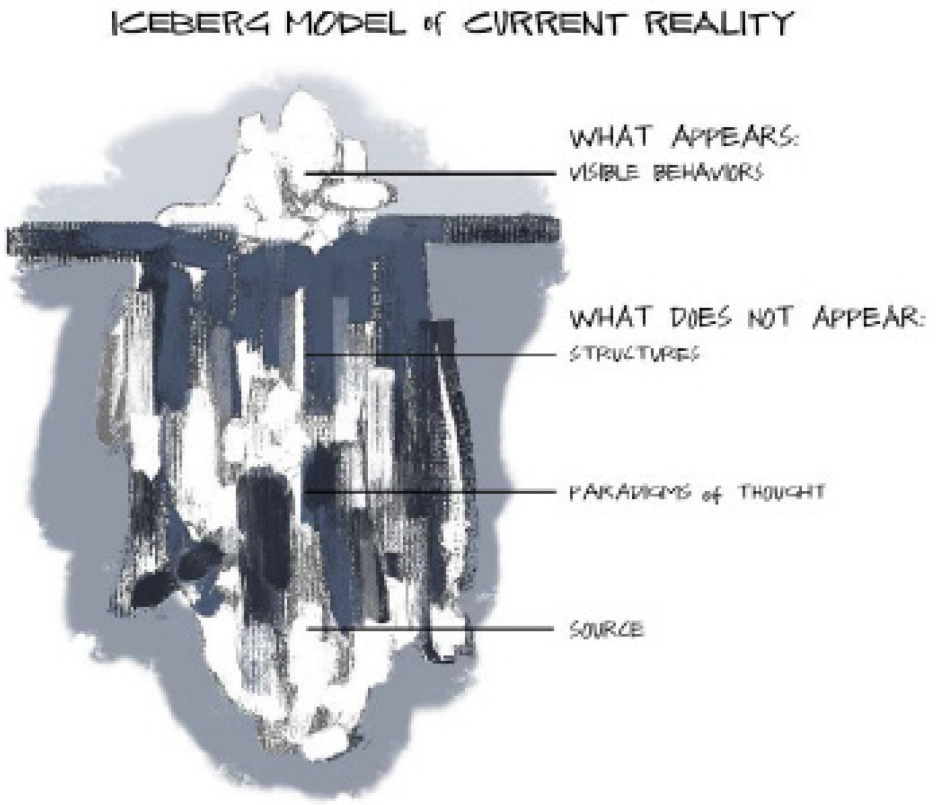


Figure 1-10 Iceberg Model in the Theory U[1] (Source: U.Lab)

In Task 1-7, pay attention to what is underneath the surface, the nature and source of the phenomena, and form a correct understanding of the relational structure, mindset and sources of problems so as to solve the problems. Theory U would allow you to dig deeper into the issues of the urban systems and give you an insight into what is really influencing Urban Resilience.

Take traffic congestion as an example. The traffic congestion during the peak time appears to be due to lagging iteration of traffic networks, narrow lanes, insufficient lanes, or poor signal timing.

However, simply widening or building more lanes is not the solution to the problem. Under the surface lie many sources of the disturbance, like imbalanced distribution of functional areas, and people's attitude towards private cars and mass transit options. Both the lagging urban planning and the absence of human-related factors in the public service system and social governance are the sources of the problem.

Step 5: Refine Your Research Question

Review the options that you listed in Step 3 "Propose Your Research Question" and combine them with the issues that you identify in Task 1-7 so as to further narrow down the research question. You can use the prompts in Table 1-1 to assess the tentative research question and feasibility of your project design.

Research Question: _____

_____

Table 1-1 Checklist of project feasibility

☐ Is there any previous research into the question? If so, what are the existing conclusions?
☐ In what aspects does your innovation intend to benefit your city or community?
☐ What changes do you expect your innovation can bring to your city or community in terms of Urban Resilience?
☐ What are your hypotheses and expected results?
☐ What methodology and strategy do you use when analyzing and designing?
☐ What data do you need? How do you gather data and analyze them?
☐ How do you explain your innovation through prototyping your creative ideas? What materials are needed? And how do you build the prototype?
☐ Is the location a restriction in your project?
☐ Can the local resources help you achieve what you want
☐ Is time a limitation?
☐ How much time do you need to complete the project?
☐ How much time and effort will you invest in this project weekly?
☐ Do you expect you can find the answers for the research problem as scheduled?
☐ Do you think the investigation group, with all the members involved, can tackle the problem you proposed concerning the time and location restrictions?

Step 6: Plan the Pilot Project and Capstone Project

After redefining your research question, you can move on to the capstone project if you (and your team members) are clear about what methods to use and what procedures to follow. A capstone project requires you to apply the knowledge and skills of multiple disciplines. The capstone project in the final module, *1m³ of Space in the Sustainable City*, includes some instructions to guide you to complete the project.

If you (and other team members) are not clear about how to carry out the capstone project, complete the pilot projects in Module Two and Module Three first. As what has been mentioned in Step 3 "Review the Profile and Propose Research Questions", the two modules as pilot studies prepare you for the capstone project. From these two modules, you can learn to evaluate and prove whether your project design is reasonable and feasible, whether your methodology is suitable, and how to use the modeling materials.

Recap

Refer to the checklist below to see whether you completed all the missions.

- ☐ Know the 17 Sustainable Development Goals
- ☐ Familiar with the outcomes of Habitat III. Participate in a model Habitat III
- ☐ Develop a community profile
- ☐ Demonstrate your Understanding of Urban Resilience in the context of your community based on your prior experience
- ☐ Organize an investigation team focusing on sustainable cities
- ☐ Understand how to choose a research question
- ☐ Identify one or more research ideas
- ☐ Decide whether to carry out the pilot projects first or directly move on to the capstone project

About the Sustainable Development Goal 11

Cities

Cities are hubs for ideas, commerce, culture, science, productivity, social development and much more. At their best, cities have enabled people to advance socially and economically. With the number of people living within cities projected to rise to 5 billion people by 2030, it's important that efficient urban planning and management practices are in place to deal with the challenges brought by urbanization.

Many challenges exist to maintaining cities in a way that continues to create jobs and prosperity without straining land and resources. Common urban challenges include congestion, lack of funds to provide basic services, a shortage of adequate housing, declining infrastructure and rising air pollution within cities.

Rapid urbanization challenges, such as the safe removal and management of solid waste within cities, can be overcome in ways that allow them to continue to thrive and grow, while improving resource use and reducing pollution and poverty. One such example is an increase in municipal waste collection. There needs to be a future in which cities provide opportunities for all, with access to basic services, energy, housing, transportation and more.

Source: UN, www.un.org/sustainabledevelopment/cities

Facts and Figures

- Half of humanity–3.5 billion people–lives in cities today and 5 billion people are projected to live in cities by 2030.
- 95% of urban expansion in the next decade will take place in developing world.
- 883 million people live in slums and most of them are found in Eastern and Southeastern Asia.
- The world's cities occupy just 3% of the Earth's land, but account for 60%-80% of energy consumption and 75% of carbon emissions.
- Rapid urbanization is exerting pressure on fresh water supplies, sewage, the living environment, and public health.
- As of 2016, 90% of urban dwellers have been breathing unsafe air, resulting in 4.2 million deaths due to ambient air pollution. More than half of the global urban population were exposed to air pollution levels at least 2.5 times higher than the safety standard.

Source: UN, www.un.org/sustainabledevelopment/cities

Goal 11 Targets

11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums.

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.

11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries.

11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage.

11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations.

11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.

11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities.

11.A Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning.

11.B By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels.

11.C Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials.

Source: UN, www.un.org/sustainabledevelopment/cities

Source: Banda Aceh, Indonesia, by Arto Marttinen via Unsplash

Notes

[1] U.Lab (2015) *The Iceberg Model*. Available from: www.presencing.org/aboutus/ego-to-eco/three-divides. [Accessed: Oct. 15th 2019].

PILOT STUDY A:

NATURAL HAZARDS AND

DISASTER RISK MANAGEMENT

Overview

Natural hazards bring adverse effects on human activities and threaten the stability of urban systems. A natural disaster not only damages the urban natural environment and ecosystem, but also triggers food, water, energy crises, and socio-economic-political-cultural problems.

Different areas are prone to different kinds of natural disasters. It is observed that natural disasters follow certain patterns of spatial distribution: earthquakes, typhoons, hurricanes and floods in coastal cities. Ecosystems in cities on islands or mountains are fragile so any kind of parasite plagues or invasion of alien species may be devastating to the ecosystems of these cities.

This module will focus on the socio-economic-political-cultural crises resulting from natural hazards. You will learn about how Urban Resilience prepares urban systems for natural catastrophes and reduce negative social impacts.

Intended Learning Outcomes

- ☐ Analyze the causes and effects of natural and technological hazards in your city or country.
- ☐ Identify the existing problems in the urban system when it is facing the socio-economic-political- cultural crises caused by natural disasters.
- ☐ Analyze the role of Urban Resilience before, during, and after a disaster.
- ☐ Design a prototype and explain how it would strengthen Urban Resilience.
- ☐ Plan strategies to help your city quickly recover from natural catastrophes.

Keywords

Continuous Tracks; The Degree of Freedom; Emergency Equipment; Functional Resilience; Great Earthquakes; Infrastructure; Natural Hazards; Physical Resilience; Technological Hazards; Urban Lifeline System

Your Study Plan

Schedule your study before working on the pilot study. Specify the expected learning outcomes and efforts. The table below includes the recommended time cost; however, you can have a talk with your course instructor to tailor your schedule.

Stage	Learning Content	Your Time	Effort
Assess	**Socio-economic-political-cultural Impacts of Natural Hazards** ● Examine the socio-economic-political-cultural impacts of natural hazards ● Describe the components and importance of urban lifeline system in the case of the disaster		1-2 hrs
Evaluate	**Coping with the Earthquake** ● List and explain the actions and measures that could be implemented to cope with natural disasters ● Solve the two challenges proposed in the context		1-2 hrs
Plan	**Designing an Emergency Equipment** ● What are the advantages of using continuous tracks? ● How to design the continuous tracks of an excavator? ● How to clear or move the obstructions? ● What is the degree of freedom? ● How to build a robot arm with 3 degrees of freedom?		2-4 hrs
	Making the Emergency Equipment ● Mechanical Structure Design ● Functionality Design		4-6 hrs
Apply	**Your Turn to Practice** ● Step 1: Assess the Task ● Step 2: Evaluate Strengths and Weaknesses ● Step 3: Plan the Approach ● Step 4: Apply Strategies ● Step 5: Reflect		6-8 hrs
Reflect	● Summarize what you have learned in this case study		1-2 hrs

Extension Activities	**Urban Resilience and Urban Flooding** ● Causes and impact of urban flooding in the context of rapid urbanization in the developing world ● **Prototype:** Drainage and Flood Control System		2-4 hrs
	Urban Resilience and Locust Plagues ● How did scientists in ancient times and nowadays cope with locust plagues ● **Prototype:** Information System for Locust Forecasting		2-4 hrs

Socio-economic-political-cultural Impacts of Natural Hazards

Natural hazards are adverse events caused by abnormal natural evolution. A natural hazard may bring catastrophic impacts on both the natural environment and human society. For instance, an earthquake may cause landslides and surface rupture, but also destruct urban infrastructure, energy, education, and medical systems.

Figure 2-1 The wreckage of houses

Figure 2-2 Cracks in the road

The Great Earthquake

For now, most urban systems are not enough resilient against earthquakes and earthquakes are difficult to predict. An urban system may be razed in seconds when struck by a strong earthquake.

On 28th July 1976, a magnitude 7.8 earthquake hit Tangshan, an industrial and coal-mining city in China. The terrible earthquake broke down all the services in the city, leaving highways and bridges collapsed, and communications failed. The city seemingly ceased to exist.

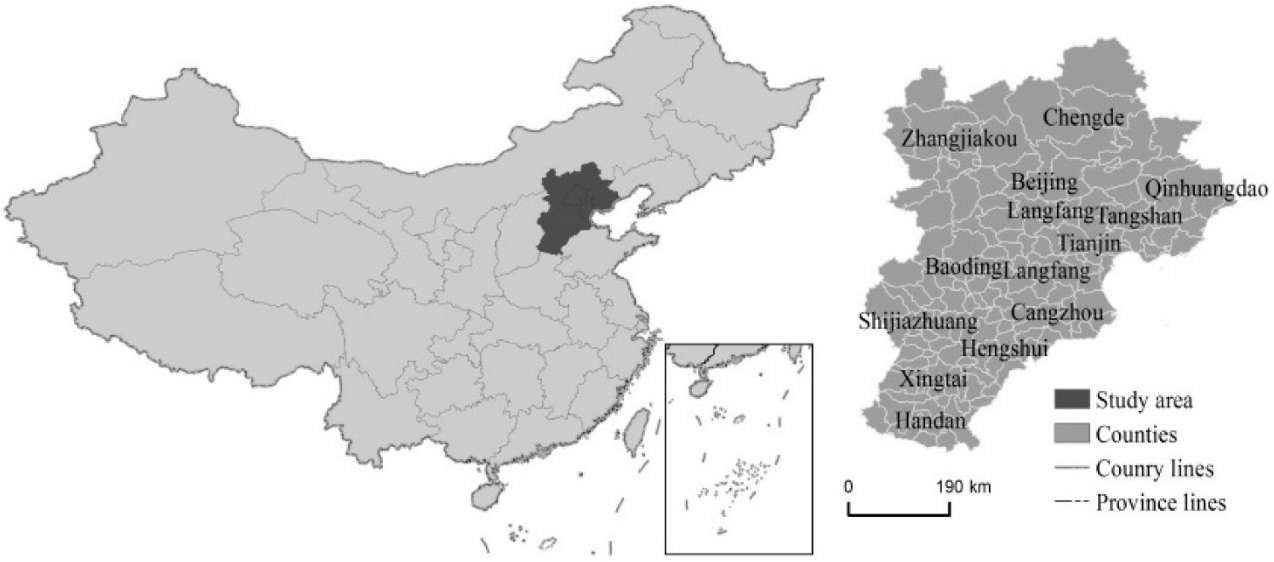


Figure 2-3 The Beijing-Tianjin-Hebei region[1]

(Source: "County-rural transformation development from viewpoint of 'population-land-industry' in Beijing-Tianjin-Hebei region under the background of rapid urbanization", Jintao Li, et al., 2017)

Reading 2-1 Damage to the Transport Network of Tangshan

Among the total 4,104km of highways, 228km was left with surface rupture and roadbed subsidence. Roads were covered with debris, sands and water and riddled with fissures, making it even harder for rescue teams to arrive at the disaster scene. Multiple civil rail lines and those for coal mining were interrupted. As estimated, 403km railway tracks were destructed due to roadbed rupture or subsidence, distortion and collapse. Moreover, the affected area along the rail lines reached nearly 740,000m^2 of areas along the rail lines were obliterated, accounting for 72% of the total area.

(Source: "*Destruction to Lifeline System in Tangshan Earthquake and Its Recovery*", Yang, 2006)

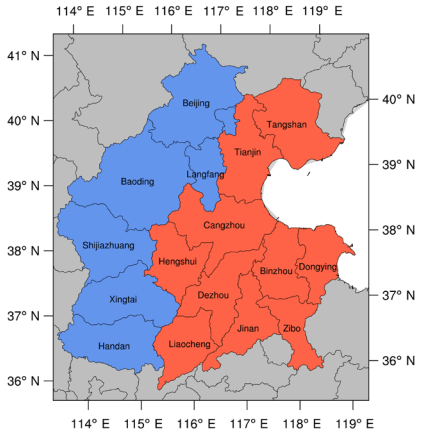


Figure 2-4 The location of Tangshan[2]

Figure 2-5 Damages to railway rails during Tangshan Earthquake

Urban Lifeline System

An urban lifeline system is a key determinant of Urban Resilience of a city against a disaster. It comprises ICT, water, electricity and transport systems. The lifeline systems are to a city what arteries are to the human body.

The urban lifeline system of Tangshan was obliterated as a result of the strong earthquake. Multiple failures in an urban lifeline system may kill the city. Tangshan needed a transfusion to recover from the fatal injury.

Reading 2-2 Disruptions in Communication, Water and Electricity System of Tangshan

The destroyed postal buildings and information and communication buildings reached 40,591m^2, accounting for 96% of their total building area. The great earthquake destructed 103 telecommunications systems, leaving Tangshan completely isolated from the world.

The city's water supply system and electrical power system failed after the terrible struck. It was estimated that 70% of the chambers of water source wells and 80% of the water pumping stations collapsed. There were 646 damaged spots in the 140km underground pipelines, mainly including disconnection at the joints, deformation, and rupture caused by external forces.

Major power generators, like Tangshan Power Plant, failed to work after the earthquake. Power grids in Beijing (the capital of China), Tianjin (a coastal metropolis in Northern China and one of the national central cities), and Tangshan lost nearly 30% of the total power generation. Four power lines connecting to Beijing, Tianjin, and nearby counties were tripped.

(Source: "*Destruction to Lifeline System in Tangshan Earthquake and Its Recovery*", Yang, 2006)

Figure 2-6 Communication tower

Figure 2-7 Water supply station

Figure 2-8 Fossil fuel power station

Now, you are an engineer of the rescue teams. Based on your understanding of the reading materials above and the background research, what measures will you take to rescue the dwellers in Tangshan? Write down your measures in Task 2-1.

Task 2-1 Assess the impacts of an earthquake on the urban lifeline system —using Tangshan Earthquake as an example

Damages	Measures
Example: *Surface rupture, roadbed subsidence, a considerable amount of debris, sand and water on the destructed roads.*	**Example:** *Send out tracked construction vehicles to the affected area. The vehicles should be equipped with a bucket so that they can excavate or move debris and rubble.*

Coping with the Earthquake

A quick response is key to saving life in disasters. The structure and equipment of an emergency vehicle should be designed to help rescue teams arrive at the scene as quickly as possible. Now, let's analyze how to make an emergency vehicle that can adapt to the damaged roads in the Tangshan earthquake.

Figure 2-9 Crawler excavator

Figure 2-10 Excavators working in the mining area

The damaged roads brought about two big challenges. First, surface rupture and sinking roadbed were all over the roads, so the emergency vehicles had to adapt to the uneven roads. Second, silt and debris on the roads made it even harder for the vehicles to move, so the vehicles should be equipped with tools to clear or move the obstructions.

Considering the first challenge, we have to prevent the vehicles from getting stuck in the fissures. Tracked vehicles can move on rough terrain and mud while wheeled vehicles are easy to get stuck.

A shovel or bucket can help the vehicles overcome the second challenge, clearing or moving debris. The robotic arm attached to the bucket can work like human arms, moving up and down to scoop up things. Better still, it can rotate.

Designing an Emergency Equipment

Wheels, continuous tracks, and legs are the most common drive mechanisms, among which wheels are most widely used. However, in this project, considering the challenges we face in earthquake-stricken areas, tracks or legs might be better options.

Tracks ensure mobility on rough terrain, while legs drive mechanisms can step on uneven or soft terrain with great stability and high speed.

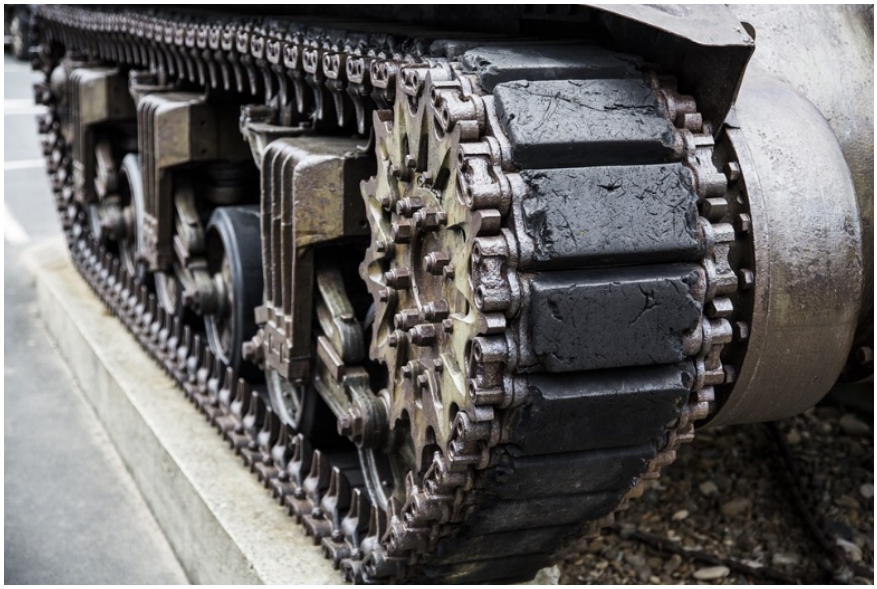


Figure 2-11 Continuous tracks

Figure 2-12 Wheels stuck in mud

The motions of a robotic arm are defined by the degree of freedom. The total number of motion types of an object in a 3D coordinate system is 6 with 3 being rotation around x, y, and z axes and 3 being translation along the three axes. Based on this calculation, an object has 6 degrees of freedom.

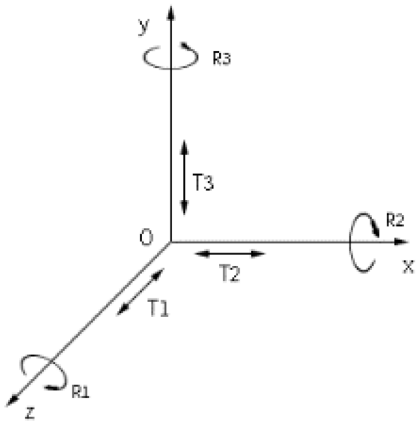


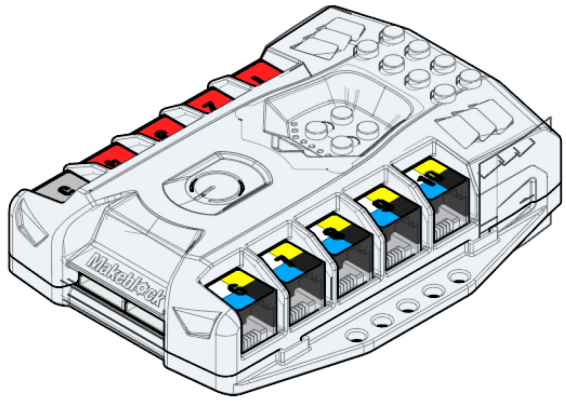
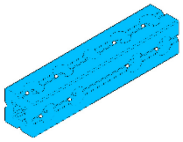
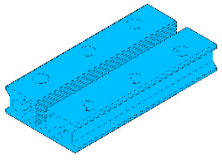
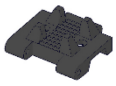
Figure 2-13 The Degree of Freedom of an object

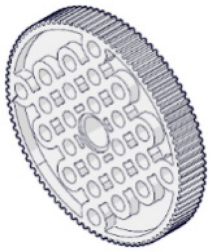
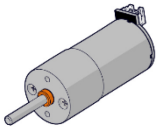
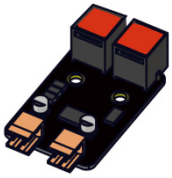
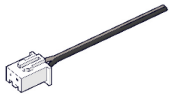
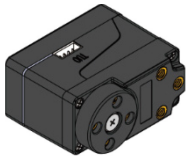
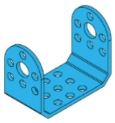
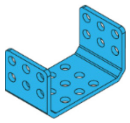
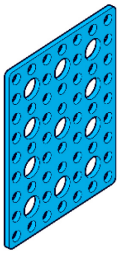
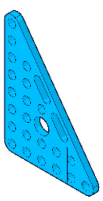
Our arms have joints, so do robotic arms. Each servo of a robotic arm is one of its joints, and the rotation brought by a joint means a degree of freedom. In other words, the number of joints determines the flexibility of a robotic arm. You will be provided with 3 servos to make a robotic arm for the project, think about why you need 3 servos. Write down your answer.

To create the continuous track, you may need to use plastic timing pulleys and tracks and track axles as well as motors to make the walking system structure. To create a robotic arm with three degrees of freedom, you need three servo motors to fulfill this function.

For more detailed information about the use of electronic modules, mechanical parts, and other relevant toolkits, please visit the website, learn.makeblock.com/en, for reference.

Table 2-1 List of key electronic modules and mechanical parts in the Emergency Equipment case

Electronic Module or Mechanical Part	Overview and Functional Features
 Me Auriga (×1)	Me Auriga control board is equipped with multiple onboard sensors, including a gyroscope, a buzzer and more; features a one-key power switch. Also, PORT 5 is isolated only with serial communication function, so it can't be used to update a program but is only for communication. It is compatible with USB serial port. PORT 6 to PORT 10 are compatible with dual-digital, simulation, 12C bus, unibus, and simulate serial port. Me Auriga has encoder motor port, smart servo port, as well as LED ring panel port (with power switch).
 Square Beam (Plenty)  Slide Beam (Plenty)	Beams are frequently used in building structures. These beams are made of aluminum alloy. They are of excellent strength and easy to install. The beams come in various length, from 16mm to 19mm, and are different in number of holes.
 Track (×42) and Track Axle (×42)  Track Surface	Tracks can be spliced into any length. Combine the tracks with timing pulleys to make a tracked walking mechanism. A tracked mechanism provides mobility even on rough terrain. The track pieces are connected with track axles.

Electronic Module or Mechanical Part	Overview and Functional Features
 Plastic Timing Pulley 90T (×4)	The plastic timing pulley is a wheel-shaped object with a hole in the center through which a shaft is inserted. Plastic timing pulleys come in 4 different sizes. Compared with gears, plastic timing pulleys have more teeth, and their teeth are smaller.
 25mm DC Motor (×2)  DC Motor-25 Bracket (×2)	The DC motor is one of the most frequently used motors. A DC Motor-25 bracket makes it easier to connect the motor to other Makeblock's mechanical parts.
  Me Dual DC Motor Drive (×1) and PH2.0 Motor Cable	The Me Dual Motor Driver module can drive two DC motors via the onboard RJ25 port with power supply of 6V-12V. This module has over-current protection. The red labels on the module mean that the module should be connected to the ports marked with red labels on the main control board.
   Smart Servo (×4), Rudder (×3) & Mounting Bracket (×3)	It is easy and quick to build a multi-joint robot with Smart Servo MS-12A. It can also be used to build a controllable rotating mechanism because of its ability to rotate continuously. The rudder and mounting brackets can support the servo motor and connect to other mechanical parts.
  Connecting Fittings	Connecting fittings come in various shapes: right-angled, U-shaped, P-shaped, circular, and triangular. The holes on the brackets are used in conjunction with beams to build mechanic frameworks, or with bearings to build bases for shaft systems and motors.

