MIET2565 | MIET2566
Systems Engineering Principles

Introduction to Systems Engineering

RMIT UNIVERSITY

Introduction

- **Systems Perspective:** Understand and optimise complete system life cycles.
- **Requirements & Design:** Translate stakeholder needs into system architectures.
- **Integration:** Manage subsystems, interfaces, and interoperability.
- **Verification & Risk:** Apply validation and risk-management processes.
- **Lifecycle Tools:** Use modelling and analysis to guide system decisions.

Learning Outcomes

On successful completion of this course you will be able to:

2. **Manage** the concept, system design, engineering, and commissioning stages of system development
3. **Apply** a systems engineering approach to develop system requirements and function hierarchies for a complex system
4. **Design** innovative engineering solutions using systems engineering principles and approaches
5. **Present** comprehensive system design documents detailing user and system requirements
6. **Analyse** the performance parameters of a complex system
7. **Critically evaluate** the functions of a complex system, compiling the findings into a detailed analysis report
8. **Reflect** on systems engineering processes and synthesis of ideas to achieve project goals

Assessments

About this course:

- Total of 3 assessments

Tutorials are every week

For the tutorials:

- Attend the face-to-face tutorial session every week
- Think about your Assessments and start working early – don’t leave till the last minute
- Participation and collaboration is essential!

Assessments

Assessments will be reviewed in the tutorial later this week;

- Assessment 1: Individual report – week 5 (30%)
- Assessment 2: Group presentation – week 11 (30%)
- Assessment 3: Group report – week 13 (40%)

- All three tasks form a progressive project for the engineering task of a battery swap system for electric motorcycles

- Assignment details have been released. Please make sure you review these as soon as possible.

Course Overview

- **Topic 1** – Introduction to System Engineering
- **Topic 2** – User Requirements
- **Topic 3** – System Requirements
- **Topic 4** – High Level Design
- **Topic 5** – Functional Flow
- **Topic 6** – Functional Analysis
- **Topic 7** – Model-Based System Analysis
- **Topic 8** – Detail Design
- **Topic 9** – System Engineering Management Plan
- **Topic 10** – System Verification and Validation

What is the difference between scientists and engineers ?

Scientists discover the world.

Engineers create the world (using knowledge of science).

By designing and building systems

What does this system do?

Ferrari Monza SP1

Ferrari Monza SP1 – system capabilities

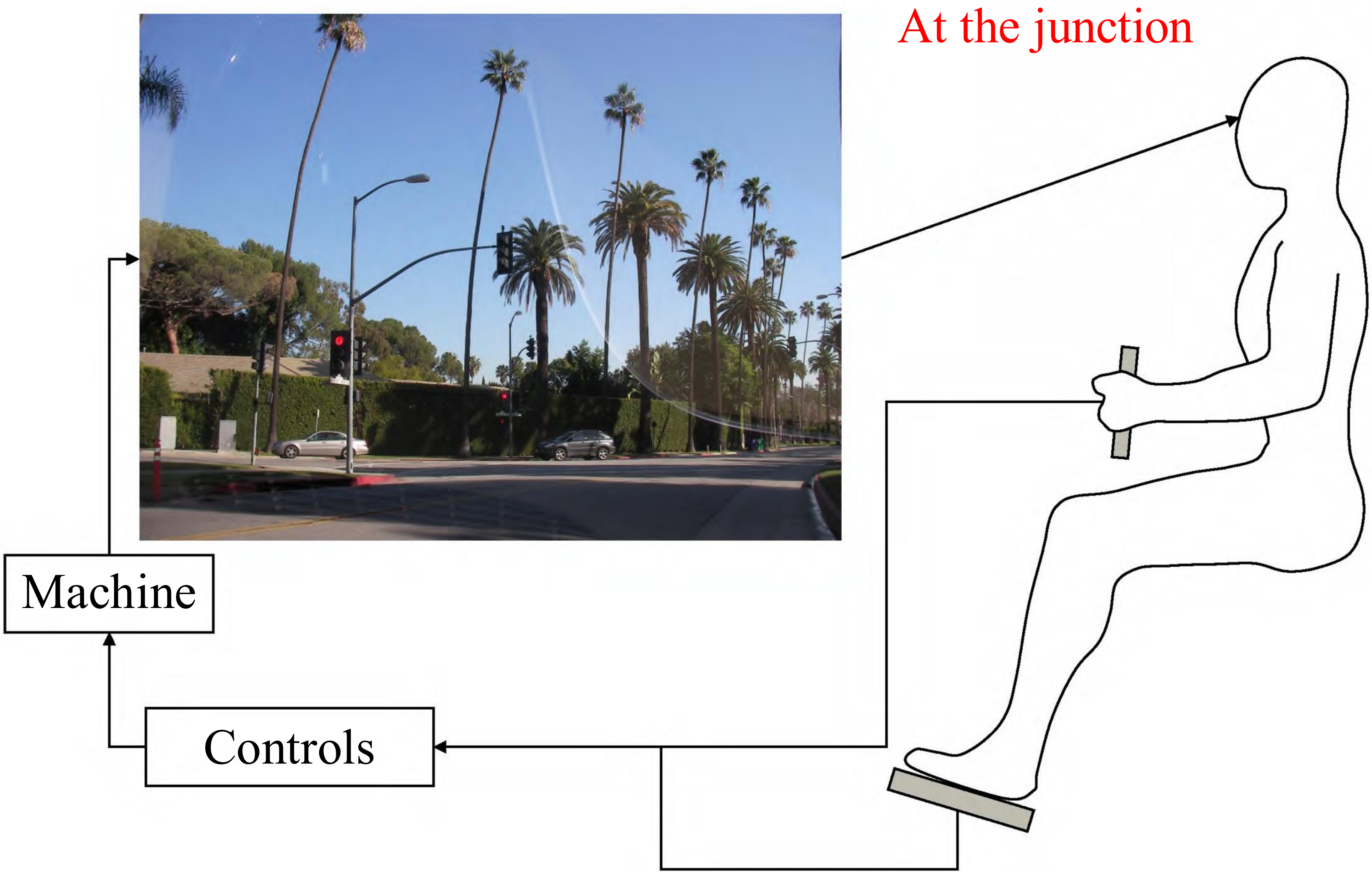
- Transport on roads
- Change direction
- Change speed
- Carry two people
- Protect passengers
- One person driving (i.e. managing steering, braking, decelerating, signalling)
- Aesthetically appealing

Crawford House Carriage

Crawford House Carriage – system capabilities

- Transport on roads – yes
- Change direction – need more inputs
- Change speed – need more inputs
- Carry two people – yes, can carry more people
- Protect (partially) passengers – yes, only passengers inside the carriage. Driver and attendant are not protected
- One person driving (i.e. managing steering, accelerating, braking, signalling) – yes
- Attractive – yes

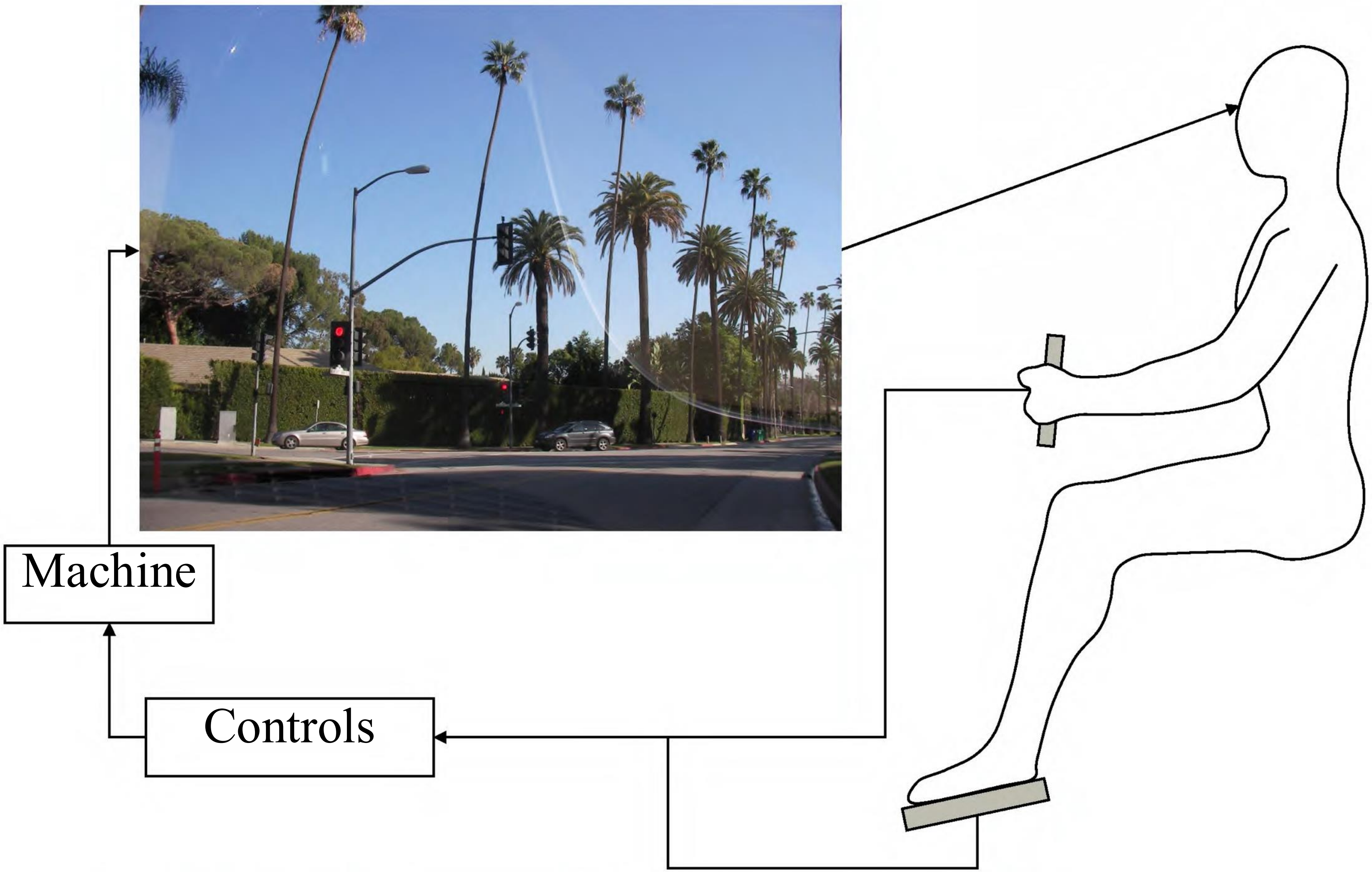
Modern systems are complex



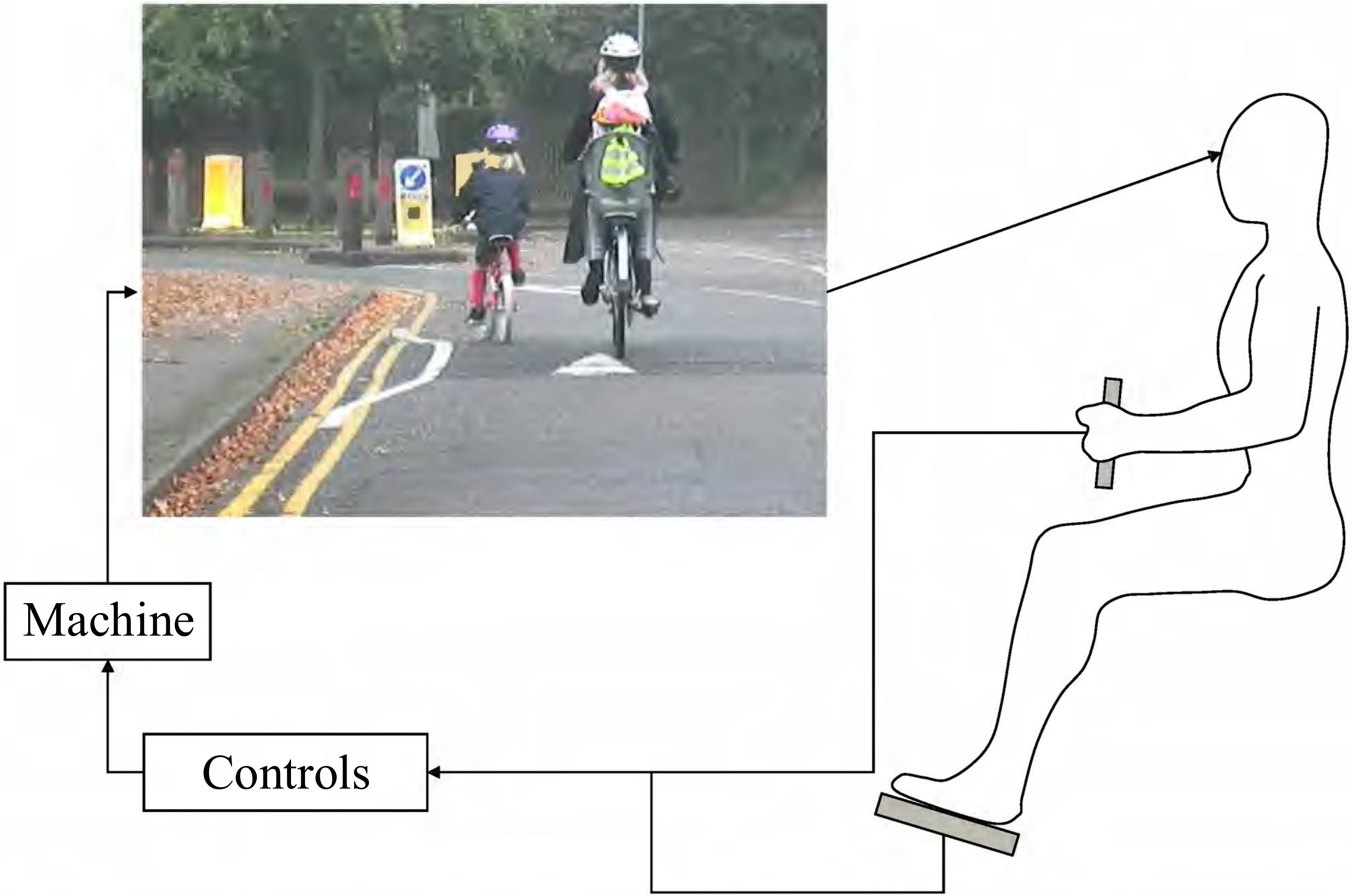
Principles of systems engineering observed