Making the Emergency Equipment

Mechanical Structure Design

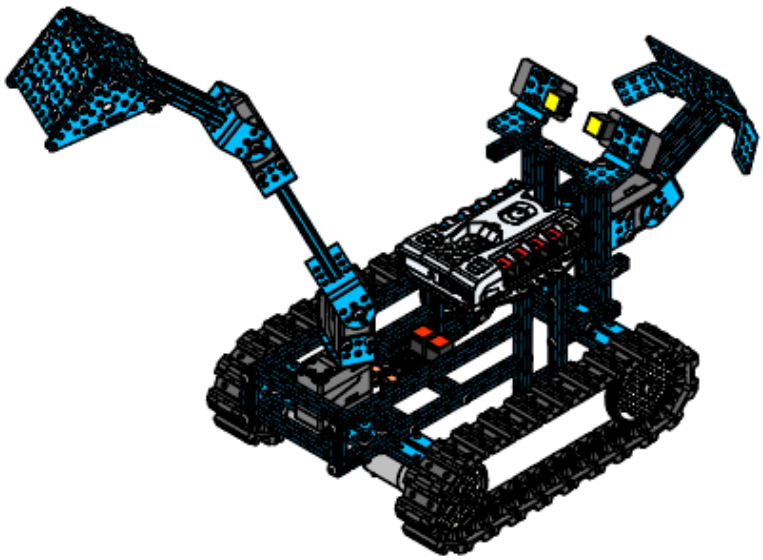


Figure 2-14 Prototype Design: Making the Emergency Equipment (a)

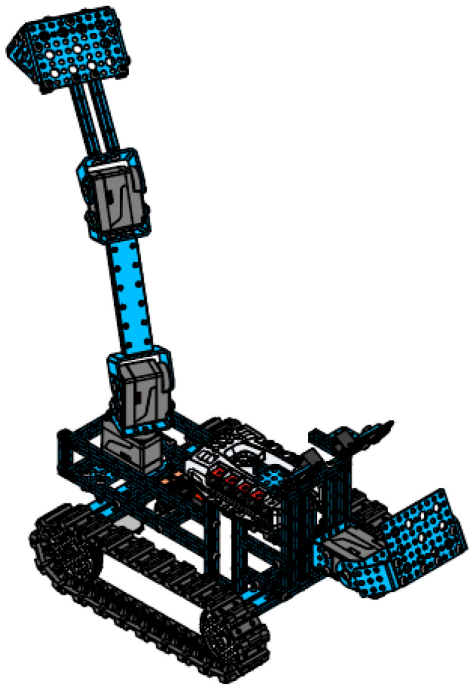
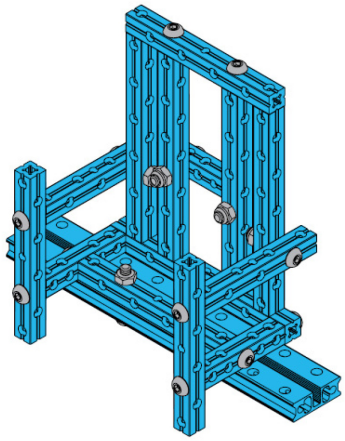
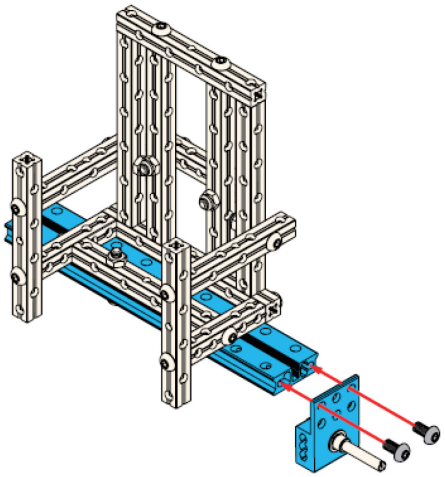


Figure 2-15 Prototype Design: Making the Emergency Equipment (b)

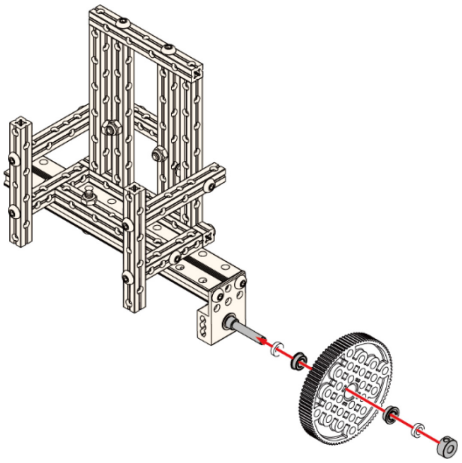
Key steps: Build the continuous tracks



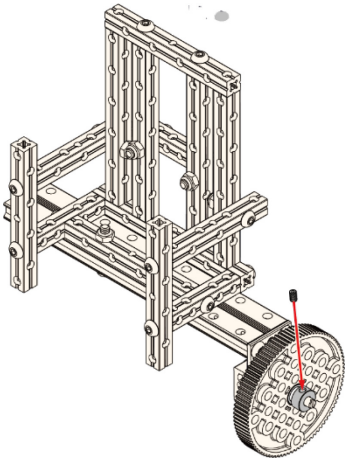
Step 2-1-1



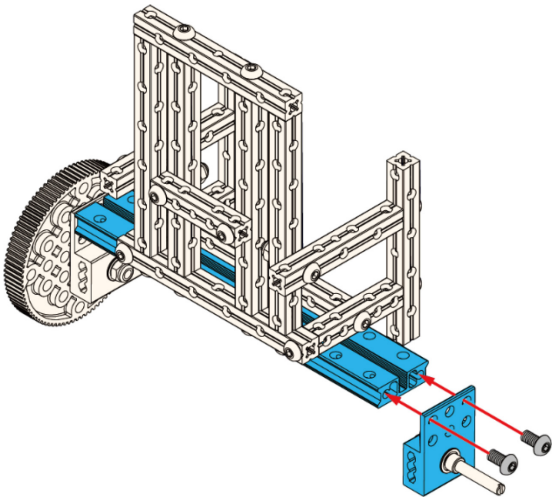
Step 2-1-2



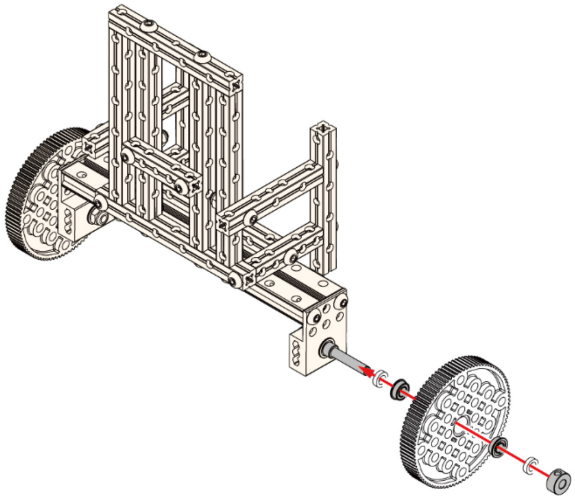
Step 2-1-3



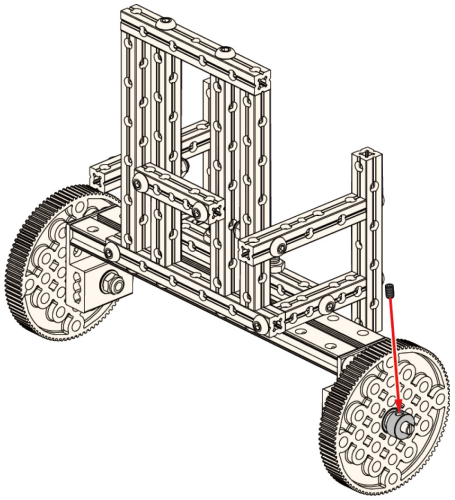
Step 2-1-4



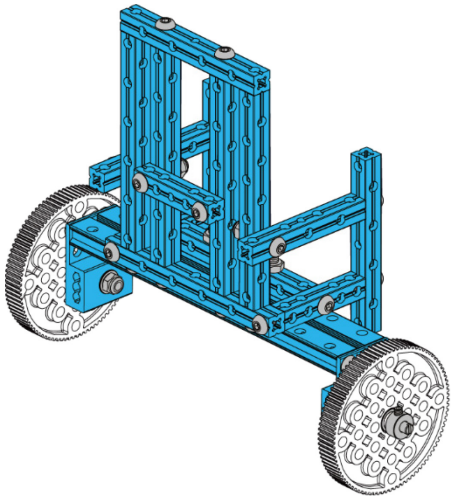
Step 2-1-5



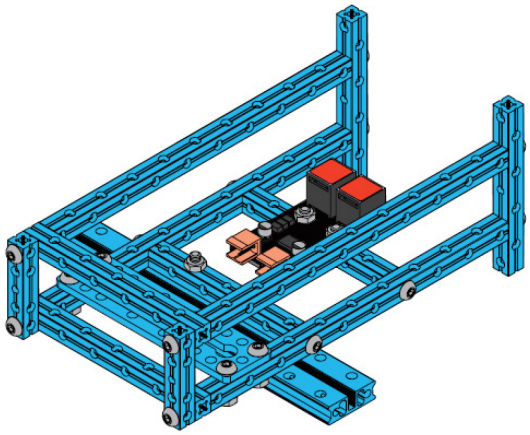
Step 2-1-6



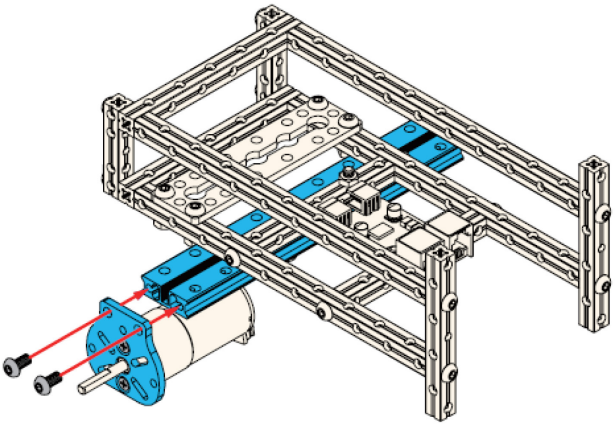
Step 2-1-5



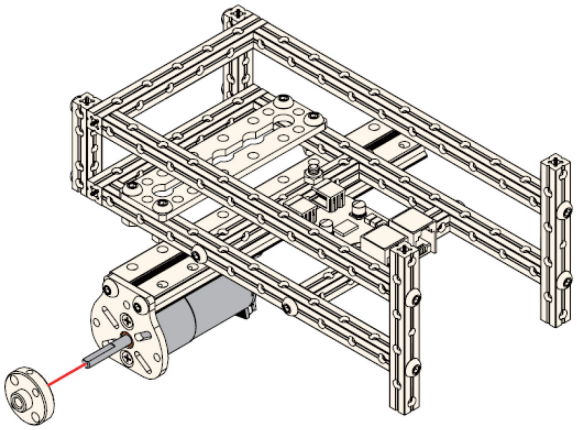
Step 2-1-6



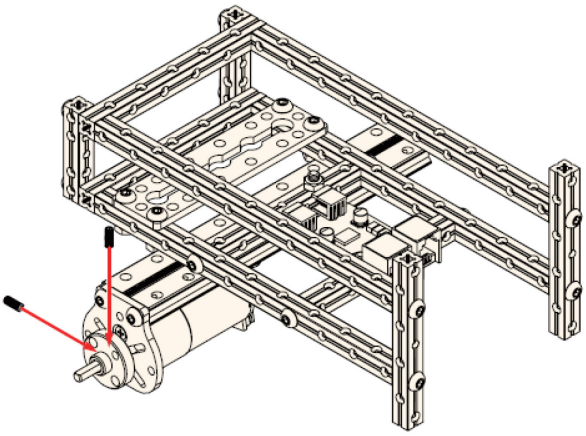
Step 2-2-1



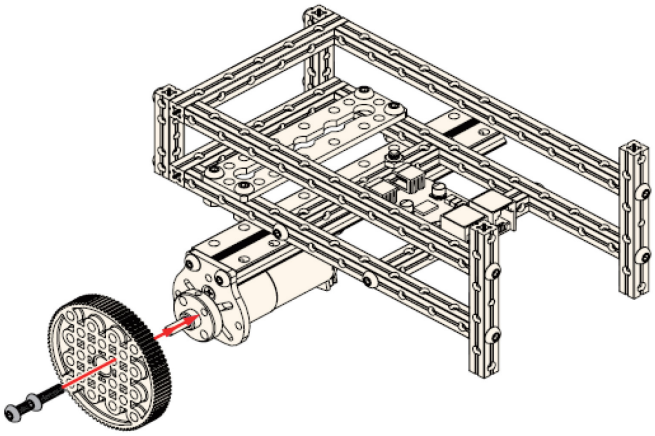
Step 2-2-2



Step 2-2-3



Step 2-2-4



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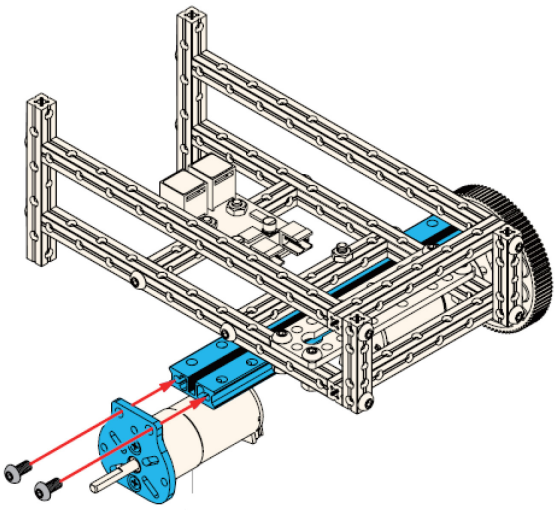

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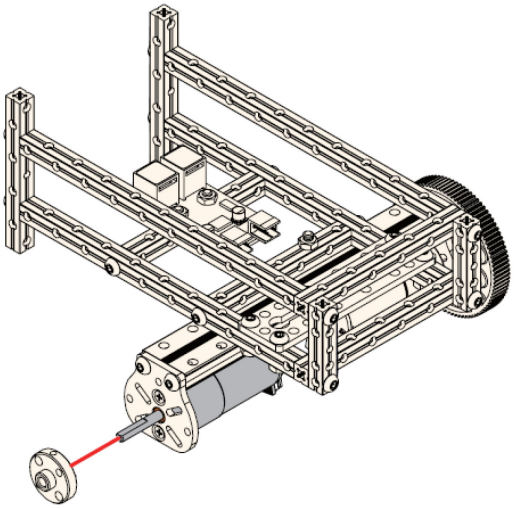

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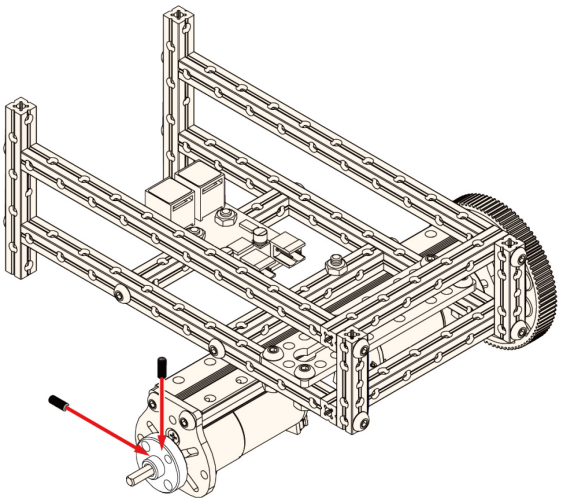

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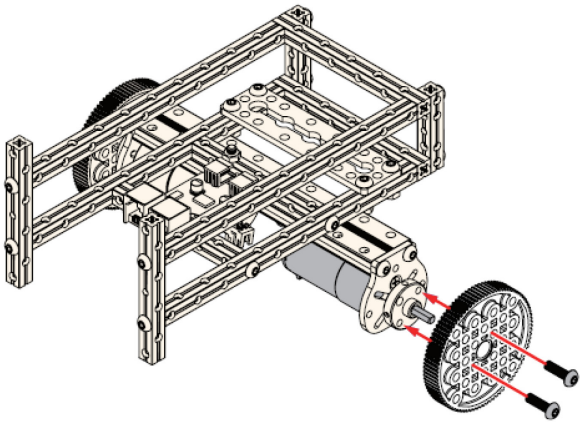

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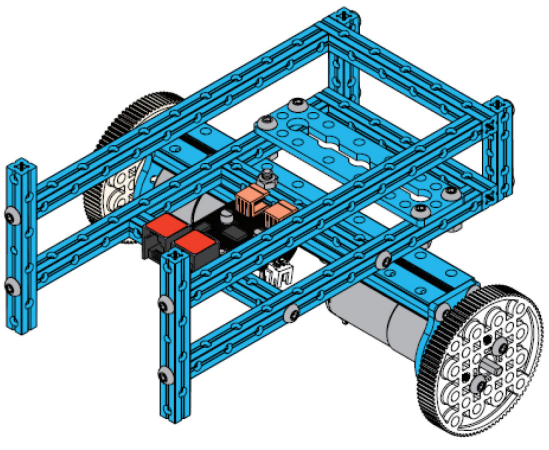

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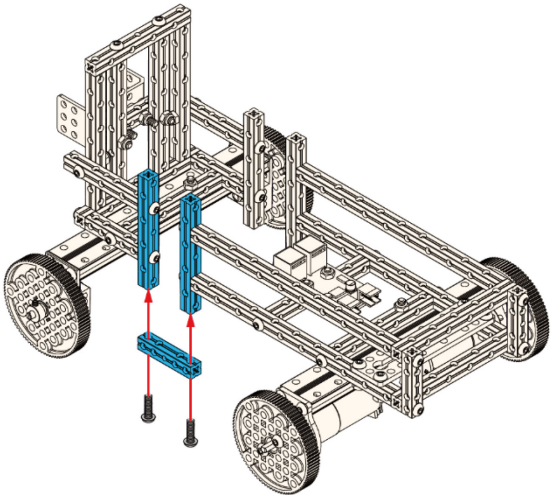

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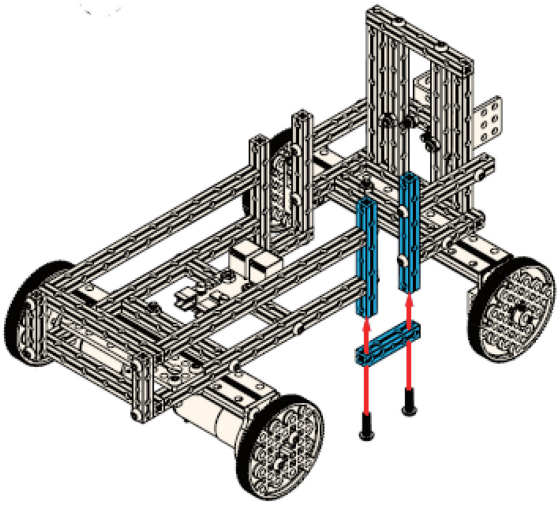

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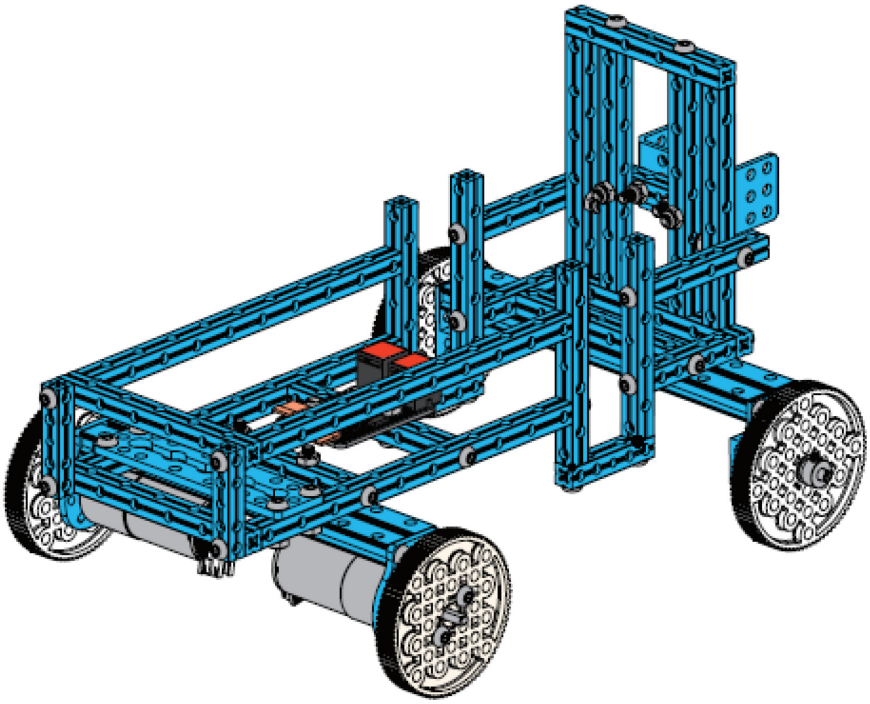
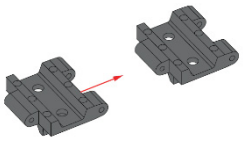


Step 2-3-3



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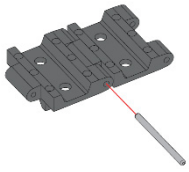

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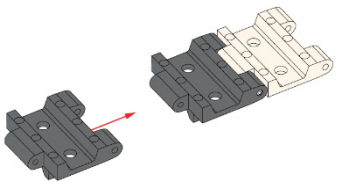

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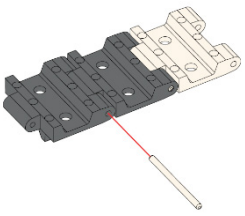
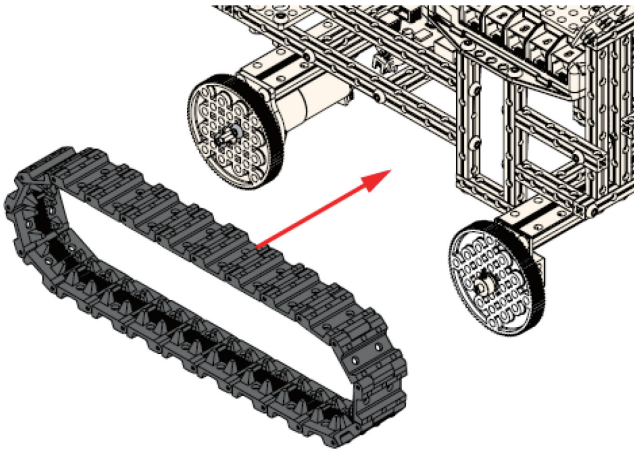


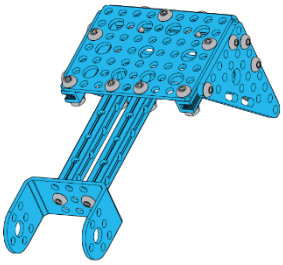
Step 2-4-4

Step 2-4-5



Step 2-4-6

Key steps: Build the robot arm



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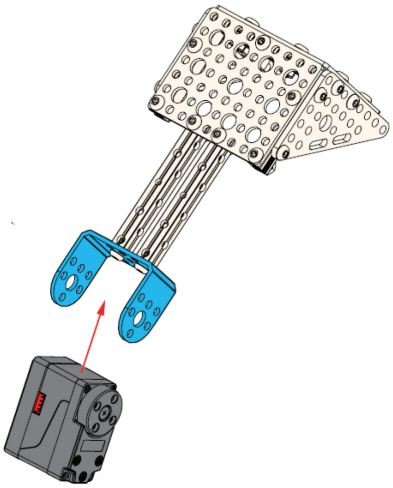

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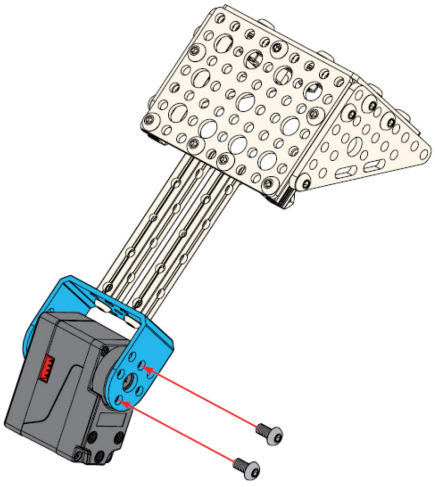

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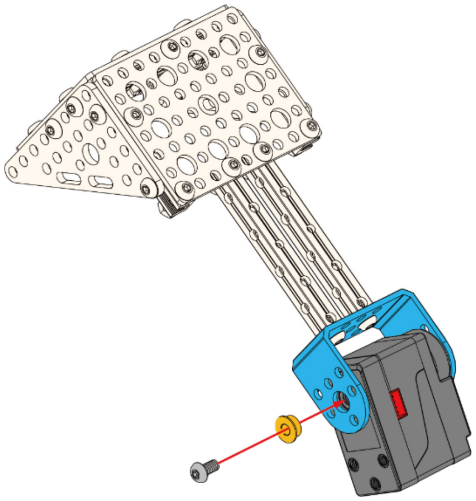

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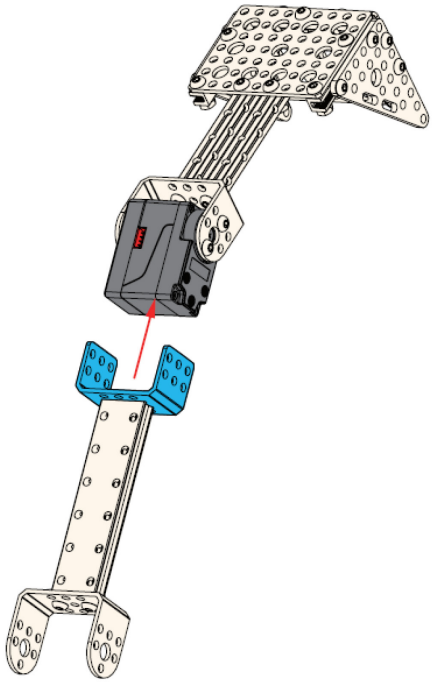

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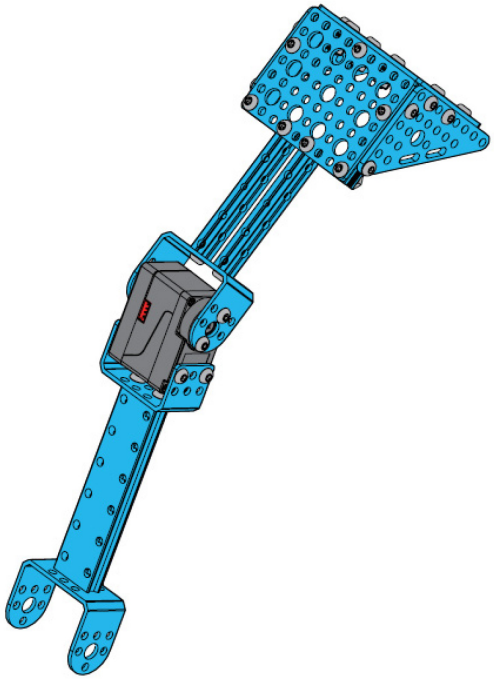

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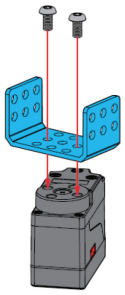

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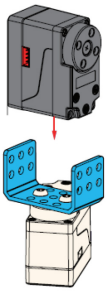

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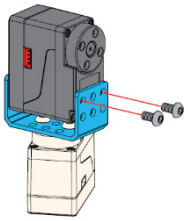

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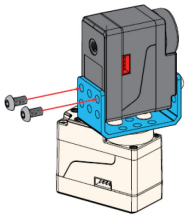

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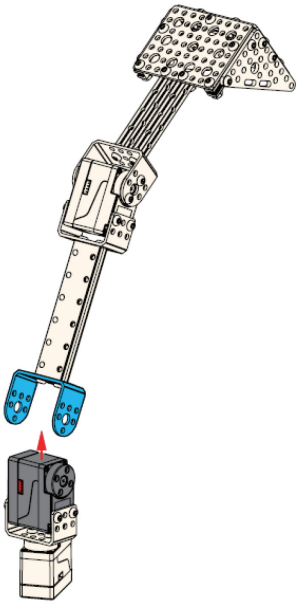
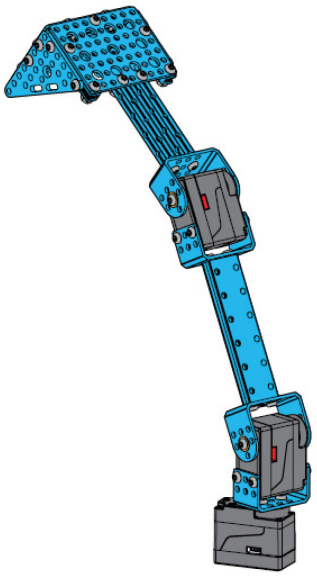


Step 2-5-9

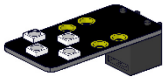
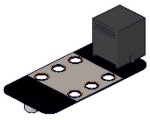
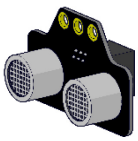
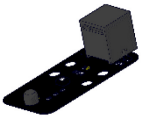
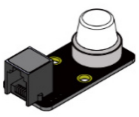


Step 2-5-10

Functionality Design

Besides the tracked mechanism and robotic arm with a bucket, what other structures or equipment would you add to the excavator? Revisit the damages and measures listed in Task 2-1, and explore other functionalities of the vehicle. Task 2-2 gives an example of the searchlight and the sensors that are used to build it.