1. Systems are created for specified purposes
2. Systems have users

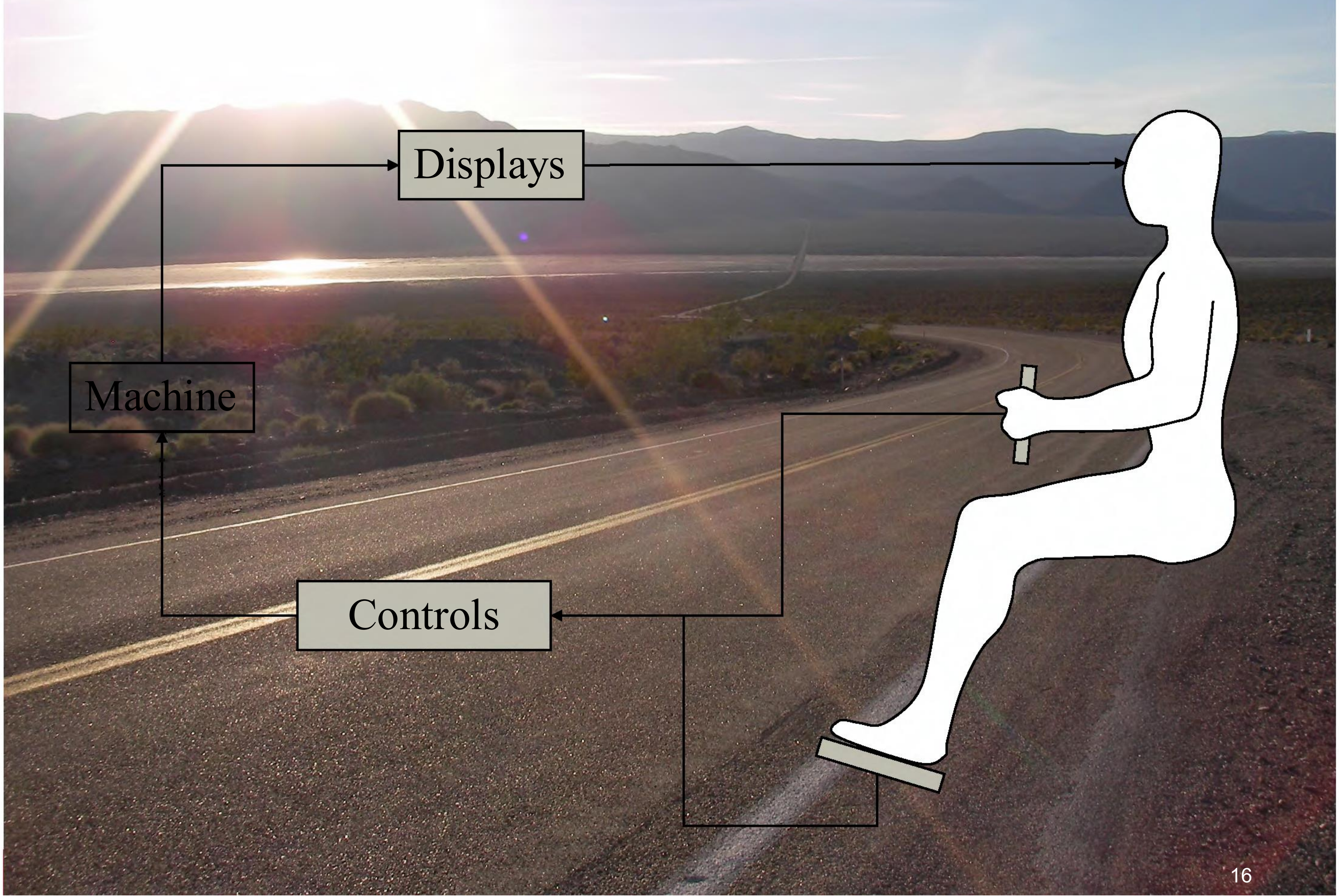
Interactions



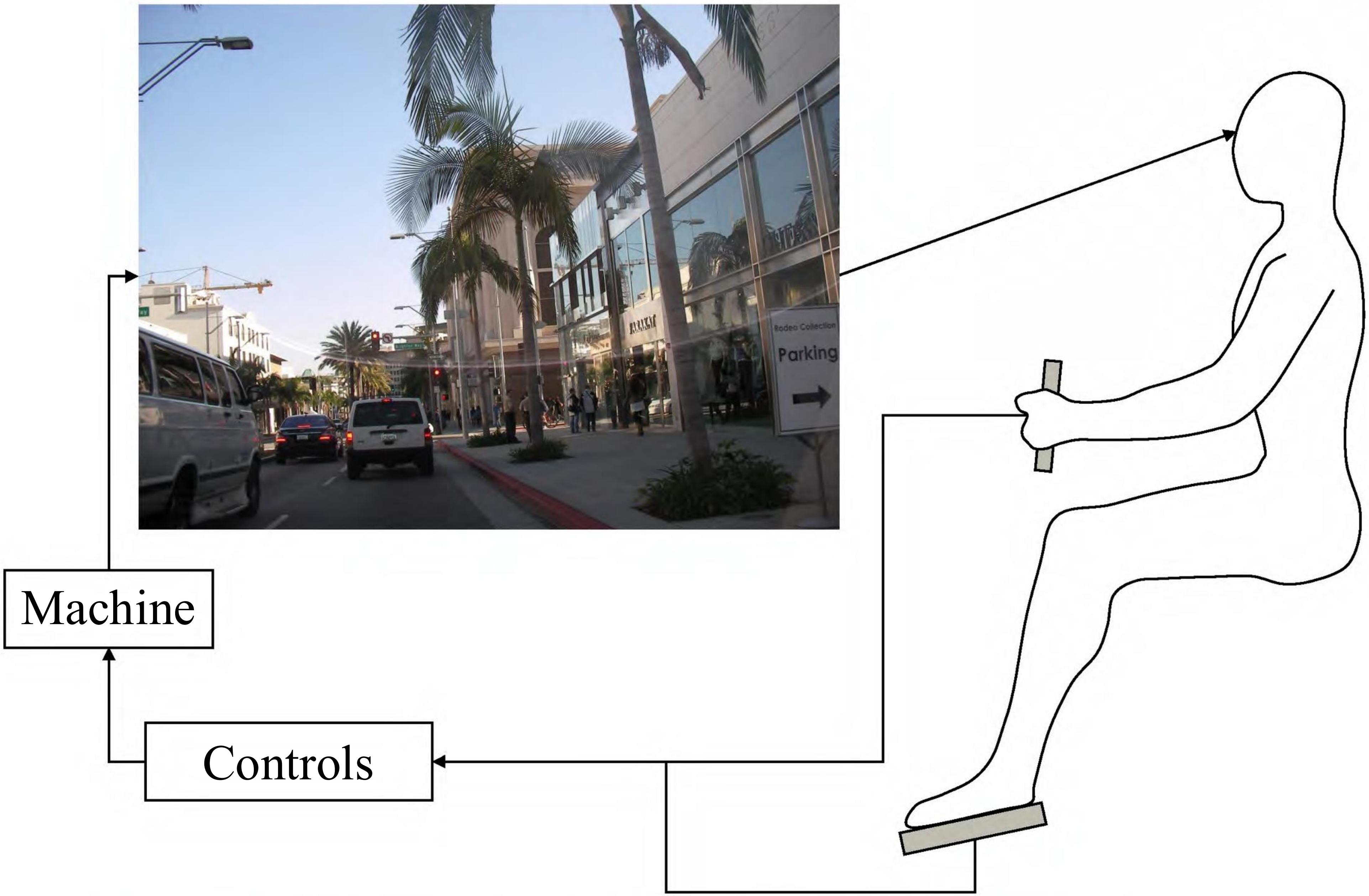
Traffic Conditions Vary – different types of road users