Task 2-2 Evaluate the functionality of possible needed sensors in the Emergency Equipment case

Intended Functionality According to the Situation	Sensors Required
Example: *Simulating a searchlight on the front of the excavator. The searchlight helps the driver to be able to see clearly in a dark environment.*	 **Me RGB LED**  **Me Light Sensor**  **Me Ultrasonic Sensor**  **Me Flame Sensor**  **Me Gas Detection Sensor**

Your Turn to Practice

Based on what you have learned from this case study and prototype design, focus on one specific natural disaster in your city or country, and investigate how to develop the resilience of your community against the disaster.

Step 1: Assess the Task

Conduct research to learn about the natural hazards over the past 3-5 years in your city or country. Assuming that you are a civil engineer, write down your analysis in terms of the socio-economic impacts in Task 2-3.

Task 2-3 Socio-economic effects of natural hazards: Problems

Natural Hazards	Socio-economic Impacts	Root Cause
Example: *a magnitude N earthquake hit X city on mm/dd/yy.*	**Example:** *The affected area is a rapidly-urbanizing tourist attraction. Over 70% of buildings were destroyed during the earthquake. However, the buildings in the neighboring area did not suffer the same extent of the damage. The residents in the affected area suspected that the contractor had cut corners during the construction.*	**Example:** *The contractor was not experienced enough in earthquake-resistant construction, so the earthquake-resistant factors were not taken into consideration during construction. Moreover, no third-party inspection was conducted after the construction was complete.*

Step 2: Evaluate Strengths and Weaknesses

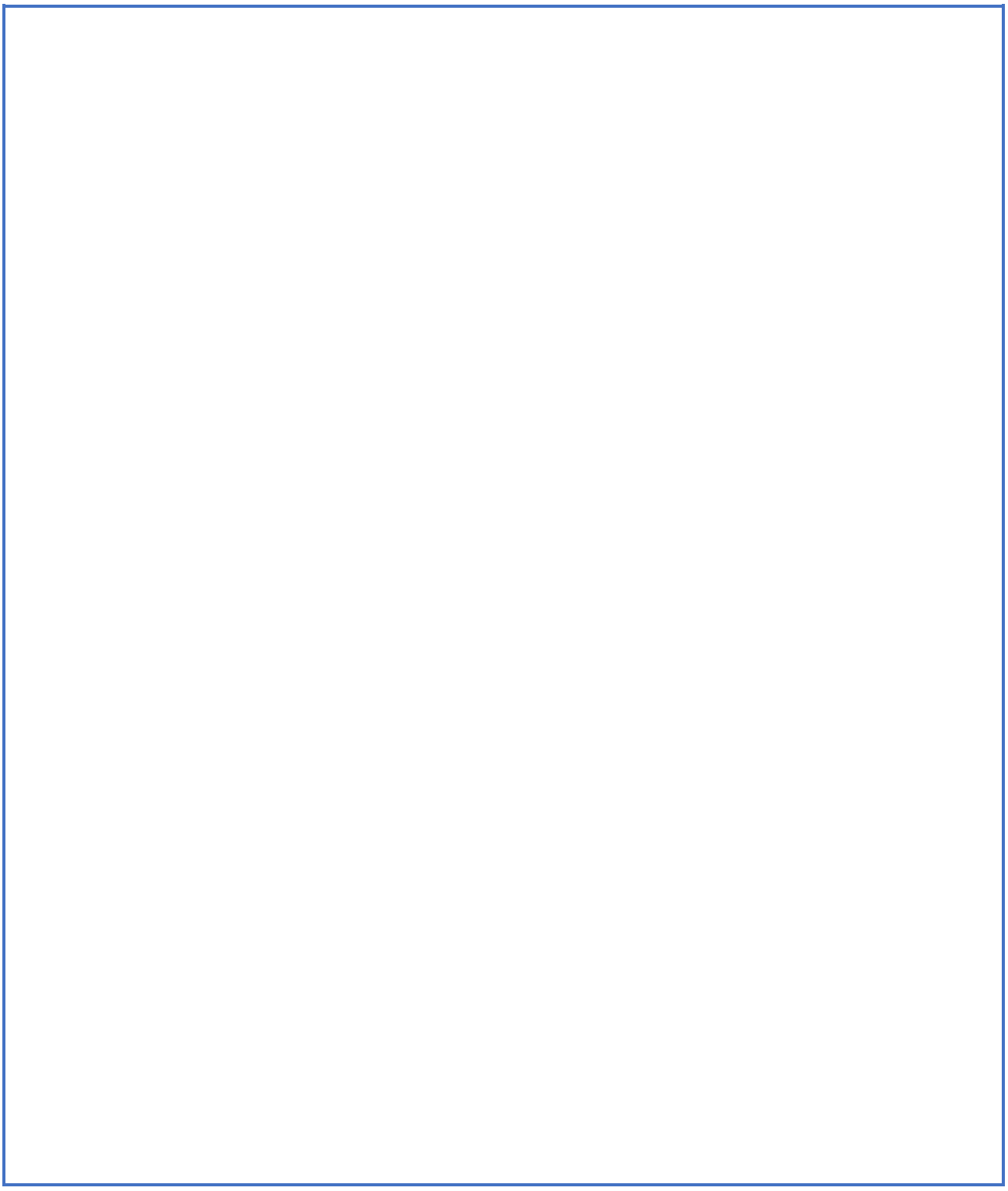
Based on your analysis in Task 2-3, write down the materials that you need to solve the problems.

Task 2-4 Socio-economic effects of natural hazards: Solutions

Strategies and Intended Functionality	Materials Required

Step 3: Plan the Approach

Based on your analysis in Step 2, draw your prototype design and specify how the structure can achieve the functionality.



Step 4: Apply Strategies

Draw the algorithm or the program design flowchart below.

Invite at least 2 external members to comment on your prototype, asking them to give advice. Then optimize the prototype based on the peer review. If you make any adjustments to your prototype, draw the new design.

Reviewer A:	**Reviewer B:**
New Design:	

Step 5: Reflect

Review the whole investigative process, from identifying problems to designing and developing the prototype. Refer to the checklist in Table 2-2 to reflect on how you've considered the following problems during the process.

Table 2-2 Checklist of project feasibility

☐ Is there any previous research into the question? If so, what are the existing conclusions?
☐ In what aspects does your innovation intend to benefit your city or community?
☐ What changes do you expect your innovation can bring to your city or community in terms of Urban Resilience?
☐ What are your hypotheses and expected results?
☐ What methodology and strategy do you use when analyzing and designing?
☐ What data do you need? How do you gather data and analyze them?
☐ How do you explain your innovation through prototyping your creative ideas? What materials are needed? And how do you build the prototype?
☐ Is the location a restriction in your project?
☐ Can the local resources help you achieve what you want
☐ Is time a limitation?
☐ How much time do you need to complete the project?
☐ How much time and effort will you invest in this project weekly?
☐ Do you expect you can find the answers for the research problem as scheduled?
☐ Do you think the investigation group, with all the members involved, can tackle the problem you proposed concerning the time and location restrictions?

At last, briefly describe your innovation and achievement.

Extension I: Urban Resilience and Urban Flooding

Flooding is a secondary disaster of meteorological disasters. In urban settings, heavy and extreme precipitation is most likely to produce more rain and cause urban floods, which are a disturbance to residents' life and properties.

Take China as an example, the annual average precipitation in China is 630mm. The spatial and temporal variability of rainfall is prominent. Substantial rainfall occurs in spring and summer. Besides, the precipitation volume gradually reduces from coastal areas to inland, from southeastern regions to northwestern [1].

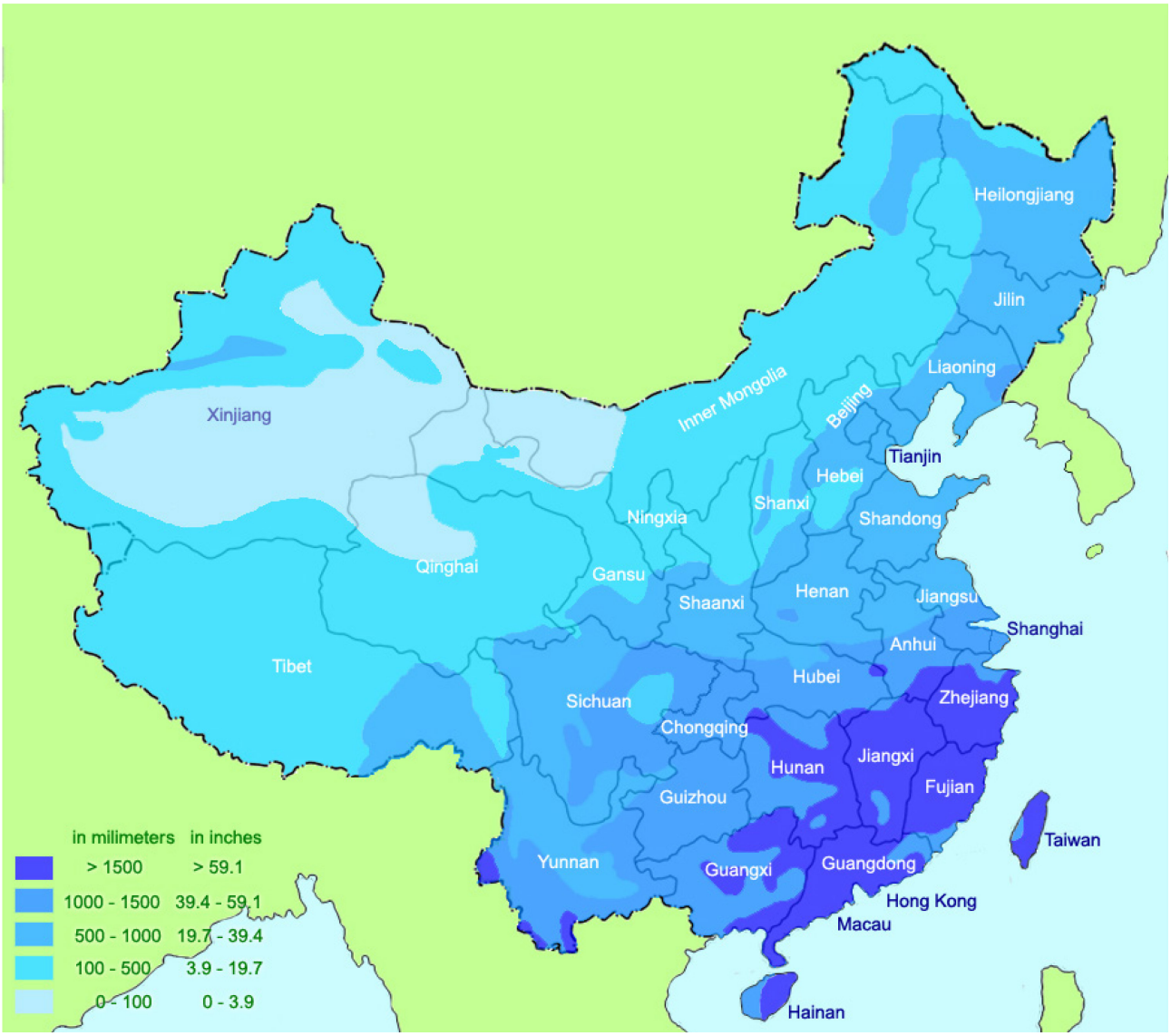


Figure 2-16 Rainfall Distribution in China

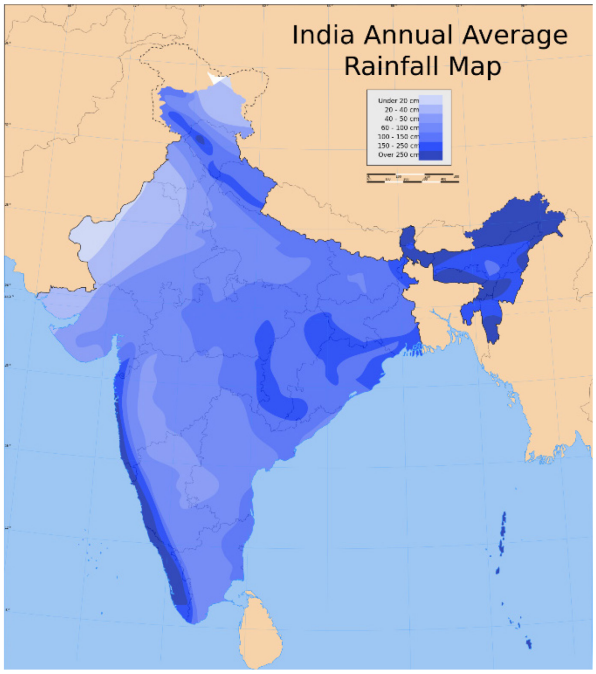


Figure 2-17 Rainfall Distribution in India

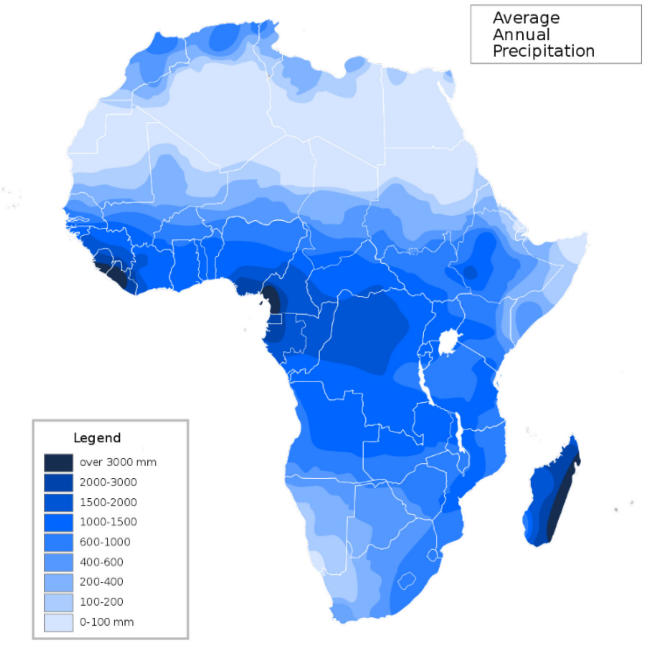


Figure 2-18 Rainfall Distribution in Africa

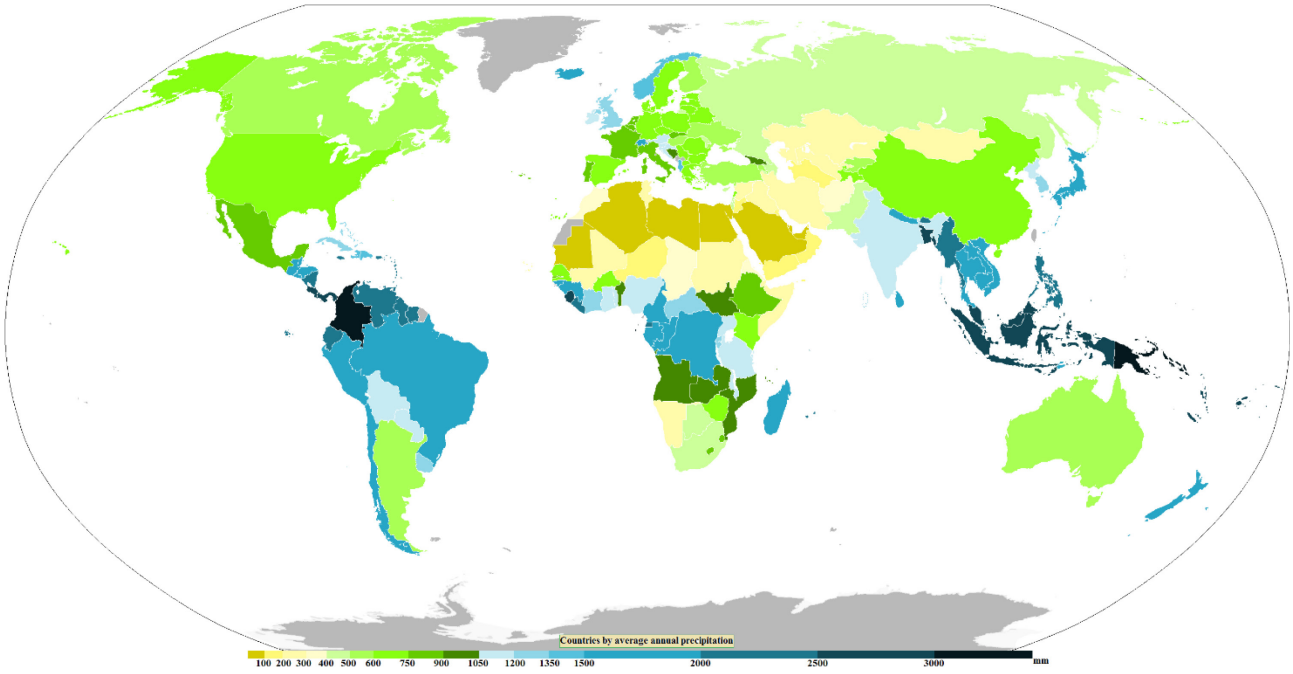


Figure 2-19 Global average annual rainfall distribution

Similarly, most of the coastal areas in India and Africa also face large amounts of precipitation particular in the rainy season. The tropics and tropical Asia often experience heavy rains and floods, which is common to these areas.

Increasing city resilience to urban floods under climate change has become one of the major challenges. The escalating problem of urban floods is bound up with the rapid development of urbanization. Particularly, some of the fastest developing countries have the poor quality infrastructure, which increases the risk of flooding.

Under normal situations, excessive runoff can be drained away with draining canals or in more natural ways, infiltrated by vegetation cover or stored by the ecosystem. However, built-up areas in cities weaken the capacity of the natural drainage systems. Hard surfaces, such as concrete or tar roads are not permeable, significantly reducing areas available for rainfall infiltration. Moreover, water bodies have been encroached upon for more lands, which further destroys the natural drainage systems.

Figure 2-20 Floods in a Thai city

Figure 2-21 Streets under water in floods

Gather news about urban flooding events in your local area that happened over the past 3 to 5 years. Sum up the bad consequences of these events and analyze why they happened. Write down your answer in Task 2-5.

Task 2-5 Assess the socio-economic impacts of urban floods

Facts and Figures	Problems	Impacts and Root Cause

Prototype Design: Drainage and Flood Control System

From the reading materials above, we can assume that a drainage system with terrace design might help postpone the stormwater runoff reaching its peak and mitigate the flooding in low-lying areas.

The runoff-reducing drainage system simulates terraced fields in the mountains. When we view it from bottom to top, it is a system of graduated terrace steps. When we view it from side to side, each step appears to be a rectangle. The terrace structure slows down runoff migrating from the top to the bottom so as to postpone the convergence of rainfall-runoff reaching its peak amount.

Figure 2-22 Terraced fields Maras, Peru

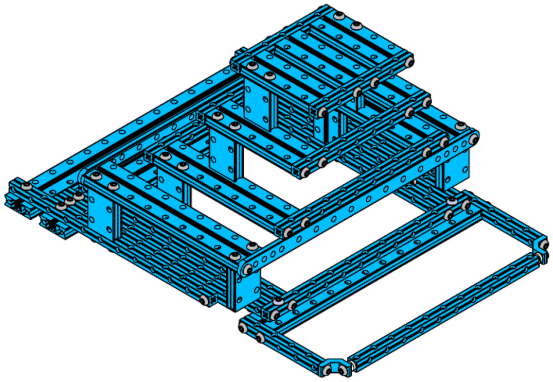


Figure 2-23 Prototype Design: Drainage and Flood Control System

Design Challenge

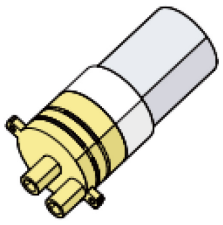
The terraced drainage system does not eradicate the urban flooding problem though it slows down the runoff. When continuous heavy rainfall hits an urban system, the terrace structure is not enough to eradicate the problem.

What about equipping the system with water pumps? If we improve the system in this way, we can recycle and utilize the rainfall water by pumping the excessive rainfall water in an affected city to another place.

You need to help the city out of the following situation:

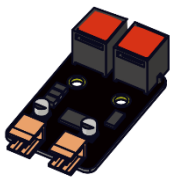
The eastern region of the city suffered days of heavy rainfall and, hence, flooded. The flood disturbed the residents' life and work. The local government decided to activate its underground pumping system to transfer the excessive rainfall water to other places. However, the reservoir in this region is not big enough to store all the water.

Fortunately, there is a large reservoir in the northern region of the city, to which excessive stormwater can be migrated. You need at least two water pumps (one to the reservoir in the eastern region, the other to the reservoir in the north), silicon tubes and other mechanical or electronic parts to simulate the drainage system and pumping stations of the city. Explain how the reservoir in the northern region mitigated the urban flooding in the eastern region.



Water Pump Motor

Silicon Tube



Me Dual Motor Driver

Extension II: Urban Resilience and Locust Plagues

Locusts outbreaks, drought, and flood have been known as three major natural hazards in China until the mid-20th century. Scientists and researchers studied the events of locust outbreaks in China and found 257 years being affected by locust swarms.

Figure 2-24 Desert locust

Figure 2-25 Locust swarm invasion

Ancient Chinese scientists believed that locust plagues were abnormal natural phenomena, and that it was important to find out the relationship between locust plagues and meteorological disasters, like a flood. They proposed five measures to prevent and control locust outbreaks:

(1) Catching and killing locusts;

(2) Applying chemicals;

(3) Implementing physical control measures;

(4) Implementing biological control measures;

(5) Implementing agricultural control measures.

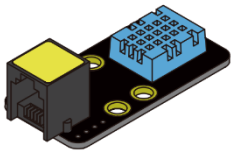
People know more about the prevention and control of locust outbreaks now. According to some research, the frequency of locust outbreaks is associated with global warming. The changes in temperature, precipitation, vegetation, as well as

air movement resulting from climate change are important indicators that we can rely on to prevent and control locust outbreaks [3].

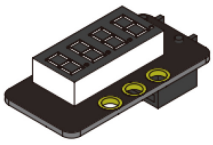
The development of contemporary genetic engineering also provides a new perspective on how to cope with the disaster. Studies show [4] that when the density of locusts reaches a certain threshold, they become gregarious, forming swarms, flying towards the same direction, and inducing locusts from other habitats to join their swarms. Scientists have discovered that modifying the genome sequence of locusts can change the mechanism that the creature uses to transmit and receive neurotransmitters, and this can interrupt their communication when they swarm. In this way, people can prevent a massive plague of locusts [5].

Prototype Design: Information System for Locust Forecasting

The Me Temperature and Humidity Sensor and Me 7-Segment Serial Display modules allow us to make a simple weather detection system. The Me Temperature and Humidity Sensor can detect humidity within a range of 20% to 90%, and temperature between 0℃ to 50℃.



Me Temperature and Humidity Sensor



Me 7-Segment Serial Display

The Me Temperature and Humidity Sensor detects Relative Humidity. Relative humidity refers to the amount of water vapor in the air against the saturation point of water vapor in the air [6].

$$Relative\ Humidity = \left(\frac{Density\ of\ water\ vapor}{Density\ of\ water\ vapor\ at\ saturation}\right) \times 100\%$$

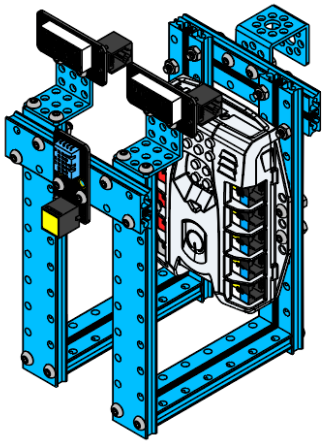
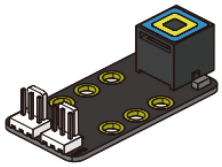


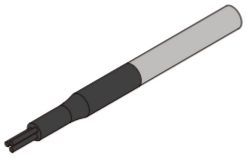
Figure 2-26 Prototype Design: Information System for Locust Forecasting

Design Challenge

Other sensors can also be applied in gathering information and data related to agricultural production. Compared with Me Temperature and Humidity Sensor, Me Temperature Sensor can measure temperature more accurately. The metal pole of Me Temperature Sensor allows us to detect the temperature of different things, such as liquid and soil. Remember that Me Temperature Sensor must be used along with RJ25 Adapter.



Me Temperature Sensor



RJ25 Adapter

Collect more data analysis and case studies about agricultural production. Add other sensors to the Locust Plague Alert, and program them to function as planned.

Draw the flow chart of your project design in the space below.

BUILD RESILIENT INFRASTRUCTURE, PROMOTE INCLUSIVE AND SUSTAINABLE INDUSTRIALIZATION AND FOSTER INNOVATION

About the Sustainable Development Goal 9

Infrastructure, Industrialization

Investment in infrastructure–transport, irrigation, energy and information and communication technology–are crucial to achieving sustainable development and empowering communities in many countries. It has long been recognized that growth in productivity and incomes, and improvements in health and education outcomes require investment in infrastructure.

Manufacturing is an important driver of economic development and employment. An important factor to consider is the emission of Carbon Dioxide during manufacturing processes. Emissions have decreased over the past decade in many countries but the pace of decline has not been even around the world.

Technological progress is the foundation of efforts to achieve environmental objectives, such as increased resource and energy-efficiency. Without technology and innovation, industrialization will not happen, and without industrialization, the development will not happen. There need to be more investments in high-tech products that dominate the manufacturing productions to increase efficiency and a focus on mobile cellular services that increase connections between people.

Source: UN, www.un.org/sustainabledevelopment/infrastructure-industrialization

Facts and Figures

- For many African countries, particularly the lower-income countries, the existent constraints regarding infrastructure affect firm productivity by around 40%.
- The global share of manufacturing value-added in GDP increased from 15.2% in 2005 to 16.3% in 2017, driven by the fast growth of manufacturing in Asia.
- Industrialization's job multiplication effect has a positive impact on society. Every job in manufacturing creates 2.2 jobs in other sectors.
- Small and medium-sized enterprises that engage in industrial processing and manufacturing are the most critical for the early stages of industrialization and are typically the largest job creators. They make up over 90% of business worldwide and account for between 50%-60% of employment.
- Least developed countries have immense potential for industrialization in food and beverages (agro-industry), and textiles and garments, with good prospects for sustained employment generation and higher productivity.
- Middle-income countries can benefit from entering the basic and fabricated metals industries, which offer a range of products facing rapidly growing international demand.
- In developing countries, barely 30% of agricultural production undergoes industrial processing. In high-income countries, 98% is processed. This suggests that there are great opportunities for developing countries in agribusiness.

Source: UN, www.un.org/sustainabledevelopment/infrastructure-industrialization

Goal 9 Targets

9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.

9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries.

9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets.

9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.

9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular in the developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending.

9.A Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States 18.

9.B Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities.

9.C Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020.

Source: UN, www.un.org/sustainabledevelopment/infrastructure-industrialization

Notes

[1] Li, J., et al. (2017) "County-rural transformation development from viewpoint of 'population-land-industry' in Beijing-Tianjin-Hebei region under the background of rapid urbanization." *Sustainability*, 9 (9): 1637. Available from: https://doi.org/10.3390/su9091637.

[2] Ansari, T. U., et al. (2019) "Effectiveness of short-term air quality emission controls: A high-resolution model study of Beijing during the Asia-Pacific Economic Cooperation (APEC) summit period." *Atmospheric Chemistry and Physics*, 19: 8651–8668. Available from: https://doi.org/10.5194/acp-19-8651-2019.

[3] Liven, I. (2013) *Locust Plagues Point to Grim Future of Climate Change*. Available from: www.chinadialogue.net/article/show/single/en/6038-Locust-plagues-point-to-grim-future-of-climate-change. [Accessed: May 1st 2019].

[4] Brahic, C. 科学家发现触发蝗灾的原因[EB/OL]. (2006-06-02) [2019-05-01]. www.scidev.net/global/news/zh-22885.html.

[5] 梁天韵, 梁现瑞. 中科院 get 一项新科技可望治蝗灾：关闭蝗虫体内"集结令"[EB/OL]. (2017-09-08) [2019-05-01]. www.thepaper.cn/newsDetail_forward_1788097.

[6] Circuit Basics (no date) *How to Set up the DHT11 Humidity Sensor on an Arduino*. Available from: http://www.circuitbasics.com/how-to-set-up-the-dht11-humidity-sensor-on-an-arduino. [Accessed: May 1st 2019].

PILOT STUDY B:

TECHNOLOGIES AND

WATER-ENERGY-FOOD NEXUS

Overview

Water resources are among the most important resources for human survival and production. Although the Earth's total water reserves are huge, the water resources that could be directly used by humans are limited. The extensive industrialization already led to many water resources being polluted; some countries or regions have sufficient water resources, but are exposed to aging and poorly maintained water facilities, leaving it hard for local people to fully use their water resources; some developing countries, however, still suffer from the lack of modern water facilities.

In response to the UN's *Water Action Decade* initiative, you need to re-think about the efficiency of water use through the lens of sustainable production and consumption. Explore how to improve water efficiency, water source management and urban systems' functional resilience by making efficient use of water facilities.

Intended Learning Outcomes

- ☐ Give examples to demonstrate how water resources influence us at economic, social and environmental levels.
- ☐ Analyze how the water resources are managed in one specific domain and the existing issues related to efficiency and effectiveness of water use.
- ☐ Distinguish different irrigation techniques and how to improve the efficiency and effectiveness of agricultural water sources.
- ☐ Create a prototype to boost the resilience of basic water facilities in cities.

Keywords

Irrigation Efficiency; Organizational Resilience; Physical Resilience; Sustainable Production and Consumption; Technological Hazards

Your Study Plan

Schedule your study before working on the pilot study. Specify the expected learning outcomes and efforts. The table below includes the recommended time cost; however, you can have a talk with your course instructor to tailor your schedule.

Stage	Learning Content	Your Time	Effort
Assess	**Water Resources and Sustainable Production** ● Explain the importance and necessity of developing water-saving techniques and measures in agriculture ● Critically analyze the relationship between water resources and sustainable consumption and production		1-2 hrs
Evaluate	**Improving Irrigation Efficiency** ● Evaluate the irrigation efficiency and discuss how to improve the irrigation efficiency in the case agricultural region in your country		1-2 hrs
Plan	**Designing a Water-saving Irrigation Machinery** ● What may affect irrigation efficiency? ● In what way can we impact the factors that related to irrigation efficiency? ● How to reduce surface water evaporation? ● What kind of irrigation system may suit the situations of the agricultural land in your country? Why?		2-4 hrs
	Making the Water-saving Irrigation Machinery ● Mechanical Structure Design ● Functionality Design		4-6 hrs
Apply	**Your Turn to Practice** ● Step 1: Assess the Task ● Step 2: Evaluate Strengths and Weaknesses ● Step 3: Plan the Approach ● Step 4: Apply Strategies ● Step 5: Reflect		6-8 hrs

Reflect	• Summarize what you have learned in this case study		1-2 hrs
Extension Activities	**Urban Agriculture and Smart Farming** • Advantages and disadvantages of developing and utilizing greenhouse farming for the urban system within a context of ICT at present and in the near future • **Prototype:** IoT-based Smart Sprinkling System		2-4 hrs
	Water in the Developing World • How to help people living in underdeveloped countries to collect and use water • **Business and Entrepreneurship Practice**		2-4 hrs

Water Resources and Sustainable Production

It is notable that water use has been increasing worldwide by about 1% per year since the 1980s. Global water demand is expected to continue increasing at a similar rate until 2050, accounting for an increase of 20% to 30% above the current level of water use, mainly due to rising demand in the industrial and domestic sectors[1]. There is a total volume of 1,386,000,000 cubic kilometers of water on the Earth, but the freshwater available for humans only amounts to less than 3%[2]. Yet most of the freshwater exists in glaciers, which means humans can hardly use them.

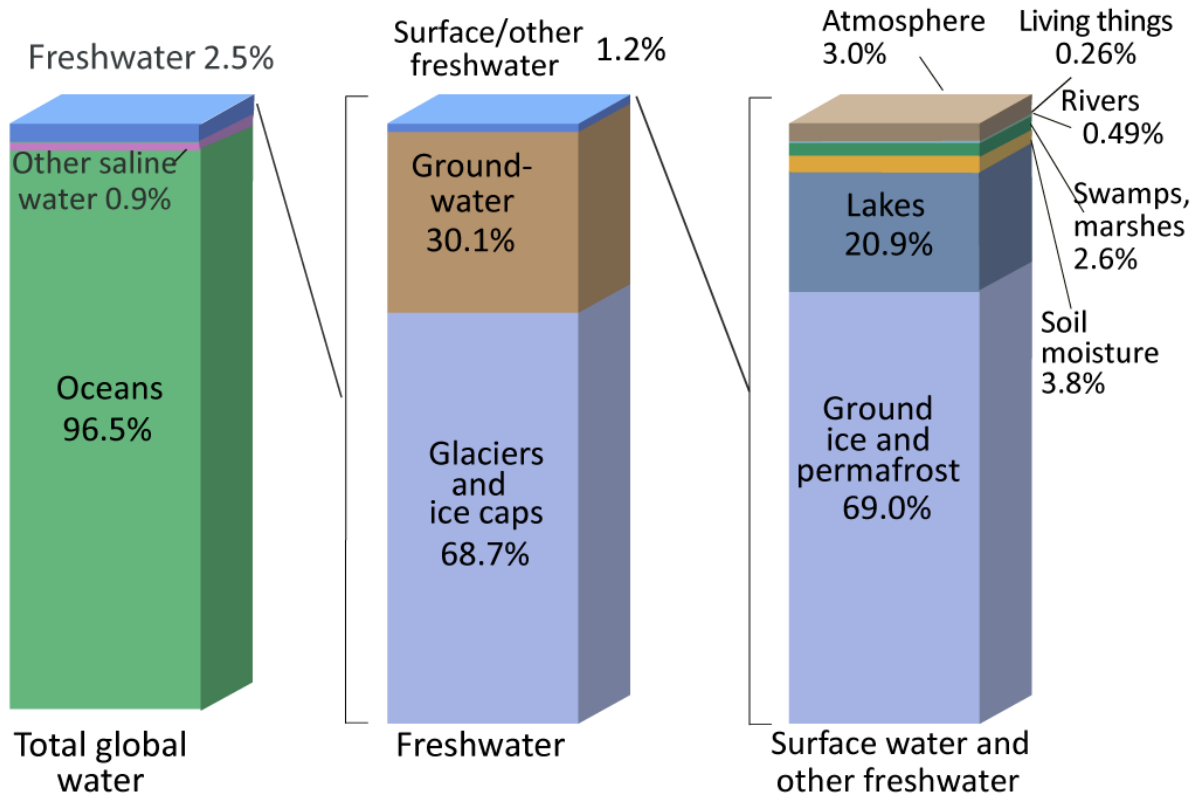


Figure 3-1 Where is earth water? [3]

(Source: "*World Fresh Water Resources*", Igor Shiklomanov, 1993;

cited in "*Where is Earth's Water?*", Water Science School, USGS)

Note: The bar chart "*Where is earth water?*" shows where all water on, in, and above the Earth exists.

Left bar: All water, freshwater and saline, on, in, and above the Earth.

Center bar: All freshwater.

Right bar: Only the portion of freshwater residing in surface water (rivers and lakes, etc.), snow and ice, and relatively-shallow ground water.

Table 3-1 Estimate of global water distribution [4]

(Per cents are rounded, so will not add to 100)

Water Source	Water Volume, in Cubic Miles	Water Volume, in Cubic Kilometers	Percent of Freshwater	Percent of Total Water
Oceans, Seas, & Bays	321,000,000	1,338,000,000	--	96.54
Ice Caps, Glaciers, & Permanent Snow	5,773,000	24,064,000	68.7	1.74
Groundwater	5,614,000	23,400,000	—	1.69
Fresh	2,526,000	10,530,000	30.1	0.76
Saline	3,088,000	12,870,000	—	0.93
Soil Moisture	3,959	16,500	0.05	0.001
Ground Ice & Permafrost	71,970	300,000	0.86	0.022
Lakes	42,320	176,400	—	0.013
Fresh	21,830	91,000	0.26	0.007
Saline	20,490	85,400	—	0.006
Atmosphere	3,095	12,900	0.04	0.001
Swamp Water	2,752	11,470	0.03	0.0008
Rivers	509	2,120	0.006	0.0002
Biological Water	269	1,120	0.003	0.0001

(Source: "*World Fresh Water Resources*", Igor Shiklomanov, 1993; cited in "*Where is Earth's Water?*", Water Science School, USGS)

Note: The above table represents the presence of Earth's water at a single point in time. It is shown that only a relatively small amount of fresh water is available to sustain human, plant, and animal life.

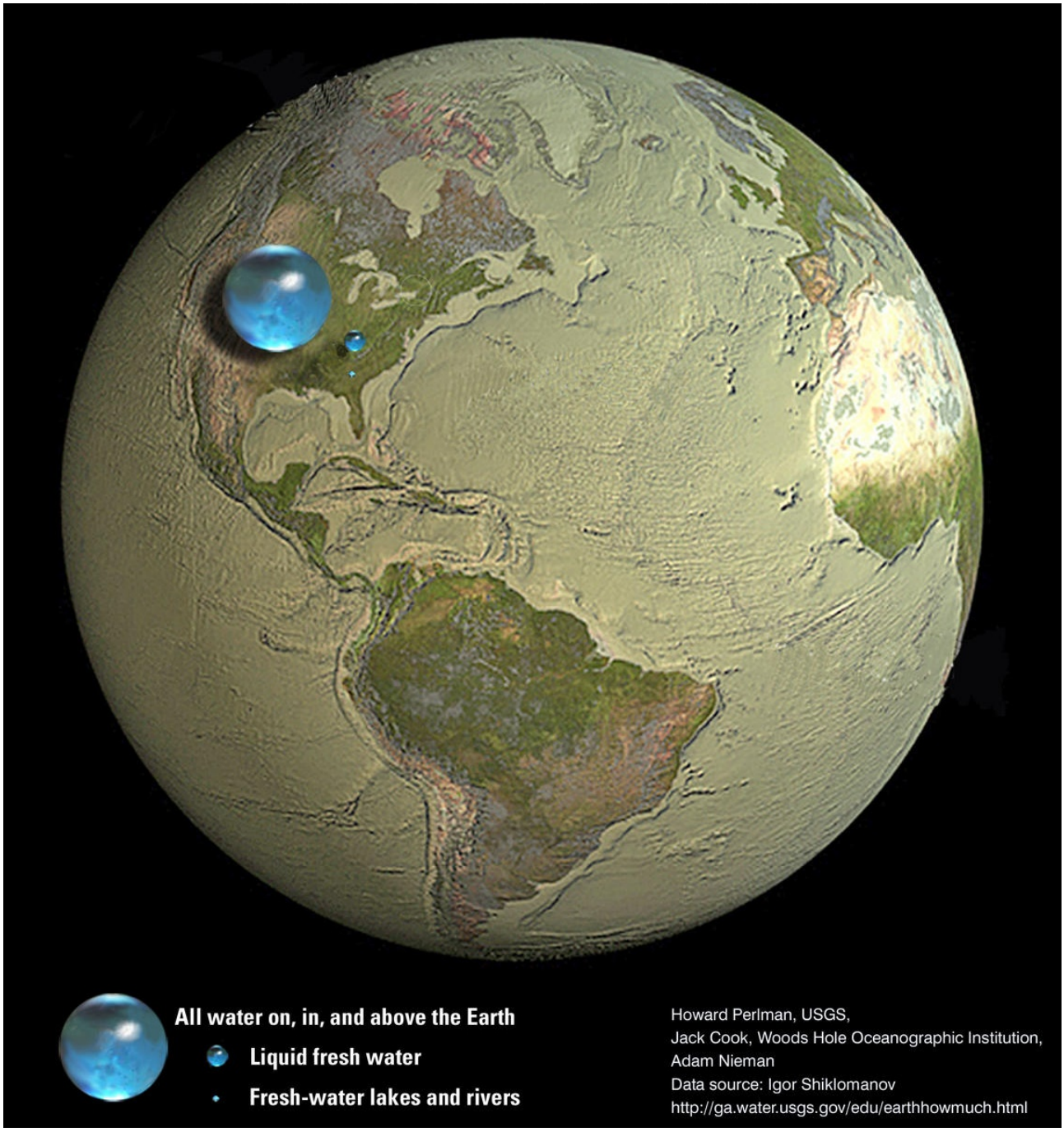


Figure 3-2 Amounts of Earth's water in comparison to the size of the Earth [5]

Note: The blue spheres in the image represent relative amounts of Earth's water in comparison to the size of the Earth. They attempt to show three dimensions:

(a) The largest sphere represents all of Earth's water.

(b) The medium sphere represents liquid fresh water.

(c) The tiny bubble represents fresh water in lakes and rivers. Most of the water people and life of earth need every day comes from these surface-water sources.

Reading 3-1　2018-2028 International Decade for Action, "Water for Sustainable Development"

The World Economic Forum ranks the water crisis in the top 3 of global risks for the third consecutive year. To respond effectively to these challenges, the General Assembly proclaims the period from 2018 to 2028 the International Decade for Action, "Water for Sustainable Development", to further improve cooperation, partnership and capacity development in response to the ambitious 2030 Agenda. The Decade commenced on World Water Day, 22 March 2018, and concludes on World Water Day 2028.

The resolution states that the objectives of the Decade should be a greater focus on:

- the sustainable development and integrated management of water resources for the achievement of social, economic and environmental objectives;
- the implementation and promotion of related programs and projects;
- the furtherance of cooperation and partnerships at all levels to achieve internationally agreed water-related goals, targets, and tasks, including those in the 2030 Agenda for Sustainable Development.

Although water shortage is a common problem faced by all countries around the world, water facilities, water sanitation, and natural water-related disasters, is still a major obstacle to the improve the water efficiency of organizations or individuals in various countries, especially in the economically underdeveloped regions.

Source：UN

Agricultural Water

Among the three pillars, agriculture consumes the most water. According to the research report by the Food and Agriculture Organization of the United Nations, agriculture accounts for 69% of the total water use[6], which is twice as much as the industrial (19%) and domestic water use (12%) combined.

In the USA, agriculture accounts for nearly 80% of the consumptive water use; and particularly in the Western United States such as Texas, Colorado, Oregon, New Mexico, and Oklahoma, over 90% of the water is used and significantly contributes to the agricultural production and exports[7]. However, it is reported more and more agricultural regions have been subject to extensive and increasing water constraints such as droughts and other extreme weather events. The diminishing surface and groundwater reserves affect the development of agriculture and further the USA's agricultural trade.

In China, one of the global leading agricultural producing countries, agriculture consumed 376.64 billion cubic meters of water in 2017, which accounted for 62.3% of the total national consumptive water [8]. Most of the water was used for irrigation. However, China's irrigation efficiency index in 2017 was merely 0.548[9], much lower than the higher efficiency level in the global community, i.e. 0.7-0.8[10]. Similarly, the northwestern areas in China also face the challenges of droughts due to its regional environment and climate, as well as the increasingly limited surface water supplies, and the pollution of groundwater resources.

The increasing population and correspondingly the increasing demand for food in the future appear to request to improve the sustainability of global agricultural development, in particular in relation to the efficiency of consumptive water use. Calls for increased effectiveness in the use of agricultural water lead to a shift to more effective irrigation measures such as irrigated agriculture.

Water-saving Irrigation

Water-saving irrigation refers to the efficient use of multiple water sources, such as rainfall, rivers, lakes, and groundwater, based on the crop types and the physical conditions of crop areas to achieve economic, social and ecological benefits.

Please investigate the geographical features of the main agricultural lands and regions in your country and then figure out how the environmental factors influence the local agricultural practices. Think about what sustainability-related issues may be facing in the agricultural region in your country.

Fill in the table below; meanwhile, consider the importance of the up-scaling of water-saving irrigation measures in your country.

Task 3-1 Assess the impacts of physical environment upon agricultural practices

Geographical features	Impacts upon agricultural practices
Example: *temperate continental climate, less annual rainfall, rainfall mostly in summers*	**Example:** *Greater demand for agricultural water use during the irrigation periods but scarce rainfall in spring*

Improving Irrigation Efficiency

One of the main strategies to improve agricultural irrigation efficiency is to increase the consumptive water sources while downsizing the consumption. When saying "increasing the sources", it means relying on more than one water source for irrigation rather than on a single one (such as surface or groundwater). To reduce consumption, farmers can use advanced irrigation machinery to boost irrigation efficiency.

In agricultural engineering, a formula below is applied to measure the irrigation efficiency–the ratio of the amount of water consumed by the crop to the amount of water supplied through irrigation[11]:

$$Irrigation\ Efficiency\ = \frac{Water\ Aborbed\ by\ Crops}{Total\ Irrigation\ Water}$$

The formula above suggests that not all of the water can be effectively used by the crops. Many factors affect irrigation efficiency. Studies[12] is conducted focusing on the water cycle process and concludes that five water consumption types exist during the process:

(1) Plant transpiration(V_1);

(2) Surface water evaporation (V_2);

(3) Surface water loss(V_3);

(4) Deep percolation(V_4);

(5) Water that crop roots lack (V_0).

The (2) (3) (4) (5) are water that is not effectively used by crops; (5) is another factor that we should consider when measuring the irrigation efficiency–extra demand of roots for water due to poor irrigation. The formula above could be more specific as shown below ("IE" is short for irrigation efficiency):

$$IE\ = \frac{V_1}{V_1+V_2+V_3+V_4+V_0}$$

Now, you are a consultant specializing in water-saving irrigated agriculture. Think about how many possible ways there are to improve the irrigation efficiency in the agricultural region in your country. Put down your advice to complete Task 3-2.

Task 3-2 Think about possible solutions and suggestions for improving irrigation efficiency

Sample answers:

a. Reduce surface water consumption, e.g. cover membranes over irrigated fields;

b. Reduce deep percolation losses while replenishing water to the roots of crops;

c. ...

Figure 3-3 Irrigation machines walking in the agricultural land

Designing a Water-saving Irrigation Machinery

The key to improve irrigation efficiency lies in reducing the evaporation and loss of surface water, and deep percolation. Table 3-1 lists different irrigation systems and how they solve the problems:

Table 3-2 Water-saving Irrigation Systems and Technologies

Factors Affecting IE	Solutions
Surface Water Evaporation	● Sprinkler irrigation: Water is distributed through pipes and sprinklers spray the small water drops into the air in a natural way just as rainfall. ● Chemical treatment: Use high polymer to improve the ability of the ground surface to absorb and save water.
Surface Water Loss	● In-ground irrigation system: Install pipes or canals underground and apply water pressure of no more than two pascals to convey the water to irrigated fields. ● Bay/border strip irrigation: Divide large irrigated fields into several smaller and short basins, and shorten the long canals as a way to water the basins separately.
Deep Percolation Loss (or seepage from canals)	● Soil facilitated: Cement composite soil, such as clay, sand clay and spodosol on the ground surface to form an anti-seepage layer. ● Cement soil facilitated: Mix soil, cement and water together and pour the mix on the ground to form an anti-seepage layer. ● Membrane facilitated: Place membranes on the irrigated field and pour a layer of soil to form an anti-seepage layer.
Insufficient Water in Crops Roots	● Micro-irrigation: Micro-irrigation is a low-pressure, low-flow-rate type of irrigation that can reduce overwatering. This system conveys water (nutrients) directly to the root zone of plants- slowly and evenly, which greatly prevents runoff and reduces evaporation.
Other Factors	● Seed selection: Use drought-resistant crops

Figure 3-4 Wheel line irrigation

Figure 3-5 Center pivot irrigation

Figure 3-6 Hose reel sprinkler irrigation

Figure 3-7 Linear move sprinkler irrigation

Now, to reduce the surface water evaporation, you need to design a small sized linear move sprinkler that is suitable for ridge and furrow farming in your case on an agricultural region. How does sprinkler work? A sprinkler first delivers water from storage to an irrigated field with pumps or other engines, and shoots the water in the air to fall on the crops.

Sprinkler irrigation systems own two advantages over the conventional flood irrigation: First, the sprinkler uses a sprayer to atomize water so that water more gently falls on the crops, saving crops and soil from strong impact forces.

Second, water spray helps regulate the microclimate of the irrigated field, contributing to an environment where the temperature and humidity are suitable for the growth of crops[13].

In this project, the sprinkler you design should be suitable for ridge and furrow farming. The irrigated field features many rectangular basins so the passages

between different basins are narrow and corners are abrupt. Therefore, a sprinkler must be highly maneuverable while working on this kind of field.

Reading 3-2 Ridge and Furrow

Ridge and furrow farming refers to a system of planting crops on a wavy corrugated field. It can increase the ground temperature, and improve the resilience of the irrigated field against droughts and floods. In a ridge and furrow topography, the elevated parts are called ridges and the shallow trenches are furrowed.

Pros of ridge and furrow farming:

The ridges feature thick layers of soil and larger pore space, which makes the soil less likely to harden and therefore beneficial to the growth of crops;

A ridge-and-furrow farmland increases its surface area by 20 %-30 % and its daytime temperature by 2-3 ℃ when compared with a level ground. Moreover, a ridge-and-furrow farmland usually comes with a more dramatic swing in temperature during a day, which means a higher chance for crops to preserve the products of photosynthesis;

The heights between ridges and furrows are perfect for drainage and water-logging prevention. Furrows are for water to flow during droughts;

Ridges act as obstacles to the wind and reduce wind speed;

Suitable for localized placement of fertilizers.

(Source: China Digital Science and Technology Museum[14])

Figure 3-8 Ridge and Furrow

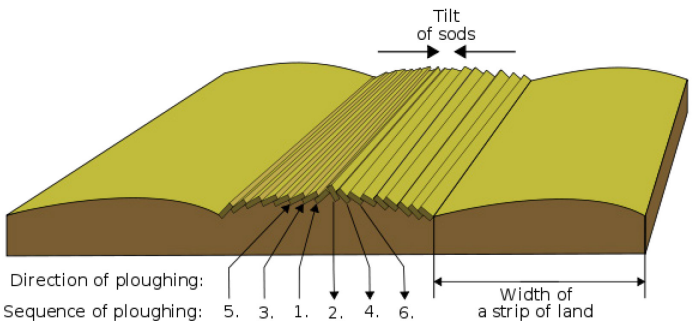


Figure 3-9 Structure of Ridge and Furrow

The maneuverability of a sprinkler is closely related to three mechanisms: Locomotion, Machinery Body Construction, Electrical Control System. In *Disaster Risk Management,* we know that the machinery body construction will influence the

maneuverability of robot locomotion. In this project, you'll use omnidirectional wheels (Figure 3-7) to build a locomotion mechanism that enables the sprinkler to irrigate crops row by row.

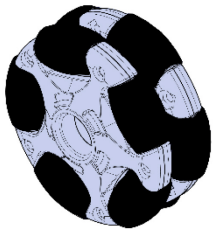


Figure 3-10 Omnidirectional Wheel

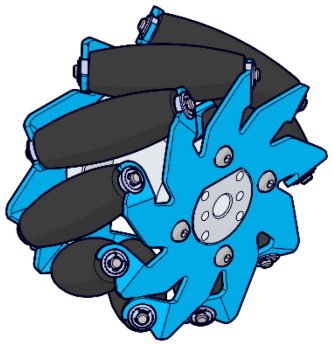


Figure 3-11 Mecanum Wheel

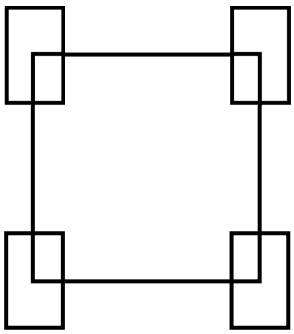
Omnidirectional wheels, in a broad sense, can encompass Mecanum wheels (Figure 3-8). In this project, however, we only refer to an omnidirectional wheel in its narrow sense (Figure3-7). An omnidirectional wheel is composed of a wheel hub (sprocket) and multiple rollers. The hub features many cogs and between 2 cogs there is a roller. The radial plane of each roller is perpendicular to the tangent of the curved surface of the hub. The structure enables the rollers to move in parallel with the axle of rotation while the hub is rotating around the axis simultaneously so that the machinery can move in all directions.

This project requires 4 omnidirectional wheels to move a sprinkler. However, not all the 4 wheels are being driven when the sprinkler is moving. Only the 2 wheels on the same diagonal of the chassis are being driven simultaneously. In other words, the sprinkler adopts a 2-wheel drive. The 2 wheels always move in the same direction as how the sprinkler moves. The sprinkler must make turns without changing the moving direction of the 2 wheels themselves. To achieve this, you should ensure that the dihedral angle between 2 neighboring wheels is 90° (or 45°).

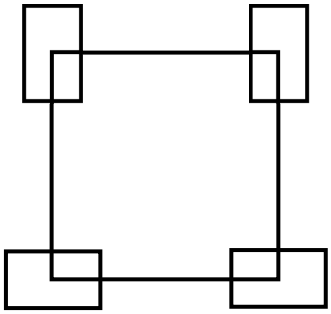
Task 3-3 shows two typical wrong assembling ways. Explain why they make it impossible for the omnidirectional wheels to move the sprinkler as expected. Write down your analysis. Then draw the correct assembly in the third square.

(Note: The squares are the vertical view of the chassis.)

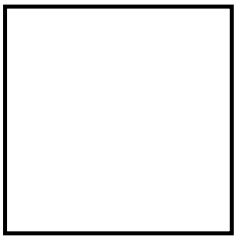
Task 3-3 How to correctly install the four Omni Wheels?