Environment



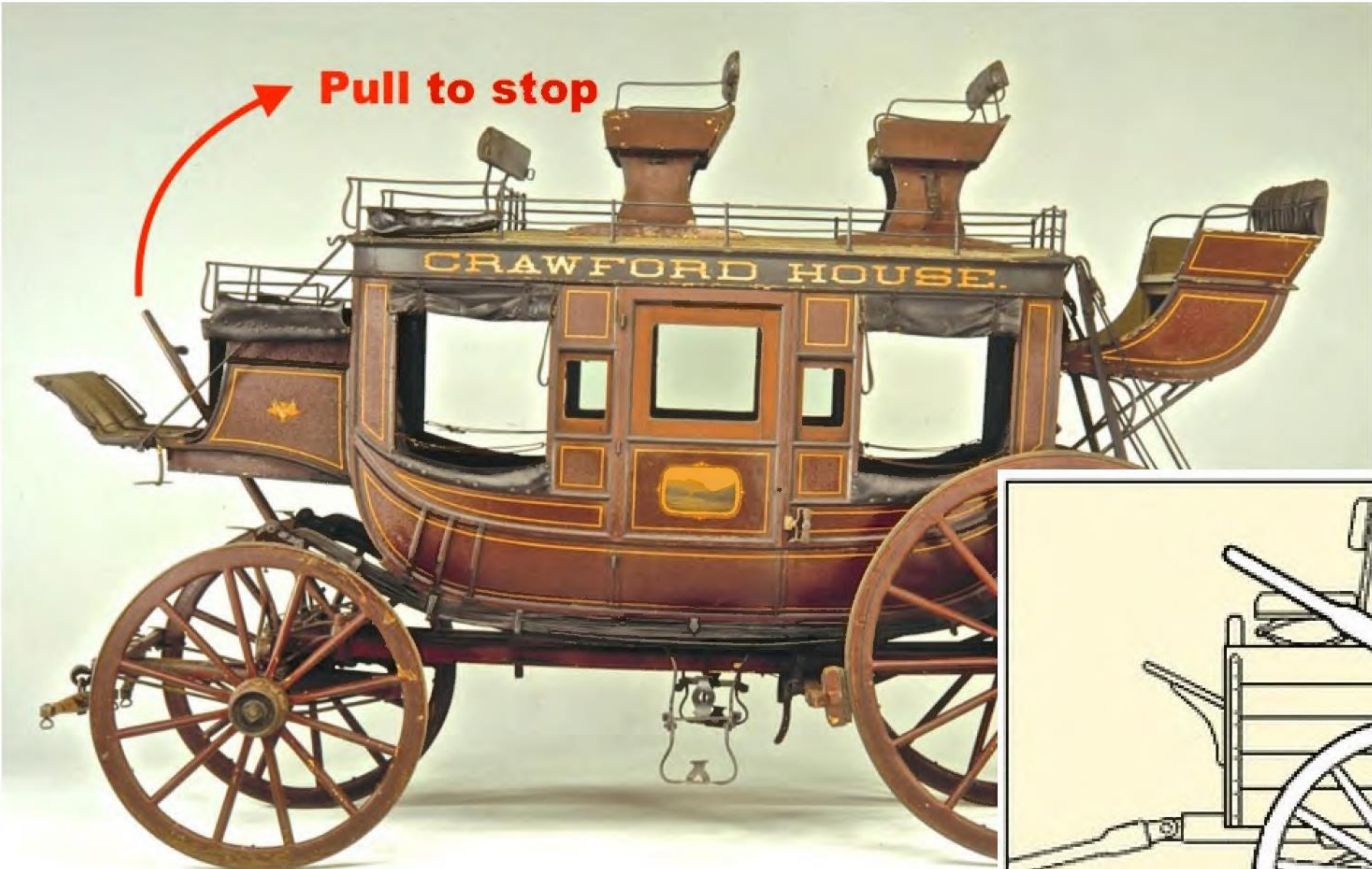
Traffic Conditions Vary – Street conditions

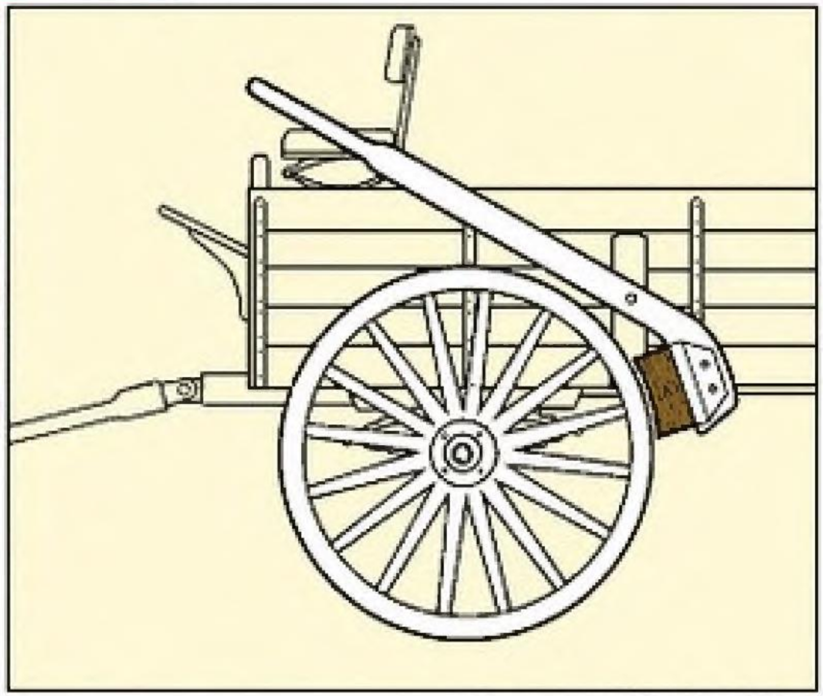


Principles of systems engineering observed

1. Systems are created for specified purposes
2. Systems have users
3. Systems interact with the environment around it
4. System boundary should be clearly defined

Braking system of the Crawford House Carriage

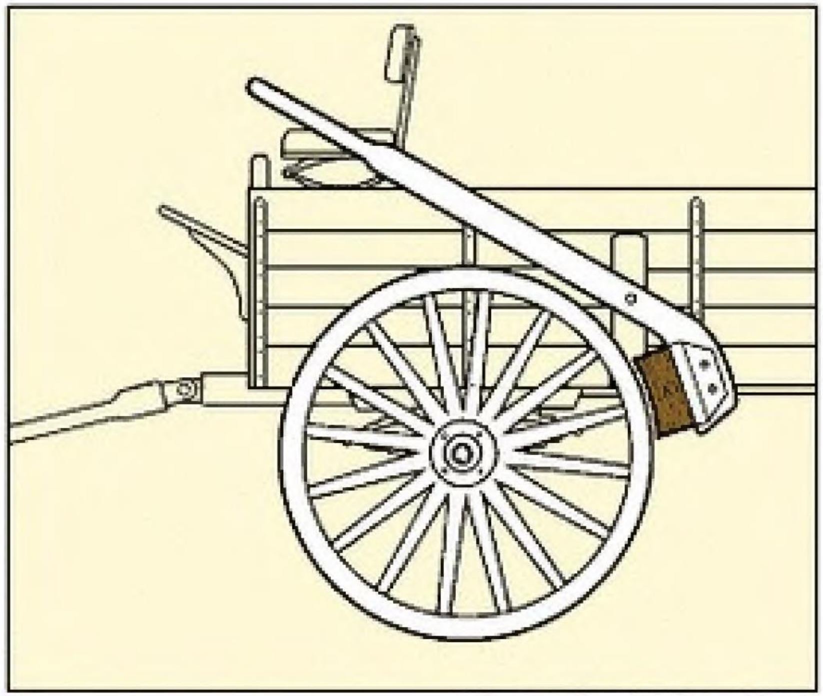




The wooden block and lever

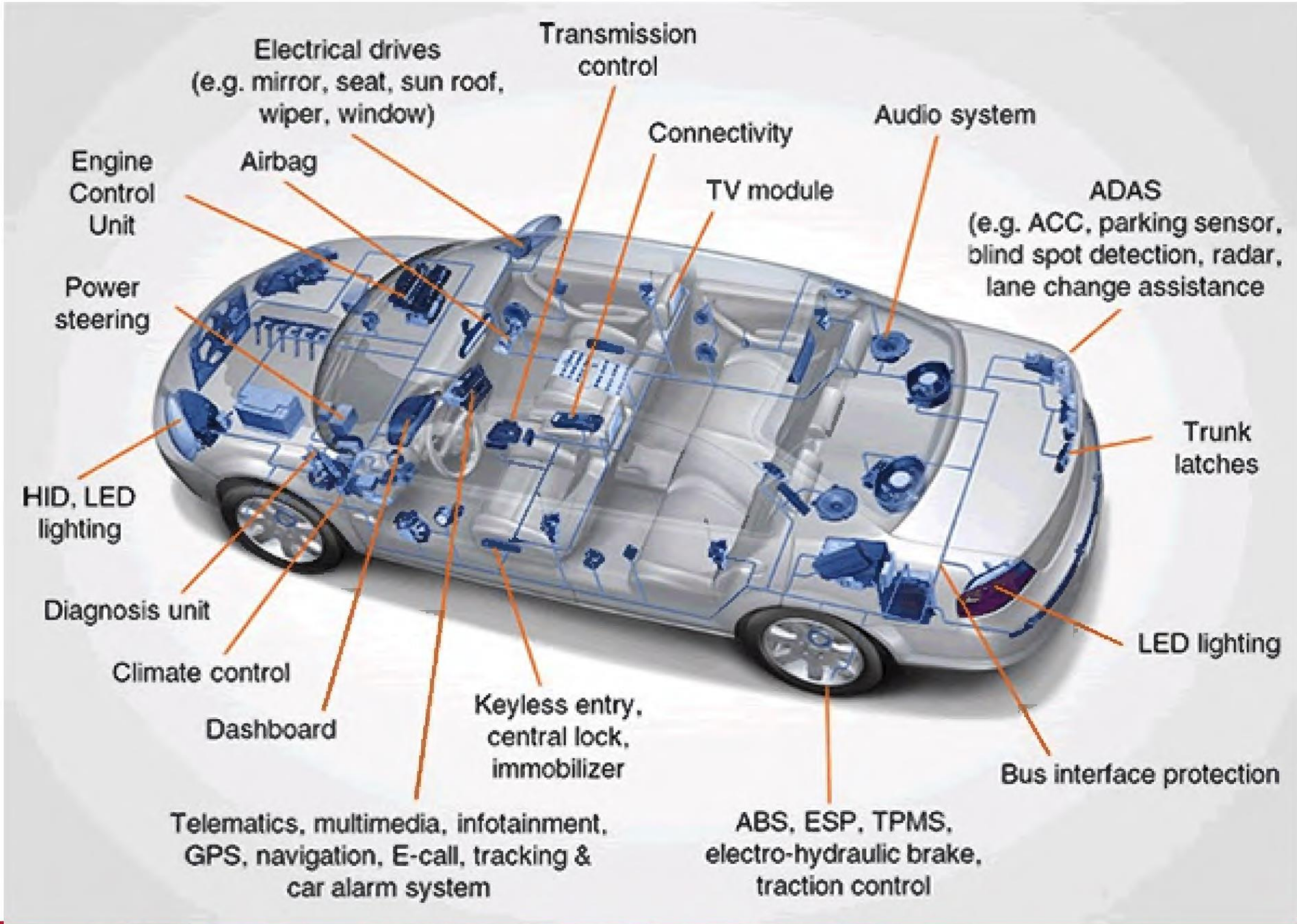
Engineering principles in horse carriage brake system

- Friction between rotating and fixed (on carriage) components
- Force enlarged by mechanical leverage
- Position of force application located at driver's convenience
- Brake effect proportional to force applied