Wrong assembly A



Wrong assembly B



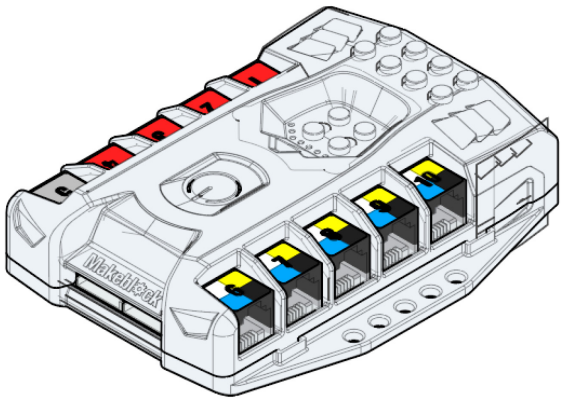
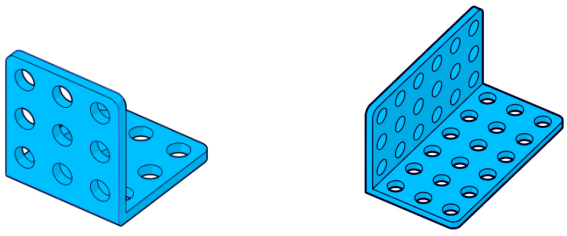
Correct assembly

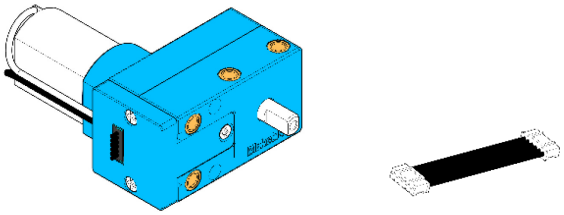
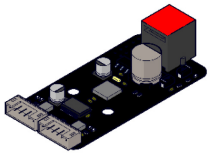
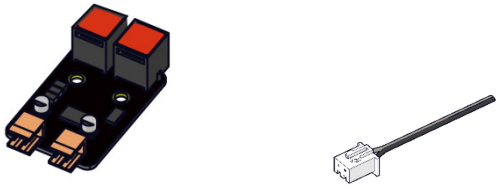
Write down your analysis:

To design the special walking mechanism structure of the sprinkle, you need to use four omnidirectional wheels to fulfill the function and meet the requirement of the contextual task. Again, think about and pay attention to its assembling way.

For more detailed information about the use of electronic modules, mechanical parts, and other relevant toolkits, please visit the website, learn.makeblock.com/en, for reference.

Table 3-3 List of key electronic modules and mechanical parts in the Sprinkle case

Electronic Module or Mechanical Part	Overview and Functional Features
 Me Auriga (×1)	Me Auriga control board is equipped with multiple onboard sensors, including a gyroscope, a buzzer and more; features a one-key power switch. Also, PORT 5 is isolated only with serial communication function, so it can't be used to update a program but is only for communication. It is compatible with USB serial port. PORT 6 to PORT 10 are compatible with dual-digital, simulation, 12C bus, unibus, and simulate serial port. Me Auriga has encoder motor port, smart servo port, as well as LED ring panel port (with power switch).
 Connecting Fittings	Connecting fittings come in various shapes: right-angled, U-shaped, P-shaped, circular, and triangular. The holes on the brackets are used in conjunction with beams to build mechanic frameworks, or with bearings to build bases for shaft systems and motors.

Electronic Module or Mechanical Part	Overview and Functional Features
 58mm Omni Wheel (×4) and the Coupling Pack (×4)	An omnidirectional wheel is composed of a hub and rollers. The omnidirectional wheel includes 10 cogs, and between 2 cogs there is a roller. The radial plane of each roller is perpendicular to the tangent of the outer circumference of the hub which enables conventional forward and backward movements, side to side and rotations.
 180 Optical Encoder Motor (×4) and Connection Cable	The 180 optical encoder motor is equipped with an optical encoder which enables precise control of the motor. And the unique structure makes this motor compatible with various parts. It produces lower noise while running and promises long-term large output torque.
 Me Encoder Motor Driver (×1)	The Me DC Encoder Motor Driver is compatible with a two-channel DC encoder motor, and includes an MCU and a motor driver chip. The MCU has a built-in PID algorithm and implements accurate control so it can be considered a micro motor development board.
 Water Pump Motor (×1) and Silicone Pipe	The water pump motor has a 12V motor and a tough thermoplastic body. It is widely used in water pumps, automotive pumps, bonsai rockery, DIY projects and so on.
 Me Dual DC Motor Drive (×1) and PH2.0 Motor Cable	The Me Dual Motor Driver module can drive two DC motors via the onboard RJ25 port with power supply of 6V-12V. This module has over-current protection. The red labels on the module mean that the module should be connected to the ports marked with red labels on the main control board.

Making the Water-saving Irrigation Machinery

Mechanical Structure Design

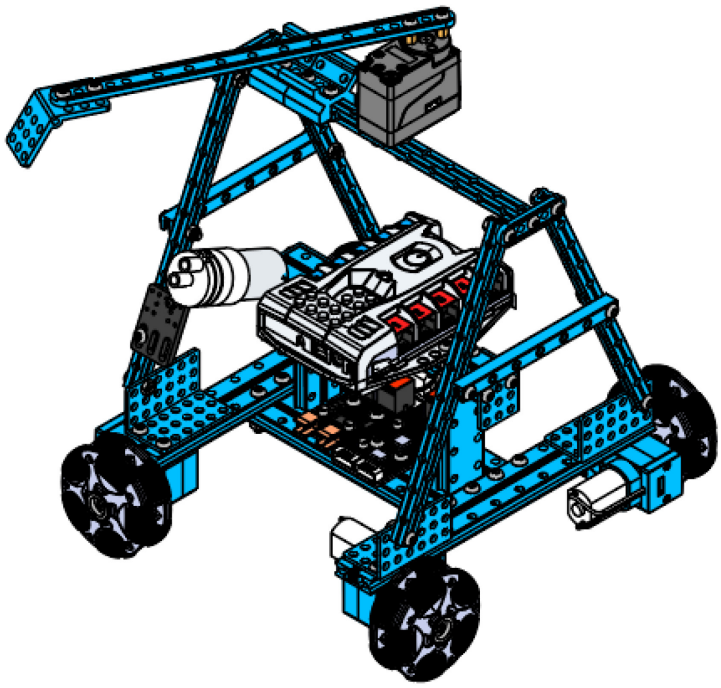
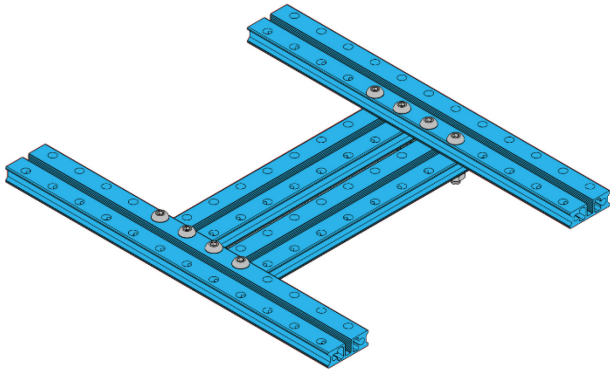
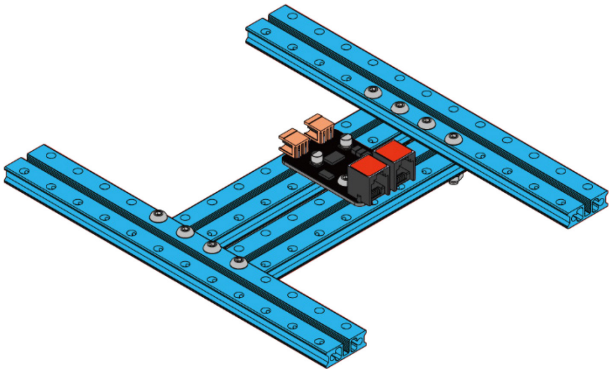


Figure 3-12 Making the Water-saving Irrigation Machinery

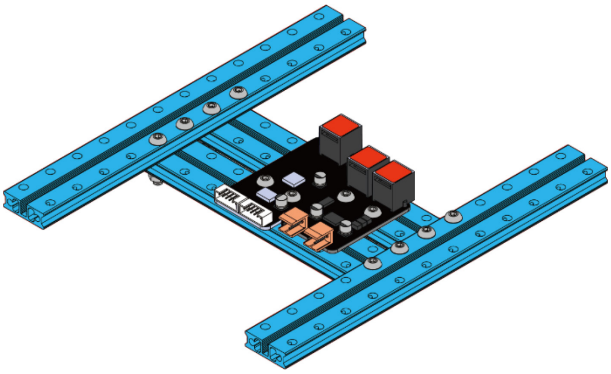
Key steps: Install the four Omni Wheels



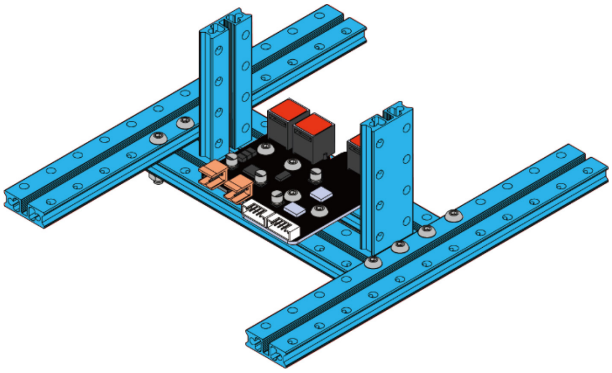
Step 3-1-1



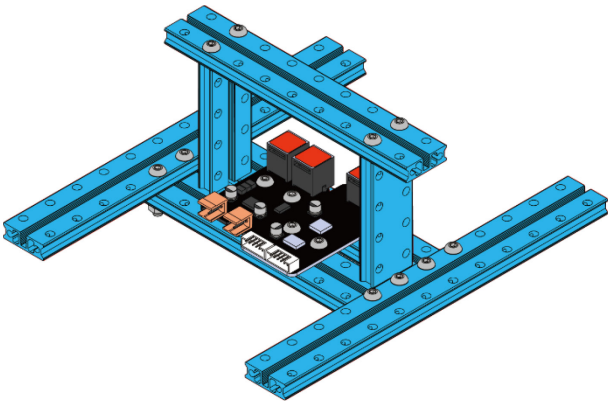
Step 3-1-2



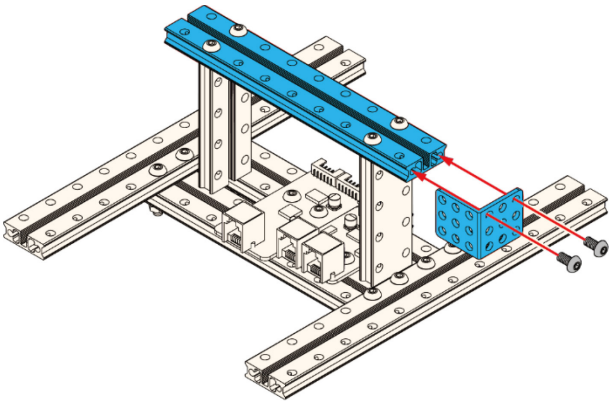
Step 3-1-3



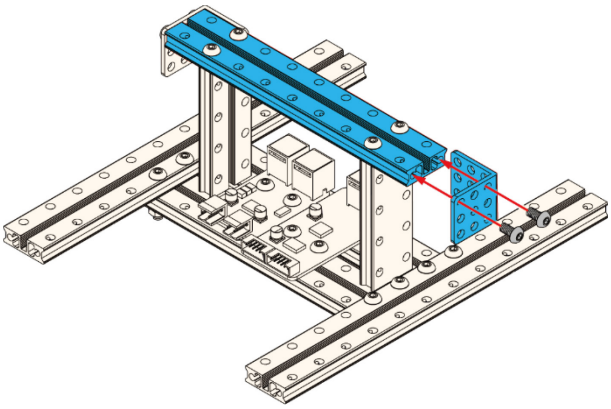
Step 3-1-4



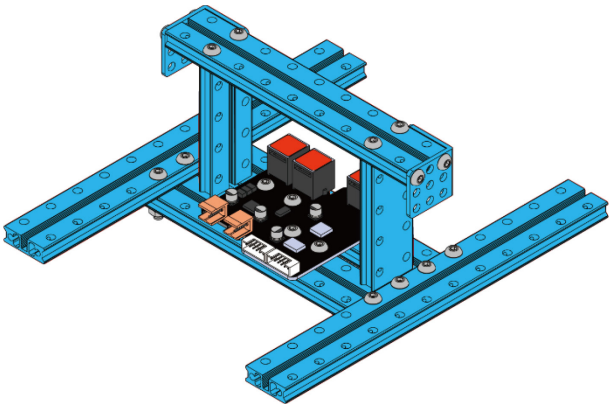
Step 3-1-5



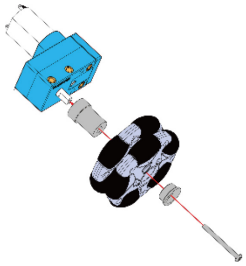
Step 3-1-6



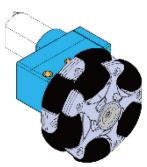
Step 3-1-7



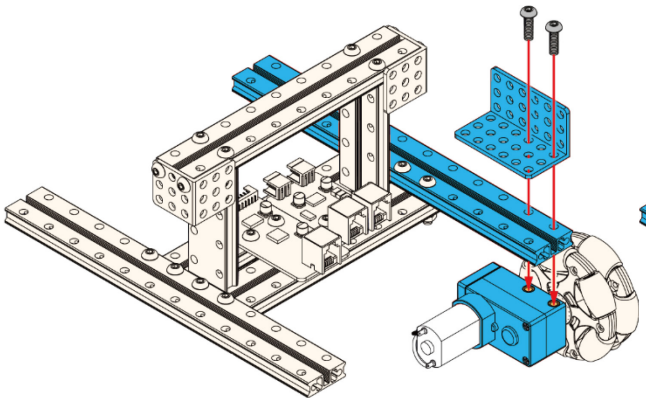
Step 3-1-8



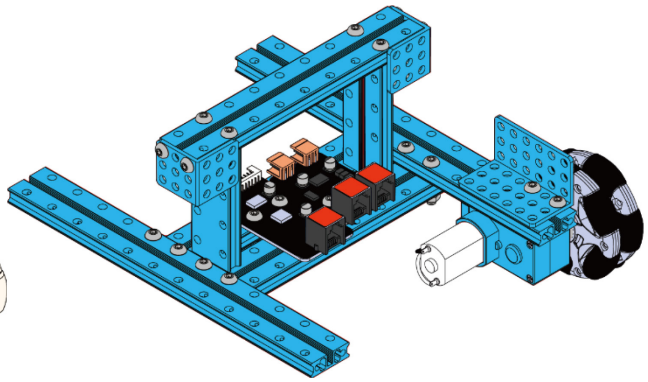
Step 3-2-1



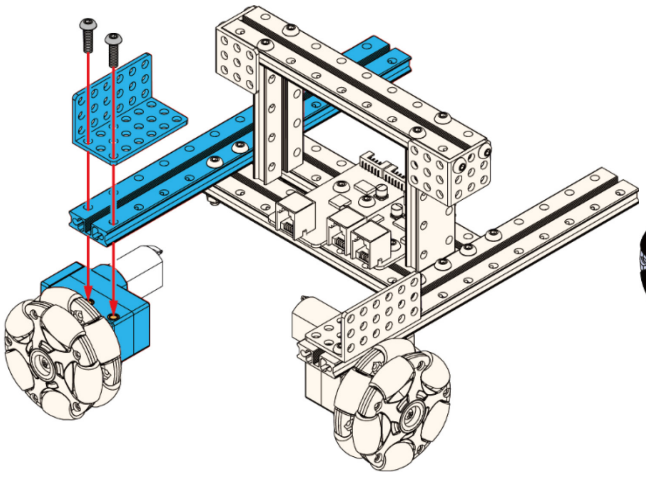
Step 3-2-2



Step 3-2-3



Step 3-2-4



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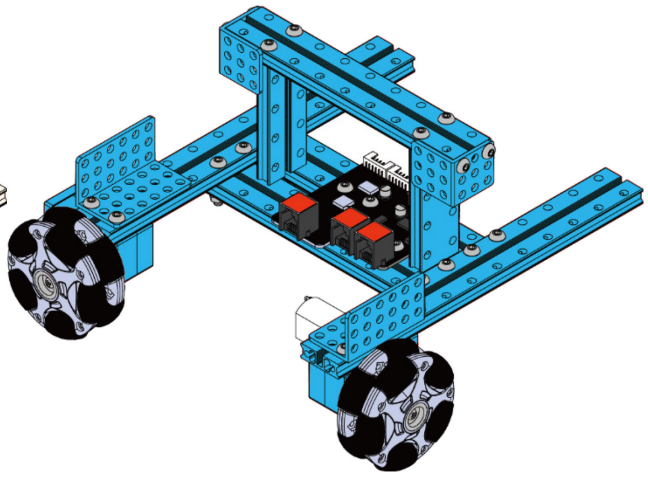
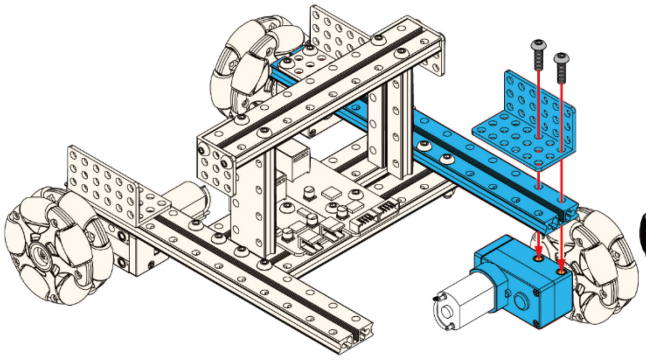
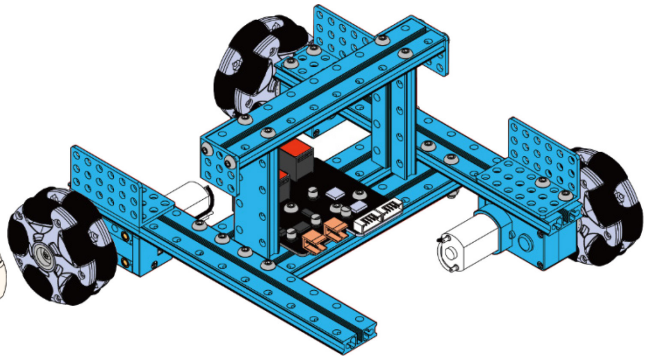


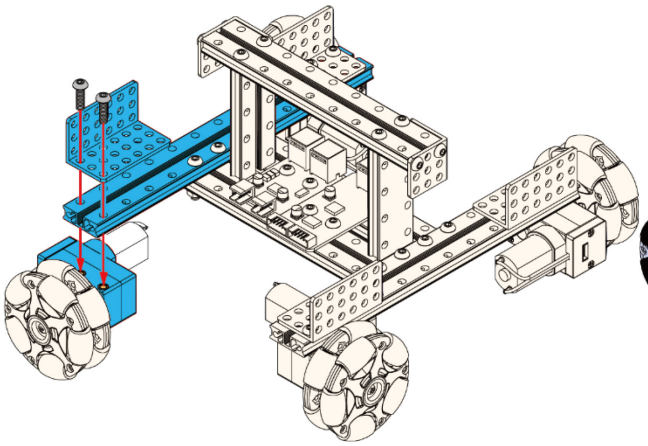
Step 3-2-6



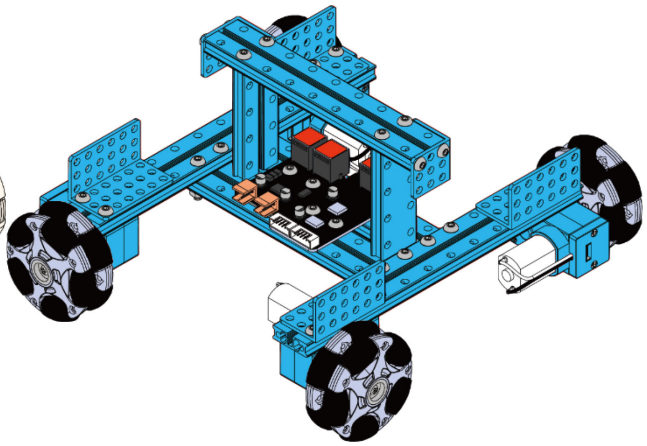
Step 3-2-7



Step 3-2-8



Step 3-2-9



Step 3-2-10

Functionality Design

The trajectory of the sprinkler on the farmland is repetitive: when the sprinkler finishes watering the crops on one ridge, it makes a turn to another ridge and continues irrigating. Please program the sprinkler to automatically take turns so as to make irrigation smarter.

(Tip: The Me Auriga comes with an on-board gyroscope.)

Your Turn to Practice

The project above mainly discussed the role of mechanization and automatic irrigation machinery in improving irrigation efficiency and developing irrigated agriculture. In the 21st century, new technologies, such as artificial intelligence and big data, enable a more intelligent approach to farming practices. With the support of information and communication technology, algorithms are applied in agriculture to help monitor water and nutrients supply.

Based on the project analysis and prototyping process covered in the session above, explore yourself how resilience strategies help boost irrigation efficiency and water resources management. You can either dig into agricultural water use or move on to domestic water use.

Step 1: Assess the Task

Focus on the efficiency of either agricultural or domestic water use. Explain how the problems can be solved using mechanical, automation or intelligent solutions.

Task 3-4 Water resources and water use issues concerning sustainability

Issues of Water Use	Mechanic/Automatic/Intelligent Solutions

Step 2: Evaluate Strengths and Weaknesses

Based on the analysis in Task 3-4, write down the materials you need for building a machinery prototype to solve the problems.

Task 3-5 Possible solutions for effective water resources management

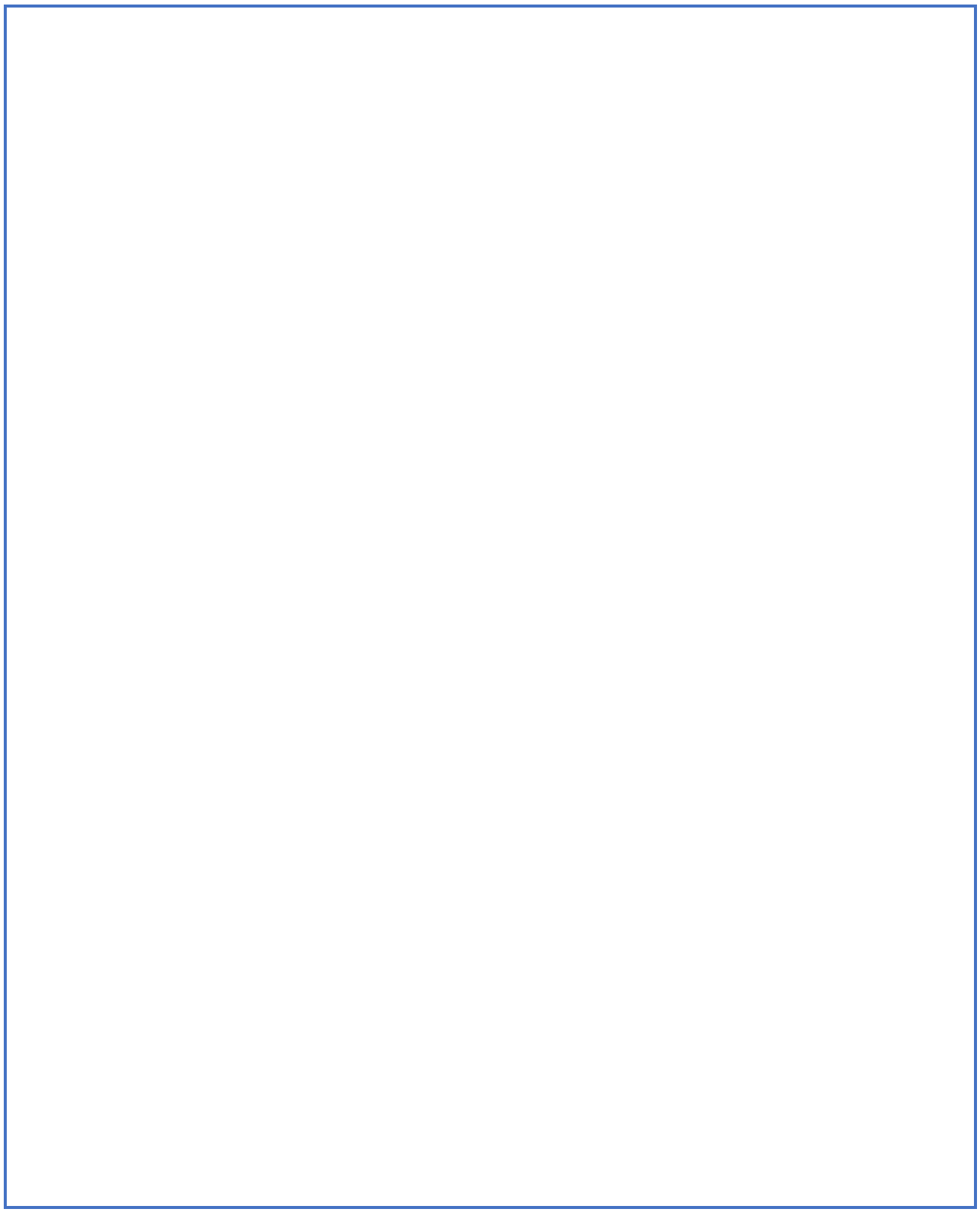
Solutions	Materials Needed

Step 3: Plan the Approach

Based on your analysis in Step 2, draw your prototype and specify how the structure can achieve the functionality.

Step 4: Apply Strategies

Draw the algorithm or the program design flowchart below.



Invite at least 2 external members to comment on your prototype, asking them to give advice. Then optimize the prototype based on the peer review. If you make any adjustments to your prototype, draw the new design.

Reviewer A:	**Reviewer B:**
New Design:	

Step 5: Reflect

Review the whole process, from identifying problems to designing and developing the prototype. Refer to the checklist in Table 3-3 to reflect upon how you've considered the following problems during the process.

Table 3-4 Checklist of project feasibility

☐ Is there any previous research into the question? If so, what are the existing conclusions?
☐ In what aspects does your innovation intend to benefit your city or community?
☐ What changes do you expect your innovation can bring to your city or community in terms of Urban Resilience?
☐ What are your hypotheses and expected results?
☐ What methodology and strategy do you use when analyzing and designing?
☐ What data do you need? How do you gather data and analyze them?
☐ How do you explain your innovation through prototyping your creative ideas? What materials are needed? And how do you build the prototype?
☐ Is the location a restriction in your project?
☐ Can the local resources help you achieve what you want
☐ Is time a limitation?
☐ How much time do you need to complete the project?
☐ How much time and effort will you invest in this project weekly?
☐ Do you expect you can find the answers for the research problem as scheduled?
☐ Do you think the investigation group, with all the members involved, can tackle the problem you proposed concerning the time and location restrictions?

At last, briefly describe your innovation and achievement.

Extension III: Urban Agriculture and Smart Farming

Urban Agriculture is one of the major farming practices in urban areas. The most feature that distinguishes urban agriculture from rural agriculture lies in its use of existing urban resources, including land and the ecosystem, to satisfy the daily need of urban residents and serve socio-economic purposes.

Greenhouse Farming is one of the common urban agricultural practices. A greenhouse is a place where cash crops, such as vegetables, fruits, and plants, are planted. Considering the limited space in cities, a greenhouse is usually designed to be space efficient and flexible. Specifically speaking, if compared to open farmlands, the internal space of a greenhouse is more likely to be long and narrow so that rows of crops are usually planted line by line in a greenhouse. Apart from the ground, in a greenhouse, the vertical place can play a role. For instance, plant supports are applied in a greenhouse to make the best of the vertical space of a greenhouse.

Figure 3-13 Glass greenhouse

In spite of this, the space in a greenhouse is still limited for crops to grow. In addition, a greenhouse features a less diverse ecosystem and relies more on human intervention. On the one hand, the absence of natural water cycles, such as rainfall, water from rivers, lakes and mountain glaciers, might lead to less diverse nutrient sources. On the other hand, crops in a greenhouse are mostly planted for profits, which means massive crops being planted each time, shorter production period and higher plant density. All of these factors call for a more precise irrigation system.

Irrigation systems used in open farmlands might not work properly in greenhouses. In greenhouses, irrigation systems should consider not only the demands of crops for water, but also the nutrients provided by water. Economic benefits are the top priority of urban agriculture, so it's an inevitable choice for urban greenhouse irrigation to be more automated and intelligent.

Task 3-6 Simulated smart greenhouse and IoT-based farming

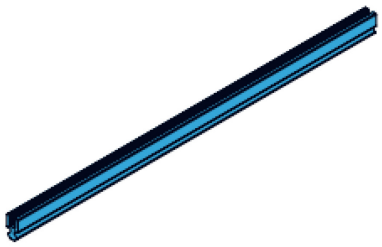
Intended Functionality	Sensors Required

Prototype Design: IoT-based Smart Sprinkling System

As a way to boost irrigation efficiency, greenhouses can use automated traveling sprinklers as the major systems. An automated traveling sprinkler keeps walking back and forth to water crops row by row, making the supply of water and nutrients in multistoried agriculture more effective and efficient.

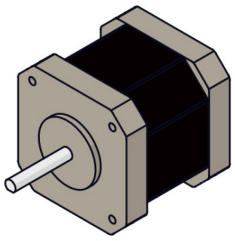
In this project, the automated traveling sprinkler draws on sliders. Guide rails are mostly used in mechanic setups meant for back-and-forth movements, for instance, sliding doors. This project uses v-slot sliders and v-slot bearings to build the prototype.

The prototype uses 2 v-slot guide rails to build the support base and guideway. Use a connector plate and 4 v-slot bearings to assemble the sliding block. On the same guide rail, 2 bearings should be installed on the separate sides. Install a Smart Servo on the sliding block to change the direction of the spray gun.



V-slot Guide Rail

V-slot Bearing



Stepper Motor

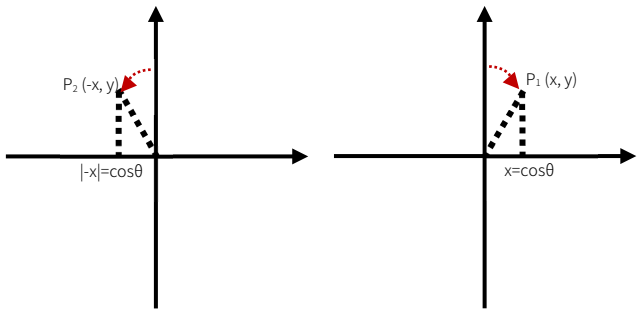
This automated traveling sprinkler provides a precise control over irrigation, ensuring every single crop being watered. In other words, the sprinkler should precisely control its speed and turning distance. To achieve this, we use a stepper motor in the prototype. A stepper motor is less vulnerable to the change of workload, so that it can move at the speed or turn around at a specific distance precisely as preset in a greenhouse.

A stepper motor performs periodic motions which we can graph as a sin or a cosine function. Take the output shaft of the stepper motor as a mass point and as the original point *O* of a rectangular coordinate system. The electrical control system drives the stepper motor to rotate at a specific angleϑ.

The stepper motor is initially located at *0°*. Imagine the cross shaped spokes of timing pulley as *x* and *y*. Specify the point of contact between the timing pulley and the timing belt as *P (0,1)*,

which is the initial position of the stepper motor. When the stepper motor rotates clockwise, P moves to quadrant I, becoming P_1 *(x, y)*, and the top timing belt moves by $x=cos\vartheta$. The bottom timing belt drives the sliding block towards the stepper motor at the same displacement of *x* as the top timing belt.

When the stepper motor rotates counter clockwise, P moves to quadrant II, becoming P_2 *(-x, y)*. The top timing belt moves by |-x|=cosθ. Similarly, the bottom timing belt drives the sliding block away from the stepper motor by|-x|.



Stepper Motor Rotates Clockwise **Stepper Motor Rotates Anticlockwise**

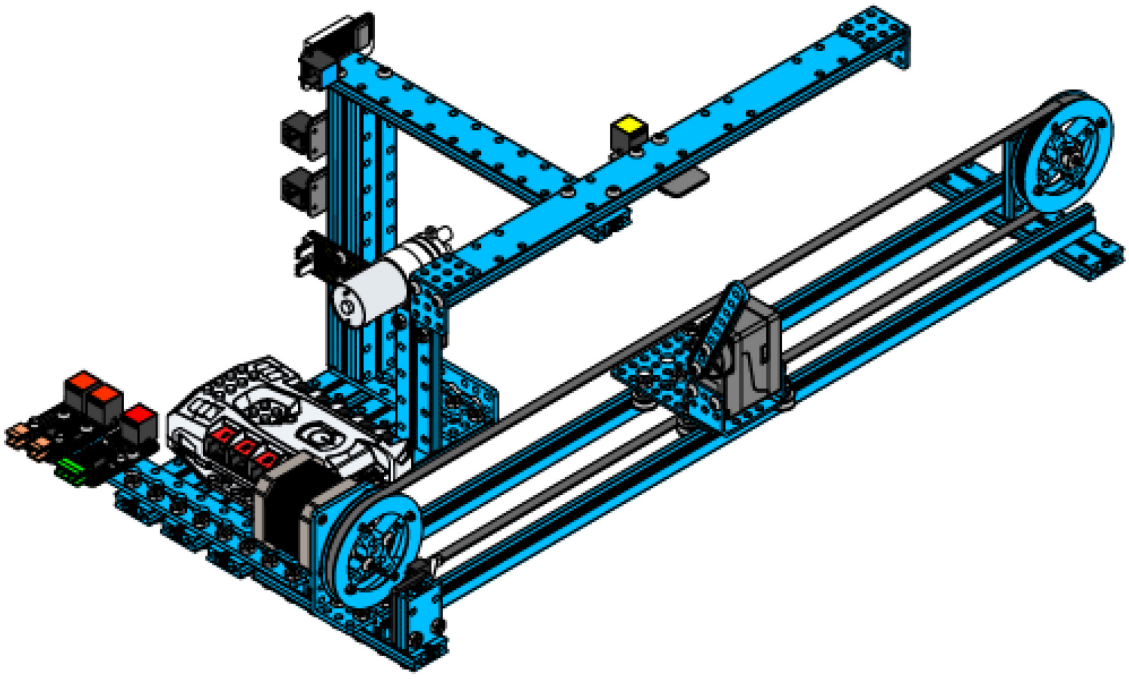


Figure 3-14 Prototype Design: Automated Traveling Sprinkler

Design Challenge

The session above analyzed how to apply a proper construction body (guide rails-based structure) and functionality (stepper motor being the driving mechanism) to design an automated sprinkler.

Your next challenge is to make your sprinkler even smarter. Add a Ranging Sensor in the prototype and program the sprinkler to precisely move as preset.

Here's what the sprinkler is expected to do: From the preset initial position, the sprinkler starts watering the crops. There are 10 crops in a row. The sprinkler automatically decides when to move to the 1st crop, stop moving and regulate its spray gun to water the 1st crop. Then, the sprinkler automatically moves to the 2nd crop, stops moving and starts watering the crop. And move on to the 3rd crop...

Tip: When you were building a robot, which electronic module did you use to measure distance, which module for avoiding obstacles? Could these modules be useful for this prototype as well? Why?

Extension IV: Water in the Developing World

Safe and economical access to water remains a challenge in many developing countries and regions, particularly in the least developed countries. In Africa and Latin America, lots of people still rely much on hand-dug wells and hand pumps. Many factors, such as high costs of mechanic pumping equipment and pipelines, bad climate and poor local government finance, all contribute to the sluggish transition to sustainable water use in underdeveloped countries.

Do some research or read environment news to investigate water sustainability in a developing country, region or city. Write down your analysis of why water sustainability is hard in the area considering the economic, environmental and social costs. Also, list your solutions to effectively reduce the costs as a way to solve the problems.

Task 3-7 Analyze the economic, environmental and social costs of domestic water use

Country/Region/City:	
Water Use Costs	**Cost-saving Solutions**
Economic Cost:	
Environmental Cost:	
Social Cost:	

Domestic water use may account for a less proportion of the total water but it greatly affects people's livelihood. The sluggish socio-economic development and improperly maintained facilities entail insufficient water supply and inadequate sanitation, which negatively impacts residents in underdeveloped regions, with children being particularly affected. *Water Under Fire (2019),* a report by UNCF, said that children under the age of 15 living in countries affected by protracted conflict are, on average, almost three times more likely to die from diarrhea caused by a lack of safe water, sanitation, and hygiene than by direct violence[15].

Reading 3-3 Water Resources Management in Developing Countries —Using Cambodia as an example

Water facilities in areas such as Sub-Saharan Africa, Central Asia, Southern Asia, South-Eastern Asia, call for improvements. These regions share a lot in common, be it environmentally or economically: All are located in hot, dry areas with large areas being deserts. Besides, water facilities in these areas are seriously aging. For example, Cambodia, a country awash with rivers and boasting the largest freshwater lake of Southeast Asia, still suffers from water scarcity.

Figure 3-15 National flag of Cambodia

Figure 3-16 Symbol of the Cambodian monarchy

Cambodia has 75 billion cubic meters of surface water and 17.6 billion cubic meters of groundwater. The annual precipitation is about 1,400-3,500 millimeters. The Mekong River, the main river in Cambodia, brings about 475 billion cubic meters of water every year.

According to the research conducted by the Economic and Commercial Counselor's Office of the Chinese Embassy in Cambodia in 2005, the total water use in Cambodia was only 750 million cubic meters, of which 95% was used for agricultural purposes. In Cambodia, only 35% of the population has access to clean and safe drinking water. Among the 35%, 65% live in cities, 26% live in rural areas.

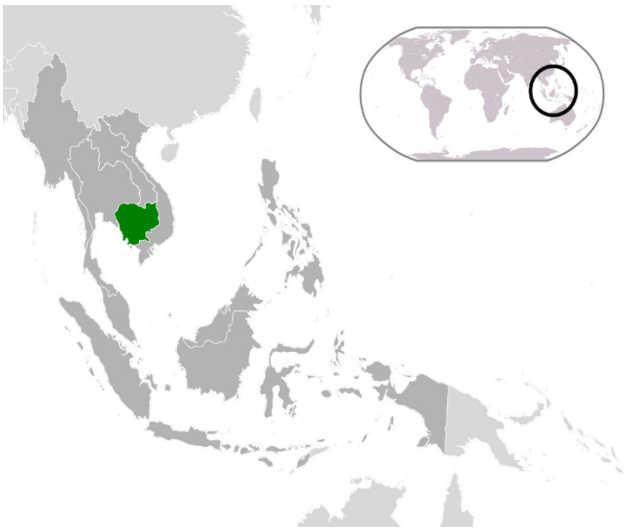


Figure 3-17 Location of Cambodia

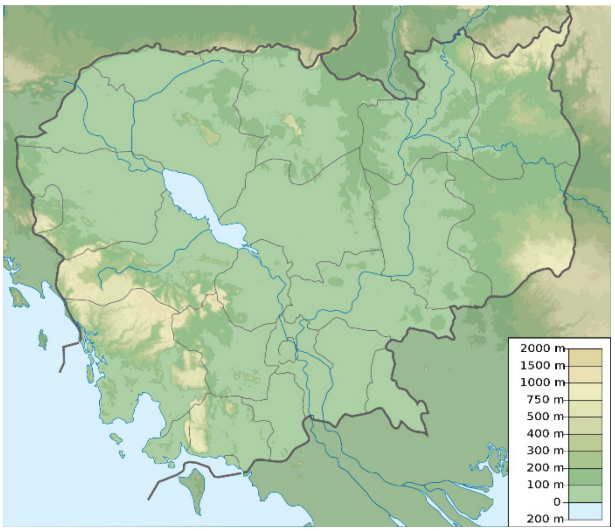


Figure 3-18 Geography of Cambodia

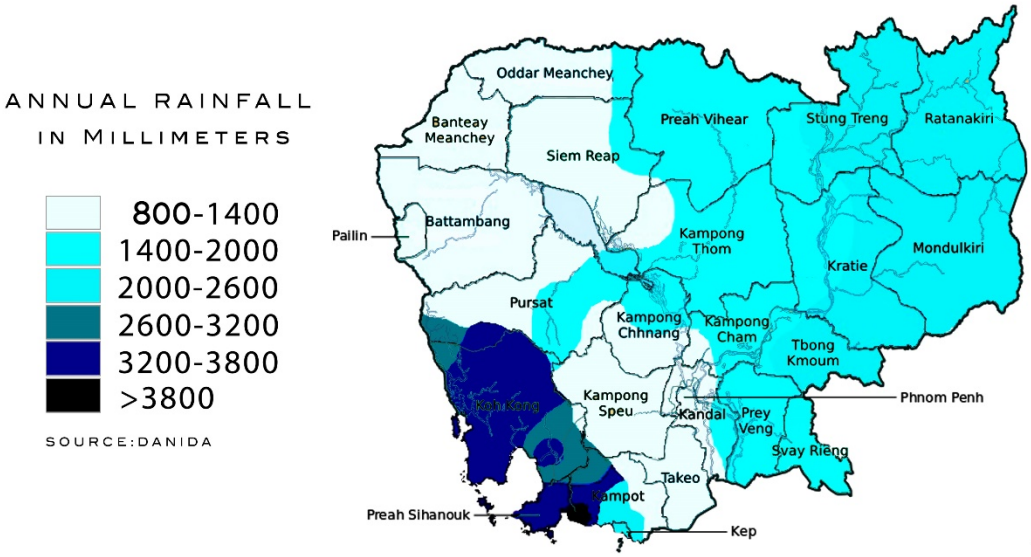


Figure 3-19 Rainfall distribution in Cambodia (Source: Danish International Development Agency)

According to the research conducted by the Economic and Commercial Counselor's Office of the Chinese Embassy in Cambodia in 2005, the total water use in Cambodia was only 750 million cubic meters, of which 95% was used for agricultural purposes. In Cambodia, only 35% of the population has access to clean and safe drinking water. Among the 35%, 65% live in cities, 26% live in rural areas.

Why Cambodia suffers from water shortage has its environmental, social and economic reasons. The tropical monsoon climate in Cambodia means abundant rainfall concentrated in high-sun seasons. Rainfall is rare in low-sun seasons, or in other words, planting seasons, as a result of which the water scarcity is intensified.

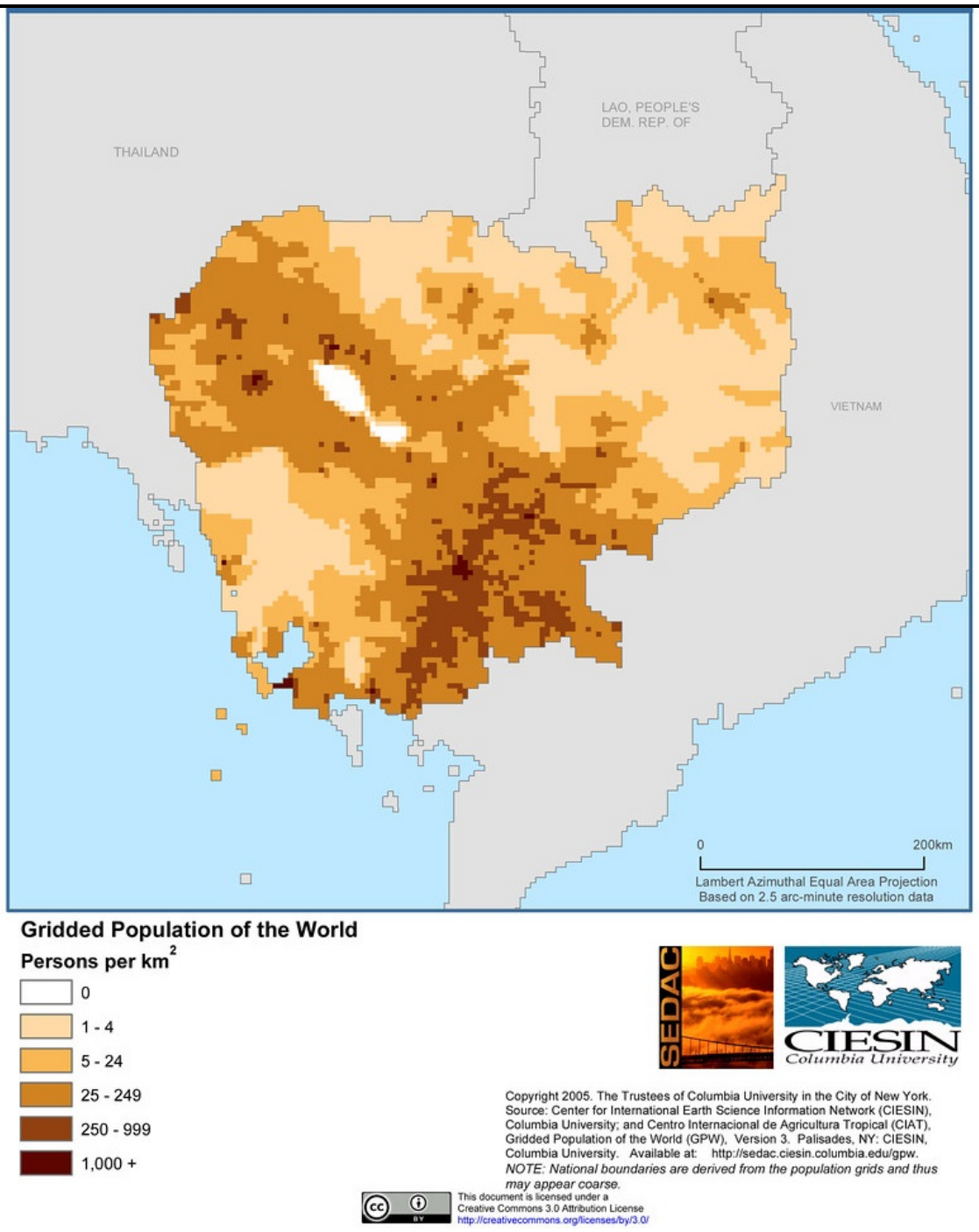


Figure 3-20 Population density of Cambodia in 2000 (Source: SEDACMaps via Flickr)

Most cities, except Phnom Penh and some capital cities, lack adequate water supply and sanitation facilities. Plenty of residents suffer from diarrhea, dysentery and typhoid fever diseases caused by contaminated water. In addition, the government's financial problems and its reliance on foreign investments slow down the progress of easing the water shortage.

(Source: Economic and Commercial Counsellor's Office of the Embassy of the People's Republic of China in the Kingdom of Cambodia[16])

Business Design: Social Entrepreneurship to Water Use

Sustainable water use is not only about the environment and resources. Limited drinking water services could have a strong gender impact because, according to research[16], women and girls are responsible for water collection in 8 out of 10 households with water off premises.

Large-scale water services require huge expenditure and long periods of investment and construction. Is there a solution that can solve the domestic water use issue with fewer costs and less time?

Design Challenge

Suppose that now you were responsible for a non-profit entrepreneurship program. Select an underdeveloped region as your target client. This region has a new well. Design a cost-efficient mechanical device which residents use to collect water. The device should have the following features:

The mechanical device should be easy to use, particularly for women, children and the senior citizens;

(2) The device is possible to make waiting less boring;

(3) The device encourages young men to collect water more often;

(4) The device comes with less economic, environmental and social costs. It should facilitate sustainable water use.

The prototype below combines essential components of a hand pump (piston and piston rod) and the drivetrain system of a bicycle. The rider pedals the bicycle to drive the piston rod and piston, relying on the atmospheric pressure to suck water to the surface.

The prototype is for reference only. You can either build on the prototype, or design a new prototype.

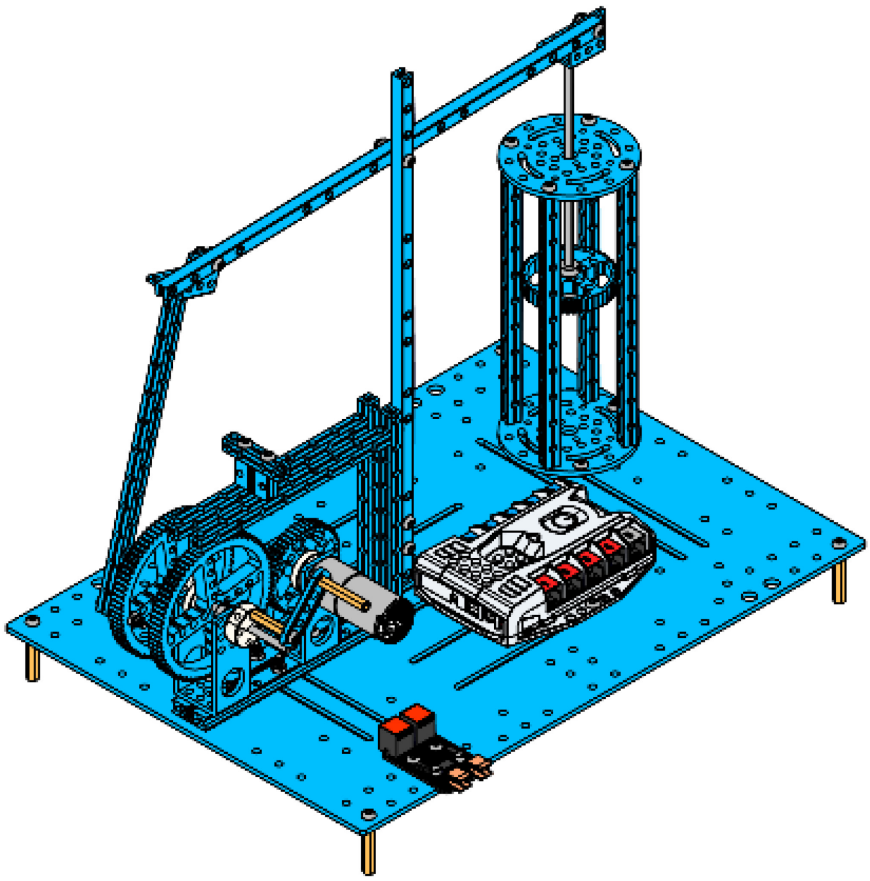


Figure 3-21 Prototype Design: Bicycle-powered Water Pump

The essence of this prototype is its Crankshaft and Connecting Rod Mechanism. This form of mechanism enables an easy transfer between linear reciprocating motions and circular motions, so it has a higher transmission efficiency than a Connecting Rod Mechanism. Use laws of mechanics and do some research to answer the question below:

What specific drivetrain systems does a crankshaft and connecting rod mechanism include?

(2) Apply the sliding system in the automated traveling sprinkler to make linear reciprocating motions possible. Compare the linear reciprocating motion system and the crankshaft and connecting rod mechanism. Explain why the latter is more efficient.

About the Sustainable Development Goal 6

Water and Sanitation

Clean, accessible water for all is an essential part of the world we want to live in and there is sufficient fresh water on the planet to achieve this. However, due to bad economics or poor infrastructure, millions of people including children die every year from diseases associated with inadequate water supply, sanitation and hygiene.

Water scarcity, poor water quality and inadequate sanitation negatively impact food security, livelihood choices and educational opportunities for poor families across the world. At the current time, more than 2 billion people are living with the risk of reduced access to freshwater resources and by 2050, at least one in four people is likely to live in a country affected by chronic or recurring shortages of fresh water. Drought in specific afflicts some of the world's poorest countries, worsening hunger and malnutrition. Fortunately, there has been great progress made in the past decade regarding drinking sources and sanitation, whereby over 90% of the world's population now has access to improved sources of drinking water.

To improve sanitation and access to drinking water, there needs to be increased investment in management of freshwater ecosystems and sanitation facilities on a local level in several developing countries within Sub-Saharan Africa, Central Asia, Southern Asia, Eastern Asia and South-Eastern Asia.

Source: UN, www.un.org/sustainabledevelopment/water-and-sanitation

Facts and Figures

- 1 in 4 health care facilities lacks basic water services
- 3 in 10 people lack access to safely managed drinking water services and 6 in 10 people lack access to safely managed sanitation facilities.
- At least 892 million people continue to practice open defecation.
- Women and girls are responsible for water collection in 80% of households without access to water on premises.
- Between 1990 and 2015, the proportion of the global population using an improved drinking water source has increased from 76% to 90%
- Water scarcity affects more than 40% of the global population and is projected to rise. Over 1.7 billion people are currently living in river basins where water use exceeds recharge.
- 2.4 billion people lack access to basic sanitation services, such as toilets or latrines
- More than 80 per cent of wastewater resulting from human activities is discharged into rivers or sea without any pollution removal
- Each day, nearly 1,000 children die due to preventable water and sanitation-related diarrheal diseases
- Approximately 70% of all water abstracted from rivers, lakes and aquifers is used for irrigation
- Floods and other water-related disasters account for 70% of all deaths related to natural disasters

Source: UN, www.un.org/sustainabledevelopment/water-and-sanitation

Goal 6 Targets

6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all.

6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.

6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.

6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.

6.A By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.

6.B Support and strengthen the participation of local communities in improving water and sanitation management.

Source: UN, www.un.org/sustainabledevelopment/water-and-sanitation

Notes

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CAPSTONE PROJECT: 1m³ OF SPACE IN THE SUSTAINABLE CITY

Overview

You will work with partners to design and build a prototype of a sustainable city or community on your own. You need to demonstrate the social innovation project to officers of the “UN-Habitat” as well as the “delegates of Habitat III”.

First, you need to fully understand the topic of and requirements for the social innovation project. Based on the Urban Systems Model Approach, establish your own understanding of the concept "1m³ of Space in the Sustainable City", including its connotation, practical implications and value. Next, apply what you've acquired in the previous pilot studies to create a prototype of 1m³of Sustainable City along with team members. You are expected to submit a written design proposal to the “UN-Habitat” and all the participants of the Model Habitat III Conference.

Meanwhile, by reflecting on the Urban Resilience mechanism that's covered in the pilot studies, you can understand the instructive role of the Urban Systems Model Approach in building a sustainable city or community.

Intended Learning Outcomes

- ☐ Describe and analyze the resilience mechanism of your prototype.
- ☐ Create your prototype of a “1m³ of Space in Sustainable City” and write a design proposal.
- ☐ Articulate your conception and its innovations.

Your Study Plan

List your expected learning outcomes before starting the project.

I expect to achieve:

Don't forget to estimate the efforts you are going to invest in the project, including time, human and physical resources. You can employ **Gantt Charts** to plan your project. Below is a sample chart.