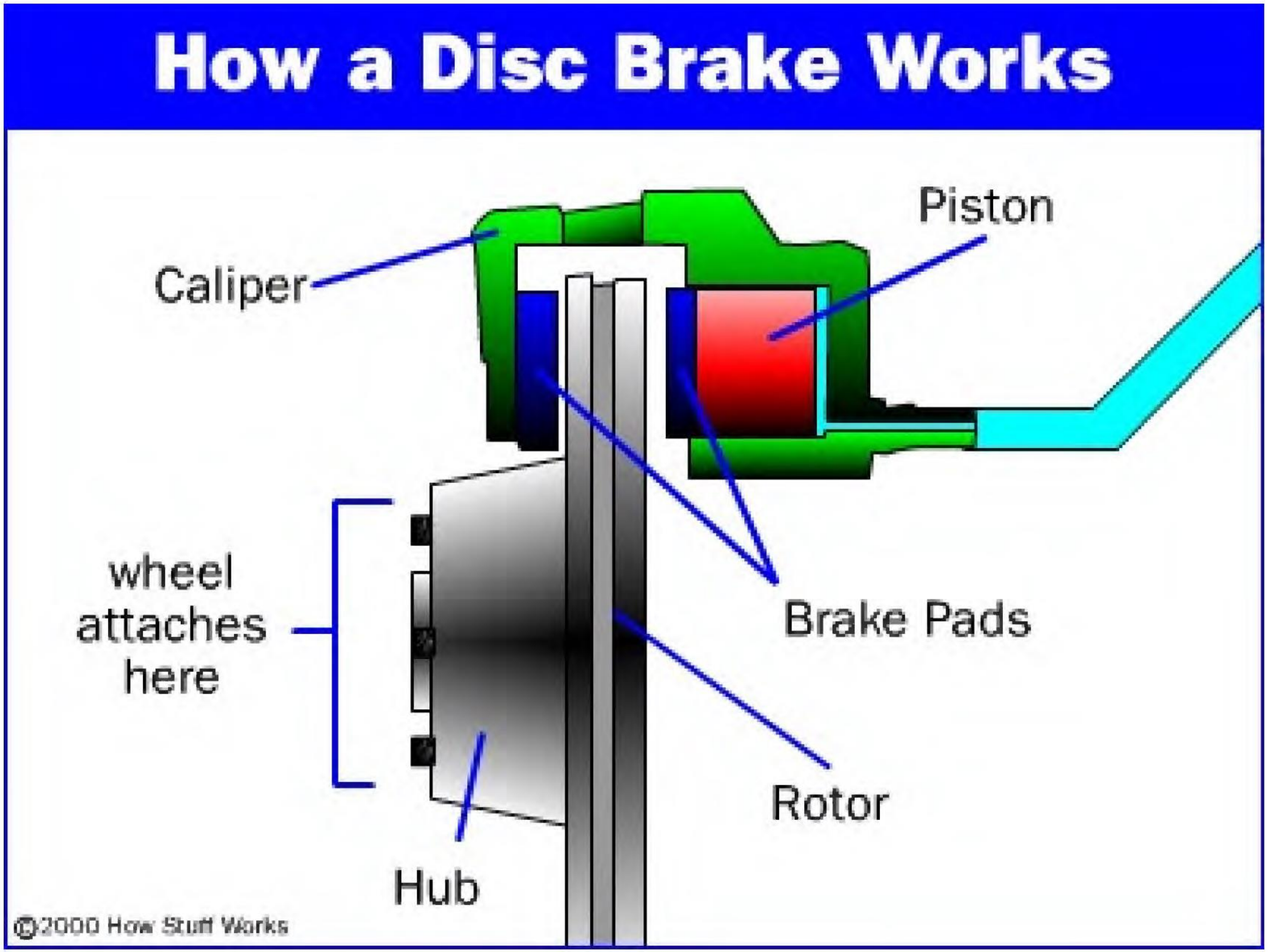


The wooden block and lever

Components of a car

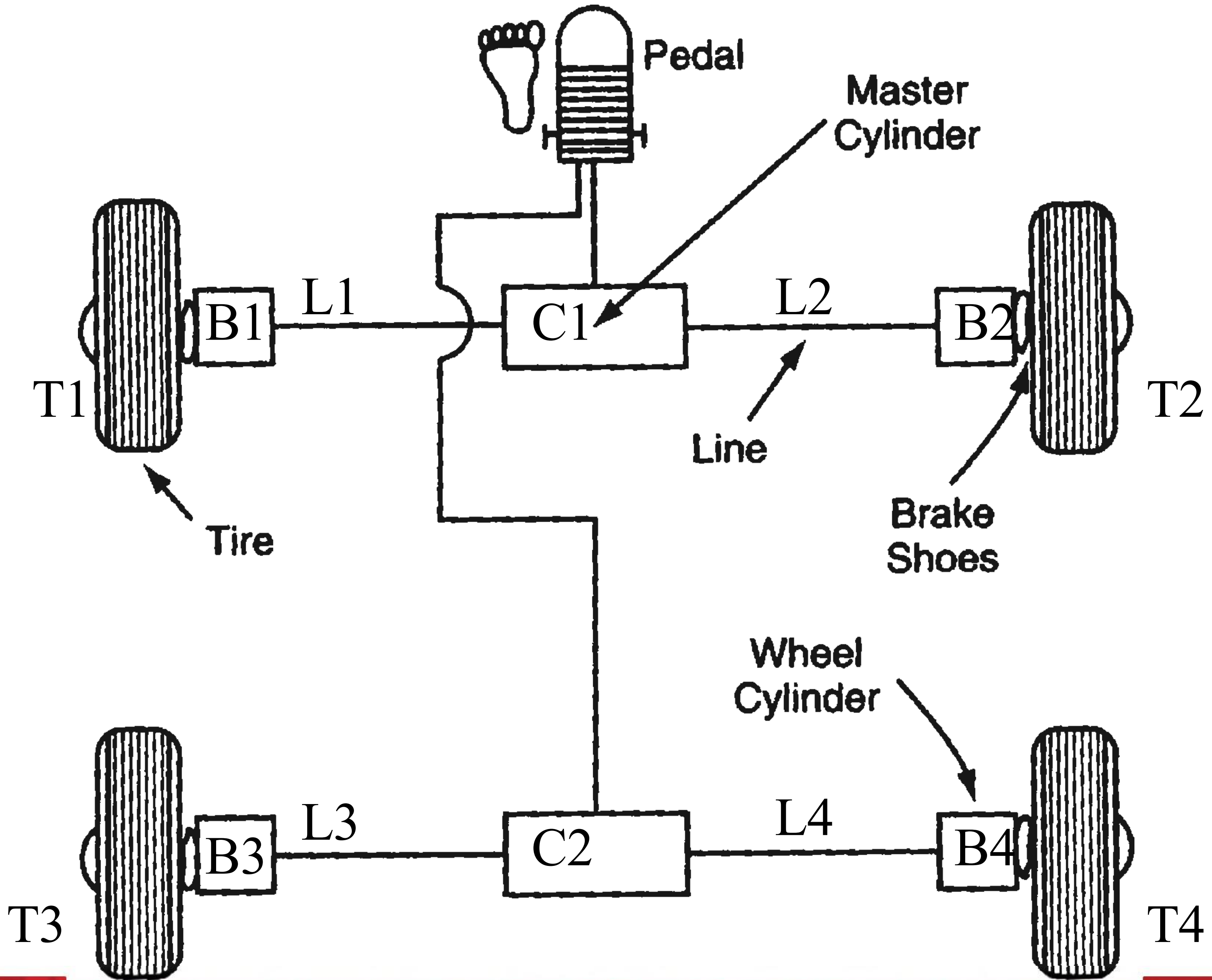


Brake – Designed to stop the vehicle



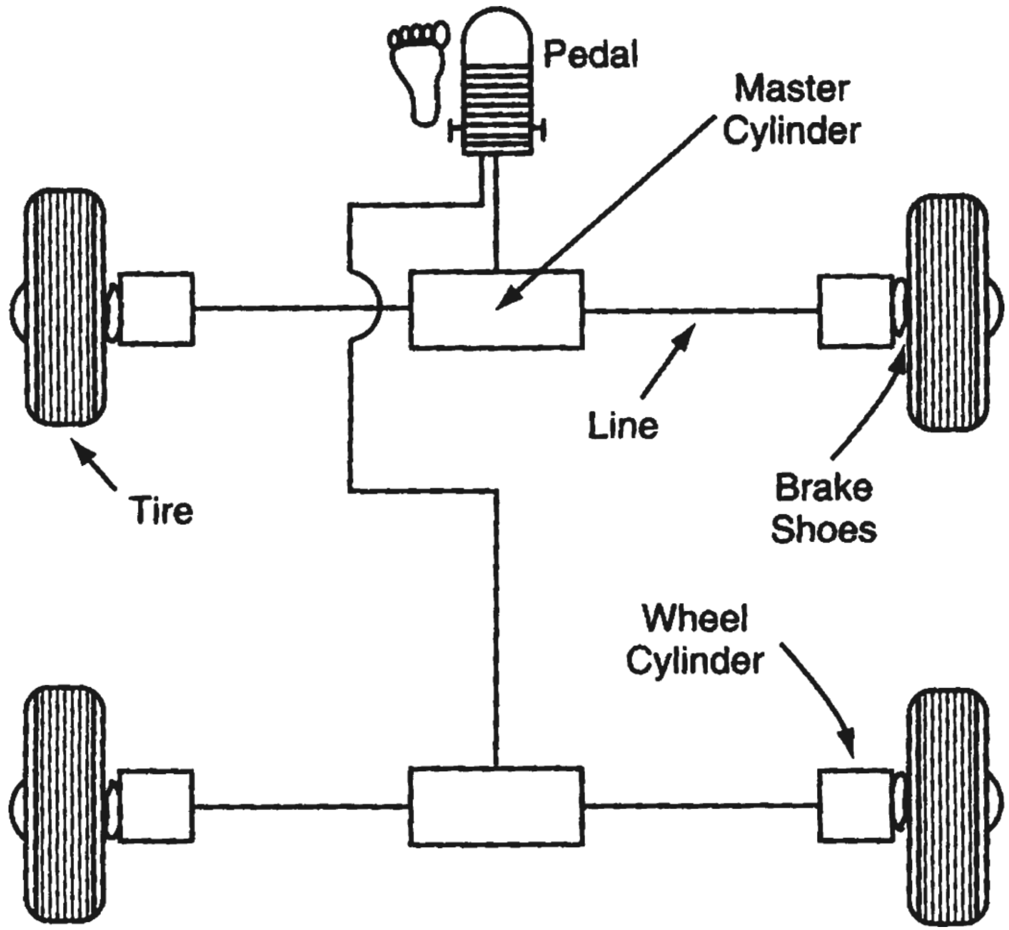
Pictures from http://auto.howstuffworks.com/brake3.htm

Braking System – a part of the automotive system