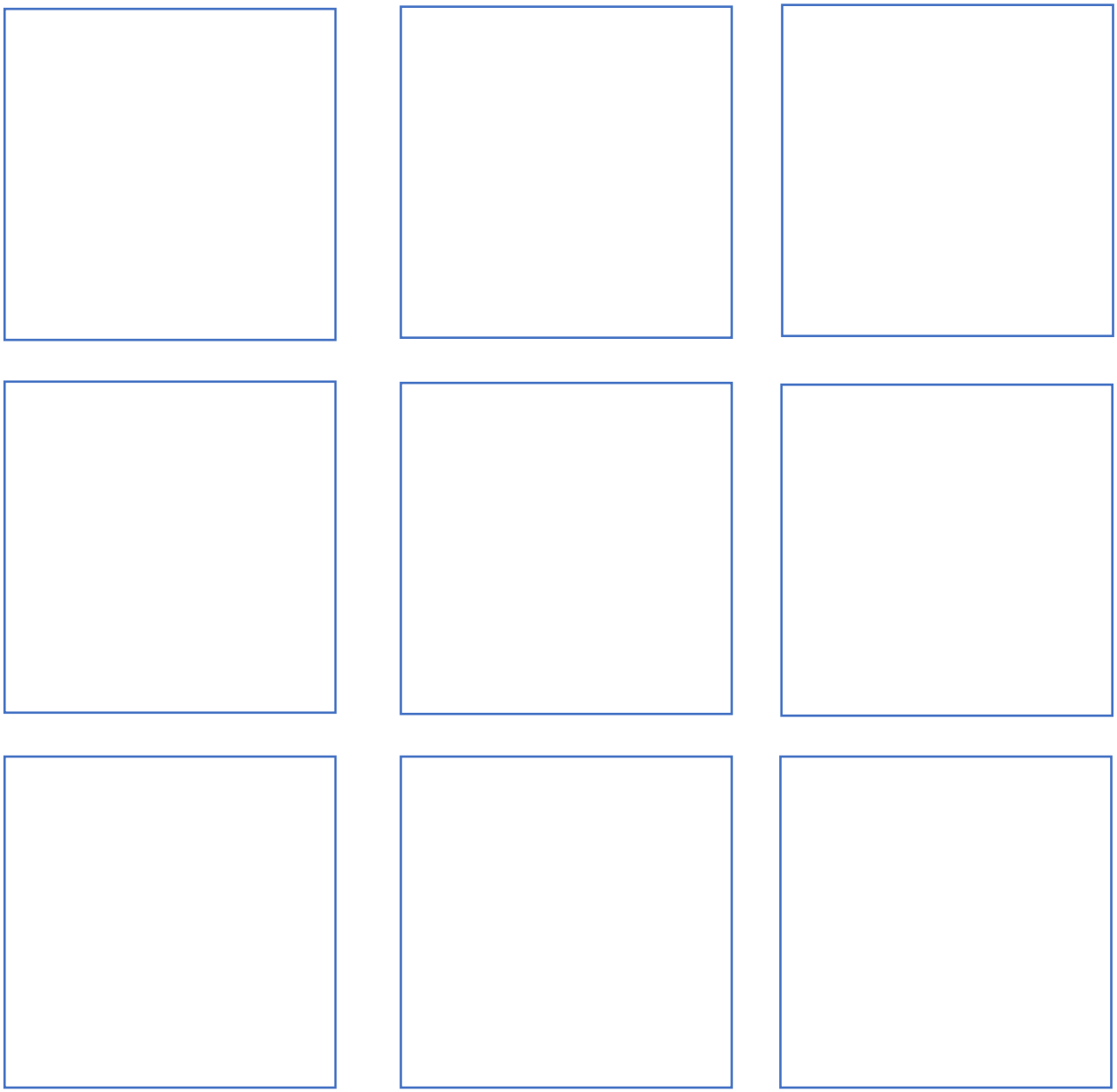
Create a similar chart on your own in Excel:

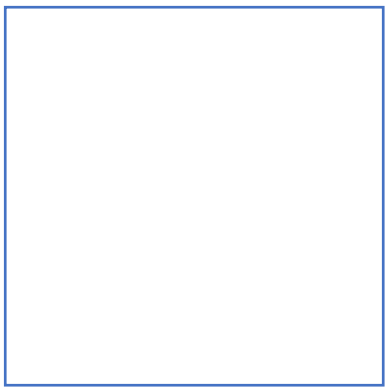
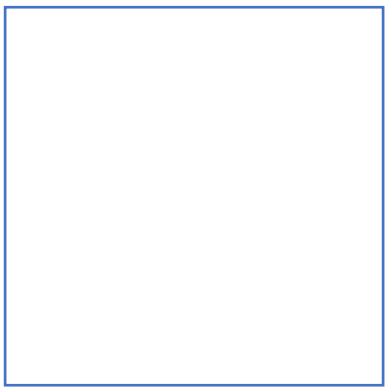
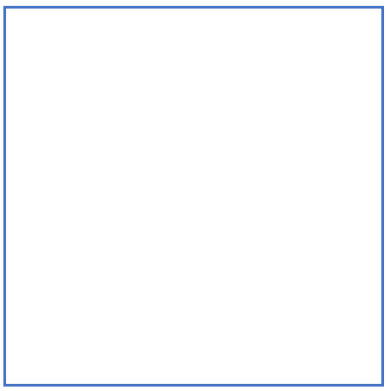
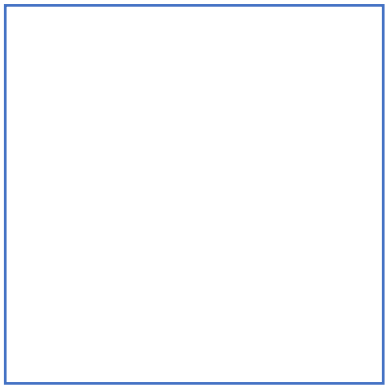
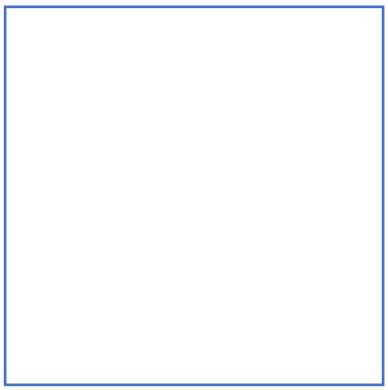
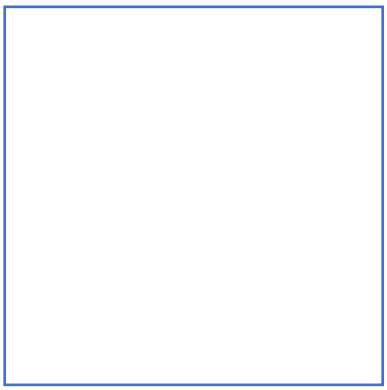
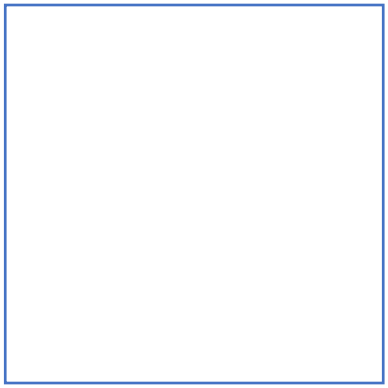
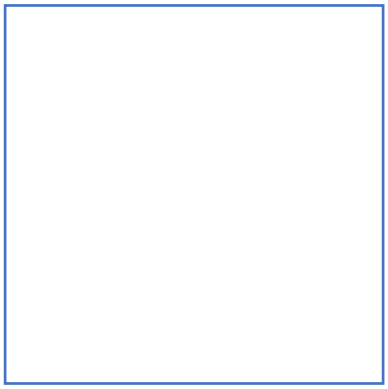
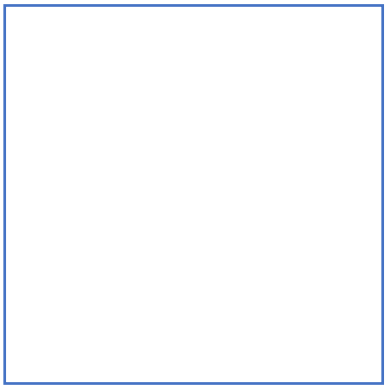
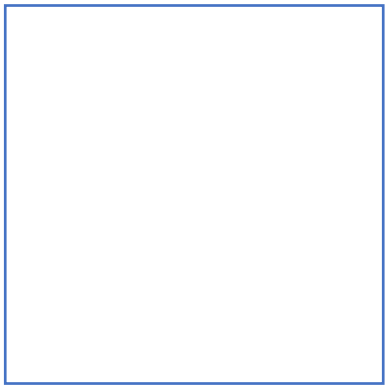
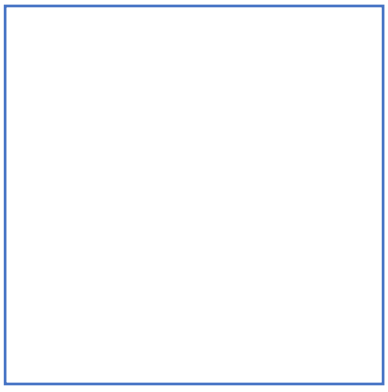
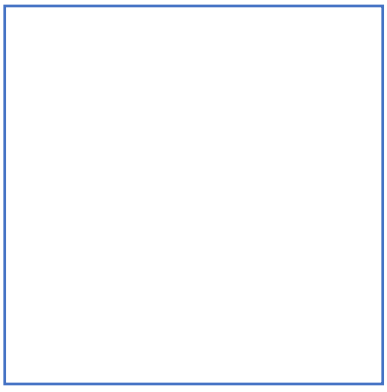
Item	My Task	Project Lead	Work Days		(%) Done	Duration		
			Start Date	End Date		Week 1	Week 2	.....
01								
02								
03								
04								
05								
...								

Doodling the Social Innovation Project Roadmap

You already decided on your research question, methodology and modeling method. Now, together with partners, sketch the steps of how to complete your project in squares below. First, write down the step name in each square. Second, draw out possible scenarios to illustrate each step. You can decide the order of how the squares are connected.

Task 4-1 My 1m³ of space in the sustainable city project roadmap



Visual Thinking

Visual Thinking refers to a range of creative thinking techniques that rely on visual imagery to organize our thoughts. Visual thinking helps visualize our thinking process to make it visible for all. You just applied visual thinking techniques to plan your project in the doodle session.

Visual thinking skills are also applied to analyze stakeholders involved in a project. In the "1m³ of Space in the Sustainable City" project, for example, if the focus is the housing demolitions of Chinese urban villages, then the stakeholders include house owners, tenants, demolitions organizers, future residents or investors.

When you are working on the 1m³ of Space in Sustainable City project, carefully consider the two questions: How will my design affect the environment, facilities, products and people, and the interconnections among them? How do I design a resistance mechanism that's consistent with people's behaviors, habits, cognitive characteristics and emotional characteristics? Use Table 4-1 as a checklist to explore how to make a human-centric project.

Table 4-1 Human factors needed to be considered in social innovation

☐ What is the setting of your 1m³ of City? What's the location and time. Why?
☐ What kind of social or natural phenomena are involved?
☐ What is the deep relationship behind these phenomena?
☐ Which group of social members are influenced by the phenomena above?
☐ What strategies or measures do you think can help them?
☐ How do your strategies or measures align with the Sustainable Development Goals?
☐ What techniques or tools do you use to implement the measures or strategies above? Why are they helpful?

The Stakeholder Map

You already completed the community file in Module I based on your analysis of the community or city. However, a community profile is not enough to reflect the needs of the local residents. You'll need to map the stakeholders to identify which groups of social members are influenced by your project and how they benefit from your social innovation.

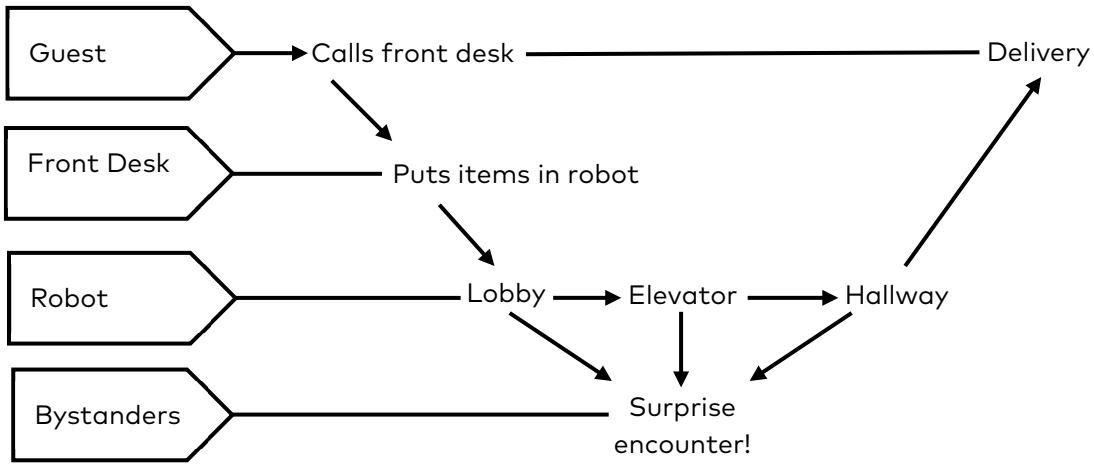


Figure 4-1 Stakeholder Map: Savioke's robot delivery map[1] (Source: Jake Knapp, et al., Sprint)

Figure 4-1 shows a sample stakeholder map. Now, follow the steps below to draw a stakeholder map for your project in Task 4-2:

List key stakeholders (on the left side): Key stakeholders could be a specific group of people that you want to help, or external members closely relating to the project (e.g. management staff of governments or social organizations). Key stakeholders don't have to be human sometimes: robots could be stakeholders as well, particularly when your project is AI-related (e.g. smart irrigation robot).

List expected outcomes (on the right side): Expected outcomes are your project goals. Keywords are fine.

Put keywords and arrows in the middle: Keywords are phrases or short sentences that Indicate factors enabling stakeholders to achieve the goals, including measures, resources, time, locations, possible negative or positive behaviors. **Arrows**

are short lines that link the left, center and right parts of the map in an orderly and logical manner.

Keep the map straightforward: You are not creating art work, so your map doesn't have to be much visually appealing. Being straightforward and efficient is your priority. Keep your steps or phases within 5-15 items. No more than 20 items.

When your stakeholder map is complete, invite external members (partners or your mentor) to give you suggestions. Refine your map based on their feedback.

Task 4-2 Map the stakeholders connecting to my project

Prototype Design

Draw your prototype design below. Think about (or mark out) the materials or tools required. Save it for later use when you have to pick up materials out of the Makerspace Kit.

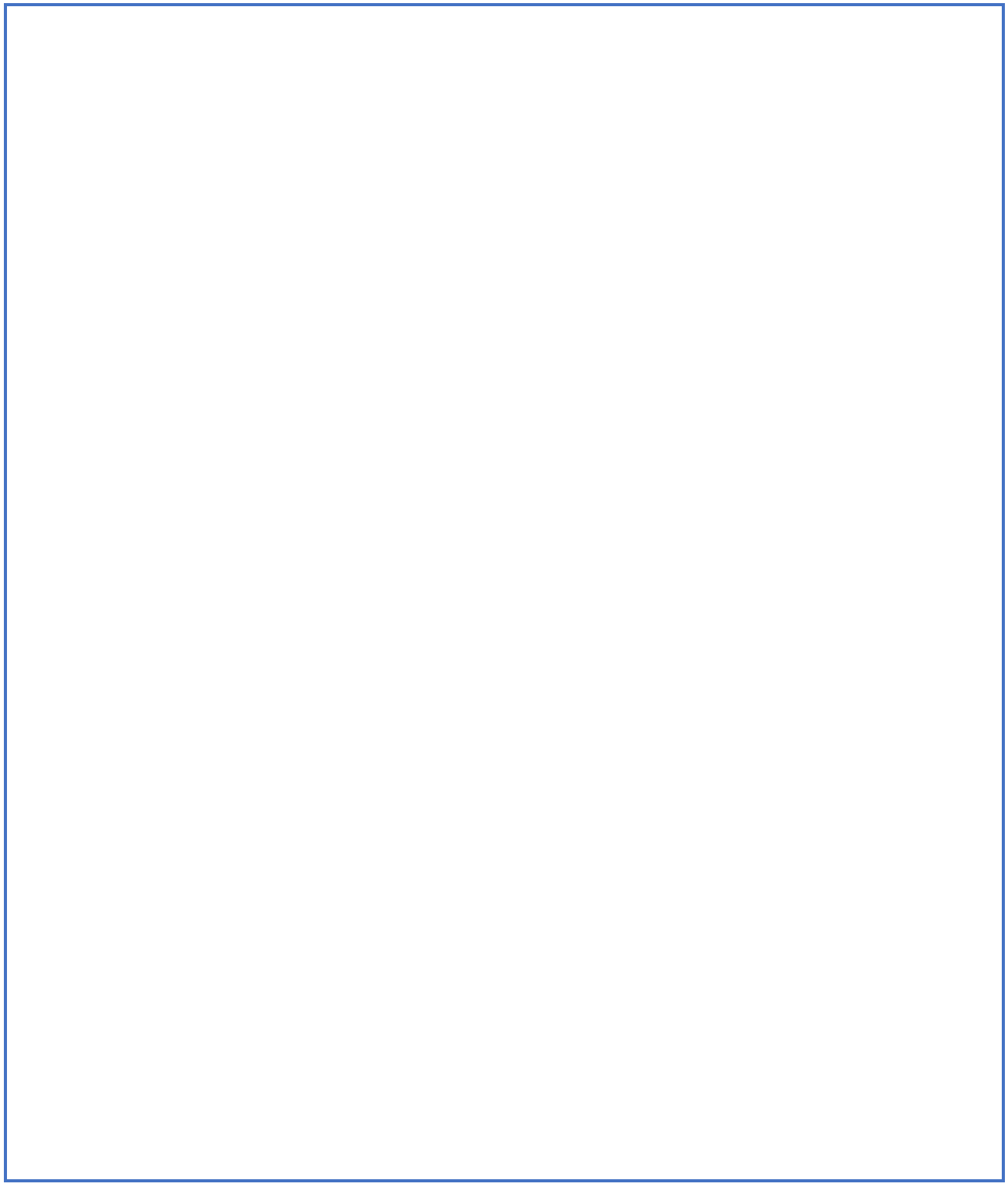
Mechanical Structure Design

Think more about what you expect the prototype to achieve. And decide what materials or tools to use for prototyping.

Intended Functionality	Equipment Required

Functionality Design

Draw your algorithm or program flowchart.



Testing and Iterating

Draw the prototype you finally developed. Invite at least 2 outside members and show them your prototype. Ask them to give you advice on how to improve it.

Draft of Initial Prototype:	
Comment 1:	**Comment 2:**

Iterate your prototype based on the feedback to ensure you've reached the best possible outcome. Draw your final prototype below. And briefly summarize in what aspects you improved the prototype and what strategies you applied to solve the problems.

Draft of Iterated Prototype:	
Previous prototype's issues:	**Modifications:**

Evaluation and Reflection

Capstone projects provide an inquiry-based approach to learning. By planning, implementing and reflecting on a social innovation project, you can obtain a deep understanding of SDGs, particularly of how to build a city for present and future generations. Meanwhile, you are exposed to many sustainability-related issues that you might find worth digging into. You could be like Greta E. Thunberg, the Swedish 15-years-old activist on climate change and global warming.

In the session below, you need to reflect on the whole process, from topic selection to project completion, and give a self-evaluation. Here are five criteria that help you evaluate the degree to which your project achieves the goal:

Table 4-2 Evaluation criteria for the Capstone Project

Criterion	Description	Level of Attainment
Innovation	Does the project promote sustainable practices in the community (or city) by effectively solving a domain-specific issue?	☆☆☆☆☆☆☆☆☆☆
Evidence:		
People-centric	Are the ultimate beneficiaries (individuals or organizations) of the project clearly specified?	☆☆☆☆☆☆☆☆☆☆
Evidence:		

Criterion	Description	Level of Attainment
Topic Selection	Is the topic selected based on real-world issues? Can the project be completed within the limited time and resources without sacrificing quality?	☆☆☆☆☆☆☆☆☆☆
Evidence:		
Coherence	Are the verbal and written descriptions of viewpoint clear? Are the descriptions well-organized and logically ordered?	☆☆☆☆☆☆☆☆☆☆
Evidence:		
Originality	Is the project independently completed? Are references properly cited?	☆☆☆☆☆☆☆☆☆☆
Evidence:		

Overall Comment:

Invite at least 2 classmates (or teachers) as external peer reviewers, your mentor for this course and teachers of other relevant disciplines to act as participants of the Model Habitat III or officials of the "UN-Habitat". Demonstrate your achievements and show your prototype design to the panel. Ask them to give comments and advice on your work in the table.

Table 4-3 Assessment

Hand out the copies of Table 4-4 to each member of the panel. Ask them to give scores and advice by referring to guidelines in **Table 4-4**.
Grading: 1 =**No Pass;** 3 = **Pass;** 5 = **High Pass**

Criteria	Grading	Comments & Advice
Research Question		
Literature Review		
Conceptualization		
Methodology		
Prototyping		
Originality		
Quality of Writing		
Oral Presentation		
Overall Grading		

Table 4-4 Notes on grading

Criteria	Grading	Descriptive Anchors
Research Question	**5**	Includes a clear description of one specific sustainability related issue, identifies gaps in scientific knowledge and/or provides strong justification for the current research study. Clarifies study question and, when relevant, provides clear defendable hypothesis.
	3	Research questions clearly articulated and sufficient background information included.
	1	Absence of a focused research question, or topic selected is outside of this course.
Literature Review	**5**	Identifies research and literature relating to project design, sustainable cities (or SDGs) and accurately summarizes and integrates the information. All references are properly cited.
	3	Cites major works and places them in context.
	1	Fails to cite or assimilate previous works.
Conceptualization	**5**	Shows understanding of the Urban Systems Model Approach, and interprets the Urban Resilience strategy in the prototype.
	3	Shows understanding of the Urban Systems Model, but lacks the application of the model.
	1	Theoretical framework (Urban Systems Model)) is lacking or is not clearly linked to the research problem (Urban Resilience).
Methodology	**5**	Demonstrates a clear understanding and proper use of methodology. Identifies relevant strengths and weaknesses of methods used.
	3	Shows understanding of the strengths of the methods used, but lacks sufficient knowledge of the weakness.
	1	The methodology is not appropriate for the project or not helpful for achieving the expected learning outcomes of the course.
Prototyping	**5**	The prototype intuitively simulates how the Urban Resilience mechanism reacts to specific disasters and risks.
	3	The prototype explains how the resilience mechanism of a city works, but not intuitively.
	1	The prototype is off-topic.
Originality	**5**	Clearly describes the advancement of knowledge or new insights on solving a sustainability related issue. Sophisticated discussion of implications of findings for outreach, theory, and research.
	3	Partially describes the advancement of knowledge or new insights on solving a sustainability related issue. But discussion of implications of findings for outreach, theory and research is lacking.
	1	Absence of new insights on solving a sustainability related issue. Or plagiarizes others' solutions.

Criteria	Grading	Descriptive Anchors
Quality of Writing	**5**	Ideas expressed with exceptional clarity, logic, and conciseness. Shows a solid understanding of the SDGs.
	3	Ideas and evidence expressed with logic. Shows understanding of the SDGs.
	1	Ideas and evidence are lacking. Significant parts difficult to understand, numerous errors. Repetition, poor organization of ideas, and poor writing hinders reader understanding.
Oral Presentation	**5**	Engaging, polished presentation with well-crafted slides that illustrate key points and emphasize conclusions.
	3	Solid presentation with coherent narrative and conclusions.
	1	Too much or too little detail, goals and directions not clear, the order of slides not logical; poor slides; or reads directly from many slides.

Extension V: Laser Cutting Technology and City Model

Proper spatial planning of a city to make it more livable is the most intuitive demonstration of how one understands the concept of $1m^3$ of Space in the Sustainable City.

We use a laser cutter or a 3D printer to design or develop a 3D city. Compared with plastic blocks and metal construction parts, laser cutting and 3D printing techniques empower people to achieve more possible results. Moreover, construction parts produced by laser cutting or 3D printing are used to build a city model that's more accurate and refined.

Figure 4-2 is part of a laser cut 3D sports center. Use a modeling software to draw a floor plan and scale the design proportionately. Then use a laser cutter to produce construction layers and pile the layers into a 3D sports center as shown below.

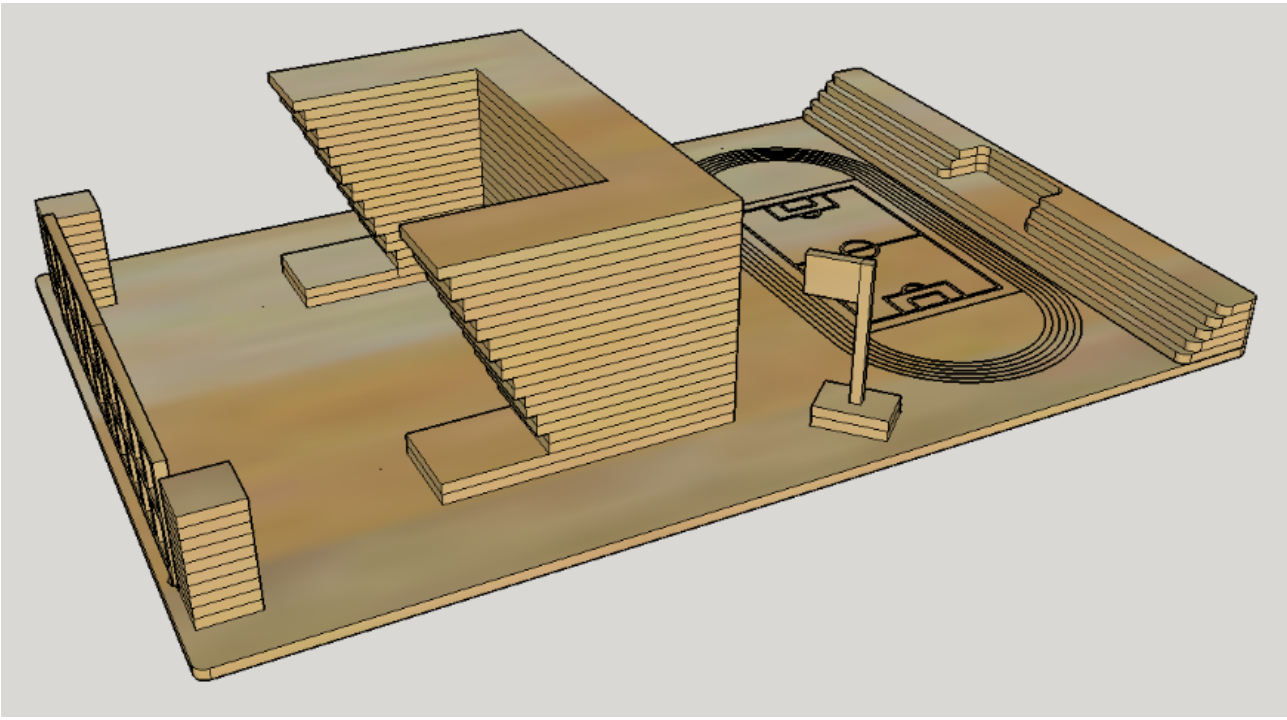


Figure 4-2 Sports center 3D Model

About the Sustainable Development Goal 17

A successful sustainable development agenda requires partnerships between governments, the private sector and civil society. These inclusive partnerships built upon principles and values, a shared vision, and shared goals that place people and the planet at the centre, are needed at the global, regional, national and local level.

Urgent action is needed to mobilize, redirect and unlock the transformative power of trillions of dollars of private resources to deliver on sustainable development objectives. Long-term investments, including foreign direct investment, are needed in critical sectors, especially in developing countries. These include sustainable energy, infrastructure and transport, as well as information and communications technologies. The public sector will need to set a clear direction. Review and monitoring frameworks, regulations and incentive structures that enable such investments must be retooled to attract investments and reinforce sustainable development. National oversight mechanisms such as supreme audit institutions and oversight functions by legislatures should be strengthened.

Source: UN, www.un.org/sustainabledevelopment/globalpartnerships

Facts and Figures

- Official development assistance stood at $146.6 billion in 2017. This represents a decrease of 0.6% in real terms over 2016.
- 79% of imports from developing countries enter developed countries duty-free.
- The debt burden on developing countries remains stable at about 3% of export revenue.
- The number of Internet users in Africa almost doubled in the past four years.
- 30% of the world's youth are digital natives, active online for at least five years.
- But more four billion people do not use the Internet, and 90% of them are from the developing world.

Source: UN, www.un.org/sustainabledevelopment/globalpartnerships

Goal 17 Targets

Finance

17.1 Strengthen domestic resource mobilization, including through international support to developing countries, to improve domestic capacity for tax and other revenue collection

17.2 Developed countries to implement fully their official development assistance commitments, including the commitment by many developed countries to achieve the target of 0.7 per cent of ODA/GNI to developing countries and 0.15 to 0.20 per cent of ODA/GNI to least developed countries ODA providers are encouraged to consider setting a target to provide at least 0.20 per cent of ODA/GNI to least developed countries

17.3 Mobilize additional financial resources for developing countries from multiple sources

17.4 Assist developing countries in attaining long-term debt sustainability through coordinated policies aimed at fostering debt financing, debt relief and debt restructuring, as appropriate, and address the external debt of highly indebted poor countries to reduce debt distress

17.5 Adopt and implement investment promotion regimes for least developed countries

Technology

17.6 Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism

17.7 Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed

17.8 Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology

Capacity Building

17.9 Enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the sustainable development goals, including through North-South, South-South and triangular cooperation

Trade

17.10 Promote a universal, rules-based, open, non-discriminatory and equitable multilateral trading system under the World Trade Organization, including through the conclusion of negotiations under its Doha Development Agenda

17.11 Significantly increase the exports of developing countries, in particular with a view to doubling the least developed countries' share of global exports by 2020

17.12 Realize timely implementation of duty-free and quota-free market access on a lasting basis for all least developed countries, consistent with World Trade Organization decisions, including by ensuring that preferential rules of origin applicable to imports from least developed countries are transparent and simple, and contribute to facilitating market access

Systemic Issues

Policy and institutional coherence

17.13 Enhance global macroeconomic stability, including through policy coordination and policy coherence

17.14 Enhance policy coherence for sustainable development

17.15 Respect each country's policy space and leadership to establish and implement policies for poverty eradication and sustainable development

Multi-stakeholder partnerships

17.16 Enhance the global partnership for sustainable development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial

resources, to support the achievement of the sustainable development goals in all countries, in particular developing countries

17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships

Data, monitoring and accountability

17.18 By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts

17.19 By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product, and support statistical capacity-building in developing countries

Source: UN, www.un.org/sustainabledevelopment/globalpartnerships

Notes

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Appendix I Glossary

Capstone Project is a multi-faceted project that serves as a culminating academic and intellectual experience for students, usually during the final academic semester or year. It can take various forms, typically interdisciplinary investigative projects that are linked with real-life problems in communities or society.

Community Profile is a comprehensive description of needs of community members and resources within the community. It requires the active involvement of the community for developing an action plan to improve the quality of life.

Crankshaft and Connecting Rod is a mechanism converting reciprocating motion of a piston from and to circling motion of a crankshaft.

Degree of Freedom refers to the minimum number of independent variables necessary to describe a state or property of a system.

Functional Resilience: It refers to the capability of any urban system to adapt and recover from hazards and crises.

Habitat III is short for the United Nations Conference on Housing and Sustainable Urban Development. It took place in Quito, Ecuador, from the 17th to the 20th of October. It has been the first UN Conference on Housing and Sustainable Urban Development since the approval of the *2030 Agenda for Sustainable Development*. The *New Urban Agenda* is one of the major fruits at the Habitat III.

Irrigation Efficiency (IE) is the ratio of the amount of water consumed by the crop to the amount of water supplied through irrigation (surface, sprinkler or drip irrigation).

New Urban Agenda was adopted at the Habitat III on October 20th, 2016. It was endorsed by the United Nations General Assembly. The agenda provides a conceptual framework for urban planning and management in sustainable urban development.

Organizational Resilience means the ability of an organization to anticipate, prepare for, respond and adapt to incremental change and sudden disruptions in order to survive and prosper.

Pilot Project (or pilot study) is research conducted for conceptualizing new initiatives and testing project ideas in initial small-scale implementation. It helps prove the viability and carry out concept principles.

Physical Resilience means capability to be sustainable in the phase of an extreme event occurrence while reconfiguring their physical configuration.

Productivity of Water (PW) is the ratio of output (physical, economic or social) to the amount of water depleted in producing the output.

Resilience is the process of adapting well in the face of adversity, trauma, tragedy, threats or significant sources of stress.

Spatial Resilience refers to flexibility in spatial plans, policies and land use management systems are accommodated to ensure sustainable livelihoods in communities most likely to suffer the impacts of economic and environmental shocks

Sponge Cities are urban systems that are designed to passively absorb, clean and use rainfall in an ecologically friendly way.

Stakeholders are persons or social groups that are involved or interested in a particular project, event, or issue.

Stakeholder Mapping is a process where people analyze, identify and discuss about the relationships among and interaction ways of relevant and interested parties of a project, event or issue.

Sustainable Consumption and Production is about promoting resource and energy efficiency, sustainable infrastructure, and providing access to basic services, green and decent jobs and a better quality of life for all.

Sustainable Development Goals (SDGs) are at the heart of the *2030 Agenda for Sustainable Development*. The Sustainable Development Goals are integrated from three dimensions: economic, social and environmental. The SDGs were

agreed on by the193 Member States of the United Nations at the Sustainable Development Summit on September 25th, 2015.

Theory U, or U Methodology, is an awareness-based method for system thinking, innovation and leadership proposed by C.Otto Scharmer.

Urban Lifeline Systems comprise critical infrastructure systems such as water, electricity, gas, heat, and transportation.

Urban Agriculture refers to the growing of plants and animals within or around cities. Urban agriculture needs to meet the residents' demands for agricultural byproducts and support the socio-economic services of the cities with existing land resources and production conditions.

Urban Resilience refers to the ability of any urban system to maintain continuity through natural disasters, technological hazards, socio-economic-political-cultural crisis while positively adapting and transforming towards sustainability. It can be understood across functional, spatial, physical and organizational scales.

Visual Thinking a method to convey abstract complex ideas and concepts with graphs, images and other forms of visual signs.

Water-saving Irrigation means to make efficient use of precipitation and irrigation water to deliver water to the crop in accordance with the required amount for crop growing and the local water resources while bringing the best economic, social and environmental performances from agriculture.

Appendix II Guide to the Model United Nations

The Model United Nations (MUN) is an education-purposed simulation of the UN General Assembly and its other multilateral bodies wherein students perform an ambassador role while holding multilateral conferences, discussing international affairs. MUN conferences are a platform where students practice and improve their 21st century skills, such as public speech, debating, drafting documents, negotiating and much more.

You are invited to a model UN Habitat III held in your school. Now you and your peers are delegates representing different countries or regions, and you need to make proposals to achieve the SDG 11.

The duration of a model conference might vary. It could be 1.5 to 2.5 hours, consecutive class periods or even a few days. You need to first contact a course instructor, after-class club mentor or student leader. Have a discussion with them about the conference agenda, setting and location.

The number of participants and the countries that they represent should depend on the agenda, size of the conference and other factors. Again, you need to contact the teaching staff responsible for MUN activities. The number of delegates from each participating country or region should be the same, and make sure that each participating country or region appoints at least 2 delegates to the conference. Moreover, the delegates from Ecuador (i.e. host country) and the country that you represent must attend the conference.

Prepare for the MUN

To thrive at the MUN, you and your team need to read, research and discuss a lot in the spare time.

First, you need to get two UN documents ready: *New Urban Agenda* (UN,2017) and *Habitat III Issue Papers 15–Urban Resilience* (UN, 2016). You can access them at the UN websites.

The following information may be helpful to prepare for the MUN:

(1) Learn about UN

Familiarize yourself with the structure of the United Nations. When you do this, you can learn which UN bodies or other multilateral committees are responsible for Habitat III. In this way, you will know which websites you should go to and what kind of information you need.

(2) Learn about the basics about your country

Research information about the country you will be representing in historical, cultural, social, economic and political aspects.

(3) Research the position of your country

To represent a country, you should be very familiar with its position on the issue that will be discussed at Habitat III. You can find out related information from international news. In addition, keep an open mind throughout the MUN conference. Remember that sovereign equality among countries is a fundamental principle of MUN conferences.

(4) Learn about your allies and opponents

In an international conference, a participating country would make allies with another country with the same interests to lead the progress of the conference, and push to agree on resolutions that are complied with their interests. Therefore, you need to research the position and national interest of your allies as well. Also, try to find out other countries that have similar positions or interests and learn about their basics. The information you collect may influence your choice and decision.

(5) Keep up with the latest news

Glance at the latest news about the Habitat III. You and your peers should not limit yourselves with the out-of-date visions and news, although the Habitat III took place in 2016. You need the latest facts, statistics and much more information to defend the position of your country and address the new challenges your country have faced or is facing.

(6) Learn about and modify the rules and agenda of the MUN

A model Habitat III conference is a variation of MUN, so it is complied with the fundamental principles and rules of MUN. However, you only need to go through the following procedures due to time limitation:

- Appoint a chairperson (You may invite a teacher to be the chairperson);
- Set the conference agenda, and go into details of what needs to be done in each session;
- Confirm the list of participating countries and issues to be discussed at the conference;
- Draft conference agenda and hand out to the delegates.

MUN Agenda

Below is a simplified and modified version of the MUN agenda. The conference is expected to last for 1.5 hours, excluding pre-conference unmoderated caucus is not included.

(1) Draft and Write Speech

Delegates need to get their speech ready before the conference. As soon as they receive the conference agenda, they should study the agenda and the said issues with peer delegates, and decide the position about the issues. Based on the decision, delegates need to prepare a speech. Each speaker will have a speaking time of no more than 5 minutes.

As soon as the speech is complete, delegates should inform the chairperson about the speech titles and 3 to 5 keywords. The chairperson will then record every speaker's speech titles and keywords, and determine the order of speakers in the conference. The order of speakers is based on the order that they turn in their speech titles and keywords.

The chairperson is responsible for collecting speech titles and keywords and generating a Speaker's List, which contains the order of speakers. The chairperson should hand out the Speaker's List to delegates from each participating country at

least a day before the model Habitat III. After receiving the Speaker's List and checking the titles and keywords on it, delegates are allowed to contact delegates from other participating countries that share similar or the same position, and make an alliance. Delegates are also allowed to have pre-conference unmoderated caucus to lobby delegates from other countries to support your position or change their positions.

(2) Opening Speech by Chairperson (5 minutes)

The chairperson announces the commencement of the conference and briefly introduces the issues to be discussed and Speaker's List.

(3) General Debate (40 minutes)

Delegates present the position of their countries and suggested actions towards certain topics. Generally, a delegate is allowed to speak only once for the same topic.

The chairperson should preside over the session, keeping the conference in order and direct speakers to follow the order in the Speaker's List. When the General Debate is considered closed, the chairperson should then announce the closure of this session and direct to move on to the next topic. Speakers are required to follow the order in the Speaker's List during the discussion of the next topic as well.

(4) Unmoderated Caucus (10 minutes)

A short break can take place after the General Debate session. During the break, delegates, again, are allowed to contact and lobby delegates from other countries to agree on some action.

(5) Draft Resolutions (10 minutes)

After the break, delegates can move on to discussing with peers or delegates from other participating countries to generate a resolution.

Delegates need to demonstrate their action plan for certain topics in their draft resolutions, stating the actions in accordance with their position and enumerating reasons for the suggested actions. Delegates are allowed to co-sponsor resolutions.

(6) Debate (20 minutes)

In this session, delegates wishing to speak should raise their hands and be called upon at the discretion of the chairperson. Delegates should present their draft resolutions only when they get permission to take the floor from the chairperson. When a delegate finishes speaking, the delegates against the draft resolution can raise hands to ask for permission to present their rebuttal. Any sponsor of the challenged draft resolution should respond to the rebuttals.

(7) Vote (10 minutes)

The chairperson shall start the Voting Procedure and all the draft resolutions shall be put to vote. Voting shall be done by delegates raising their hands. A simple majority or two-thirds majority is required to pass a draft resolution.

(8) Result Announcement by Chairperson (5 minutes)

The chairperson shall count and record all the passed resolutions and announce the result. Also, the chairperson shall re-state the main points in the passed resolutions.

Source: www.un.org/zh/cyberschoolbus/modelun

Learn more about the MUN:

(1) The Model United Nations website: www.model-unitednations.org/mun.html

(2) UNA-USA office website: www.unausa.org

The United Nations Association of the United States (UNA-USA) is a movement of Americans dedicated to supporting the United Nations. The UNA-USA is one of the influential MUN organization in the United States, as it represents the single largest network of advocates and supporters of the United Nations in the world.

(3) MUN Global website: www.munglobal.com

(4) Best Delegate Model United Nations website: www. bestdelegate.com

The Best Delegate Model United Nations is a good source for beginners to learn how to get started, which conferences to attend, how to prepare position papers, how to make and deliver speeches, how to write working papers, etc.

You could start, for instance, by reading this article, "*MUN Made Easy: 10 Things You Should Know Before Your First Conference*", to get a grasp of the fundamental rules and common issues.

(Available from: www.bestdelegate.com/mun-made-easy-10-things-you-should-know-before-your-first-conference-2)

Appendix III Brief Introduction to Me Auriga Control Board

Me Auriga's mainboard is an updated version of Orion and is equipped with multiple onboard sensors for temperature, sound intensity, a gyroscope, a buzzer driver; features a one-key power switch, wireless Bluetooth control and firmware upgrade capability, the original two red ports have been updated to four ports with the same functions; PORT5 is isolated only with serial communication function, so it cannot be used to update a program but only for communication. It is also compatible with USB serial port. PORT6 to PORT10 are compatible with dual-digital, simulation, 12C bus, unibus, and simulate serial port. Me Auriga has an encoder motor port, smart servo port and LED Ring Light Panel port (with power switch). The size of PCB is also enlarged.

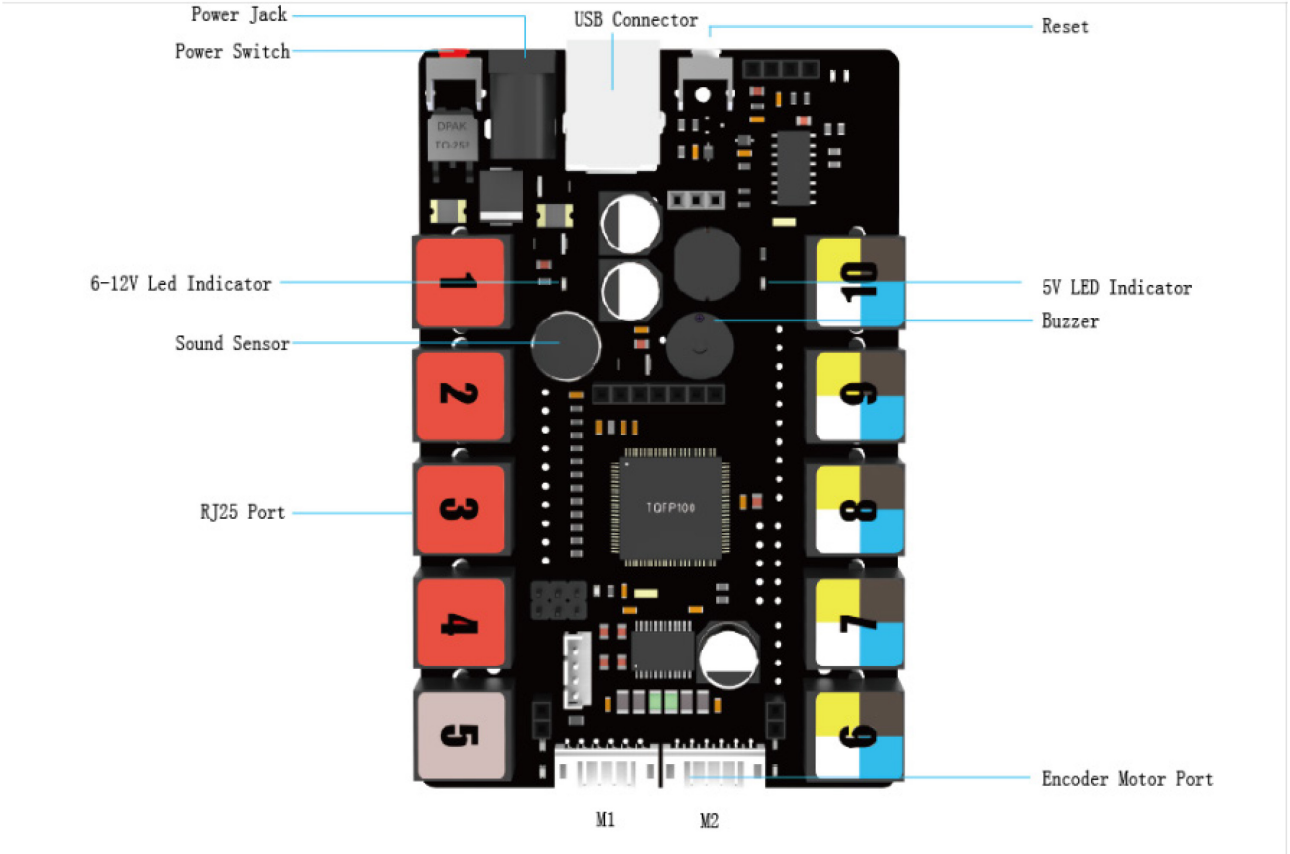


Figure 5-1 Me Auriga electronic parts

Introduction to Ports

Port Color	Compatible Module Types	Compatible Modules
	Motor driver modules (6-12V DC)	Dual Motor Driver Stepper Driver
	Hardware serial port	Bluetooth Module Raspberry Pi GPIO
	Single digital interface Dual digital interface I²C Port Single and dual analog interface	Me Ultrasonic Sensor RGB Module Limit Switch Module Nixie Tube IR Receiver Shutter Release Module Line-follower Sensor Gyro Sensor Potentiometer Sound Sensor Remote Control Module Humidity Sensor Flame Sensor

Features

- Supports DC motors, stepper motors, servo controllers, smart servos, encoder motors, etc
- Can drive two encoder motors and support over-current protection for 4A (instant).
- Supports Bluetooth and Bluetooth wireless upgrade firmware.
- One-key power switch to control the whole circuit.
- PORT5 – PORT10 support continuous 5V DC and 4A output (max 3A)
- PORT1 – PORT4 support continuous 3.5A output (max 5A)
- Onboard gyroscope, sound sensor, passive buzzer and temperature sensor.
- PORT5 –PORT10 have short-circuit protection and over-current protection for 3A.
- PORT1 –PORT4 have short-circuit protection and over-current protection for 3.5A.
- USB port with antistatic protection.
- Compatible with Arduino IDE.
- Compatible with RJ25 network port.
- Provides a dedicated library compatible with Arduino, a user-friendly interface which is powerful and easy to understand.
- Supports mBlock.

Appendix IV　Brief Introduction to mBlock

mBlock is a STEAM programming software tool designed for programming for kids. It is developed based on Scratch 3.0 and Arduino code.　It supports block-based and text-based programming languages.

mBlock also provides software programming services, software design services and maintenance of computer software services in the education of programming for those who want to promote their programming abilities.

With mBlock, children can not only create games and animations by dragging blocks or using Python code, but can also code robots or boards to do anything they can imagine. And mBlock exposes children to cutting-edge technologies, allowing children to create projects with technologies like AI and IoT. Moreover, in the mBlock Community, children are able to share projects and learn from the like-minded.

- **Based on Scratch 3.0,start programming easily**

Scratch is a programming tool developed by MIT and is credited as the most globally influential programming language for children. Based on Scratch 3.0 and Arduino code, mBlock is versatile and user-friendly enough to offer you whatever Scratch can give. And it's quite easy to pick up because you can code simply by dragging and dropping blocks.

- **Go to Python with one-click**

With mBlock, users can easily switch to Python with one-click. After students grasp how to program with blocks, they can effortlessly move on to Python. You don't have to switch between software because mBlock allows you to write code directly in its Python editor. The transition is just seamless.

- **A mix of software and robots makes it fun to learn coding**

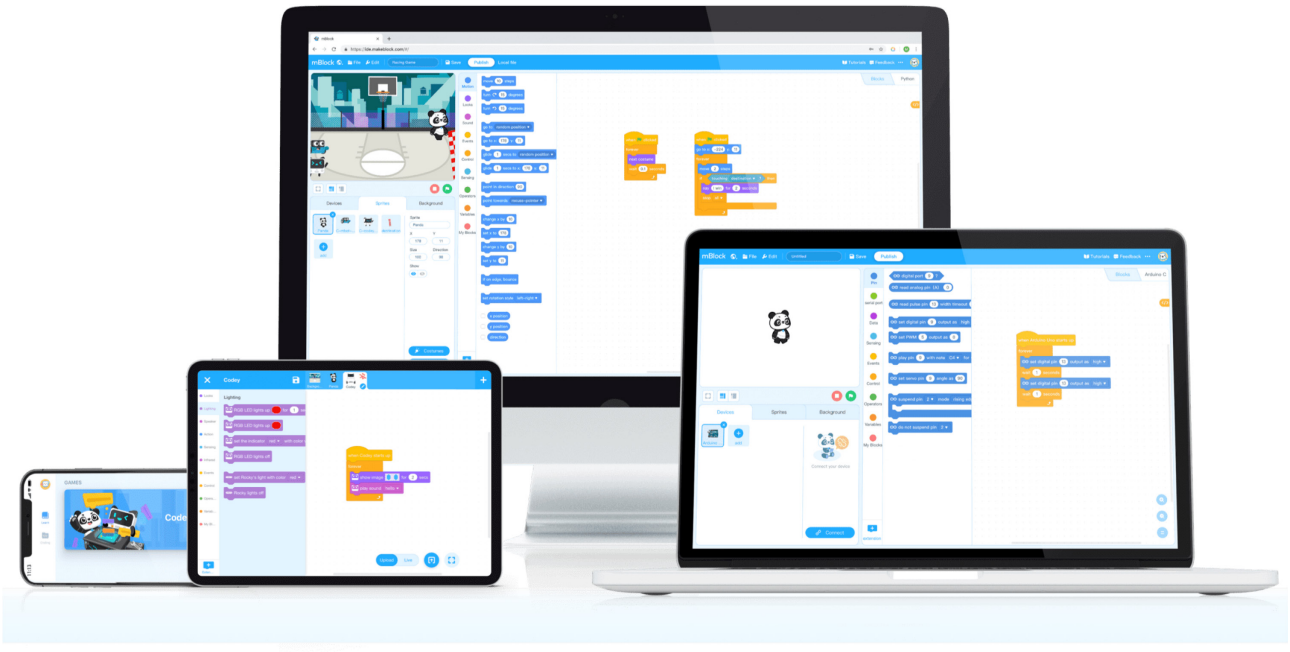
mBlock allows users to program robots to do anything they can imagine. By showing the outcomes of coding in the physical world, we attempt to keep students engaged in learning code and bring them senses of fulfillment. Also, mBlock brings diversity into classrooms because it has the power that enables educators and students to turn different ideas into reality.

- **Give your creativity an edge with cutting-edge technologies, like AI**

mBlock integrates Microsoft's cognitive services and Google deep learning into one tool. With these features, children can program to add more capabilities to mBlock, like age guessing or playing rock-paper-scissors games. We just hope to make it easier for children to master the fundamentals of AI.

- **Create in a physical world with IoT applications**

mBlock comes with the cloud service that is designed for IoT teaching. By working with robots or electronic modules, you can take advantage of the feature to create fun projects, like Weather Report, Autonomous Plant Watering Robot and Smart Lighting. For students, the best way to learn about IoT is to see how it works in real life.



Appendix V Assessment Form

Hand out the copies of this form to each member of the panel. Ask them to give scores and advice by referring to the guideline "Notes on grading" on the next page.

Grading: 1 =**No Pass;** 3 = **Pass;** 5 = **High Pass**

Criteria	Grading	Comments & Advice
Research Question		
Literature Review		
Conceptualization		
Methodology		
Prototyping		
Originality		
Quality of Writing		
Oral Presentation		
Overall Grading		

Notes on grading

Criteria	Grading	Descriptive Anchors
Research Question	5	Includes a clear description of one specific sustainability related issue, identifies gaps in scientific knowledge and/or provides strong justification for the current research study. Clarifies study question and, when relevant, provides clear defendable hypothesis.
	3	Research questions clearly articulated and sufficient background information included.
	1	Absence of a focused research question, or topic selected is outside of this course.
Literature Review	5	Identifies research and literature relating to project design, sustainable cities (or SDGs) and accurately summarizes and integrates the information. All references are properly cited.
	3	Cites major works and places them in context.
	1	Fails to cite or assimilate previous works.
Conceptualization	5	Shows understanding of the Urban Systems Model Approach, and interprets the Urban Resilience strategy in the prototype.
	3	Shows understanding of the Urban Systems Model, but lacks the application of the model.
	1	Theoretical framework (Urban Systems Model)) is lacking or is not clearly linked to the research problem (Urban Resilience).
Methodology	5	Demonstrates a clear understanding and proper use of methodology. Identifies relevant strengths and weaknesses of methods used.
	3	Shows understanding of the strengths of the methods used, but lacks sufficient knowledge of the weakness.
	1	The methodology is not appropriate for the project or not helpful for achieving the expected learning outcomes of the course.
Prototyping	5	The prototype intuitively simulates how the Urban Resilience mechanism reacts to specific disasters and risks.
	3	The prototype explains how the resilience mechanism of a city works, but not intuitively.
	1	The prototype is off-topic.
Originality	5	Clearly describes the advancement of knowledge or new insights on solving a sustainability related issue. Sophisticated discussion of implications of findings for outreach, theory, and research.
	3	Partially describes the advancement of knowledge or new insights on solving a sustainability related issue. But discussion of implications of findings for outreach, theory and research is lacking.
	1	Absence of new insights on solving a sustainability related issue. Or plagiarizes others' solutions.

Criteria	Grading	Descriptive Anchors
Quality of Writing	5	Ideas expressed with exceptional clarity, logic, and conciseness. Shows a solid understanding of the SDGs.
	3	Ideas and evidence expressed with logic. Shows understanding of the SDGs.
	1	Ideas and evidence are lacking. Significant parts difficult to understand, numerous errors. Repetition, poor organization of ideas, and poor writing hinders reader understanding.
Oral Presentation	5	Engaging, polished presentation with well-crafted slides that illustrate key points and emphasize conclusions.
	3	Solid presentation with coherent narrative and conclusions.
	1	Too much or too little detail, goals and directions not clear, the order of slides not logical; poor slides; or reads directly from many slides.

More Information and Support

About the Makespace toolsets:

www.makeblock.com/makerspace

About electronic modules in the Makespace toolsets:

www.makeblock.com/makerspace-2#electronic-modules

About structural parts in the Makespace toolsets:

www.makeblock.com/makerspace-2/#structural-parts

About transmission and motion parts in the Makespace toolsets:

www.makeblock.com/makerspace-2#transmission_motion-parts

About motors and actuators in the Makespace toolsets:

www.makeblock.com/makerspace-2#actuators

About storage products in the Makespace toolsets:

www.makeblock.com/makerspace-2#storage-products

About mBlock:

www.mblock.cc/en-us

For more teaching and learning materials:

education.makeblock.com

If you have any question, please feel free to contact us:

www.makeblock.com/support

Picture Sources

The Sustainable Development Goals logo and icons can be found on the UN's website: www.un.org/sustainabledevelopment/news/communications-material

Figure 3-1 "Where is earth water?" and Figure 3-2 "Amounts of Earth's water in comparison to the size of the Earth" come from the article *Earth's Water* on the website of U.S. Geological Survey. All the pictures in Earth's Water come from Igor Shiklomanov's *World Fresh Water Resources* (1993).

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