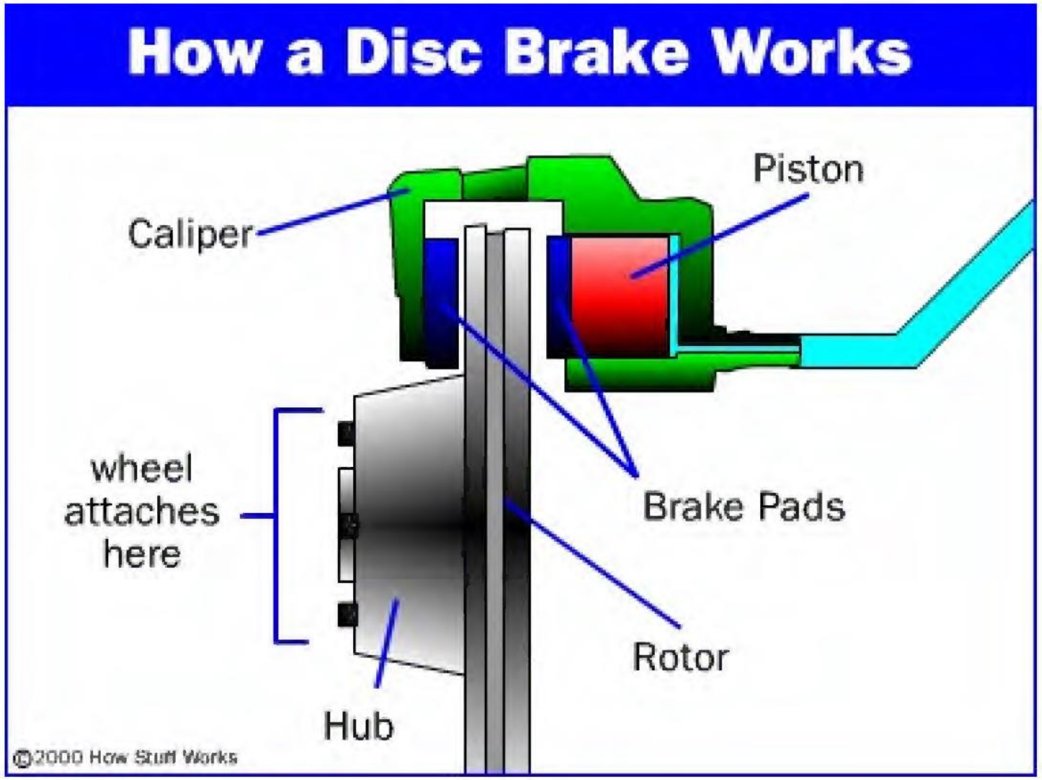
Engineering principles used in brake system in vehicles

- Pressure transmission through hydraulic – evenly distributed
- Balanced braking
- Braking force proportional to force exerted by foot
- Tyre friction on ground
- Redundancy



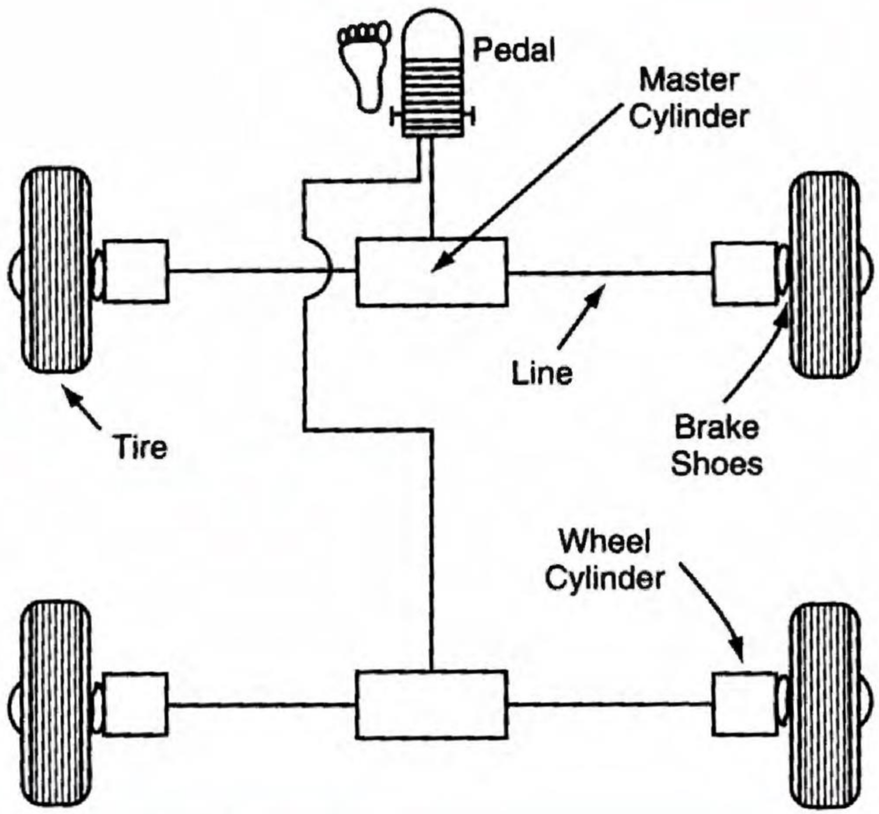
Brake component design of modern cars

- Friction pads
- Rotor (disc)
- Caliper (clamp)
- Hub (shaft)
- Hydraulic system to provide mechanical advantage
  - –Hydraulic oil
  - –Piston
  - –Oil conduit
  - –Brake cylinder



Engineering science applied in brakes of modern cars

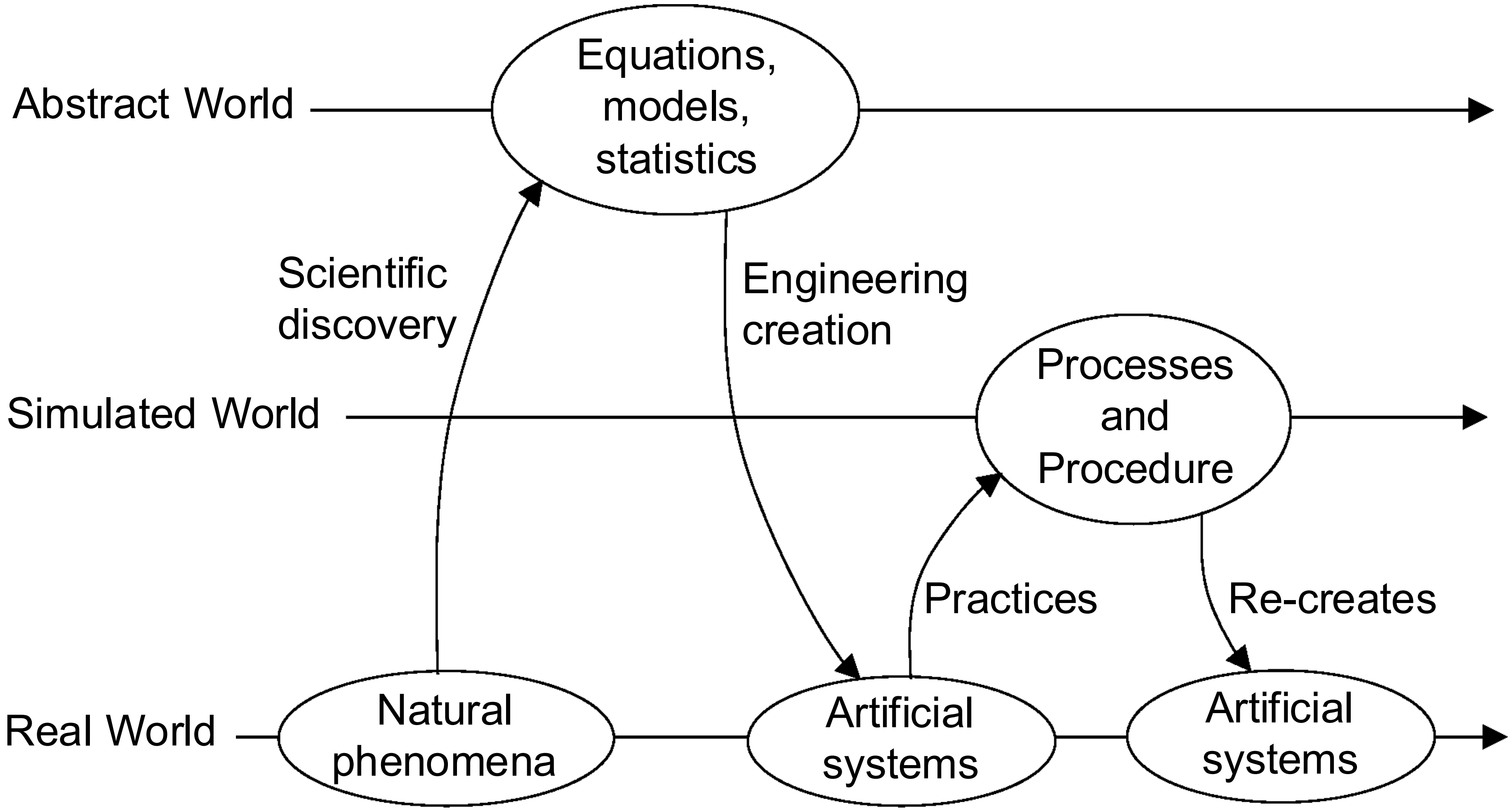
1. Friction between rotating and fixed (on the car) components
2. Force enlarged by mechanical leverage (hydraulic piston)
3. Position of force application located at driver's convenience (foot)
4. Brake effect proportional to force applied (piston distance travelled)



Principles of systems engineering observed

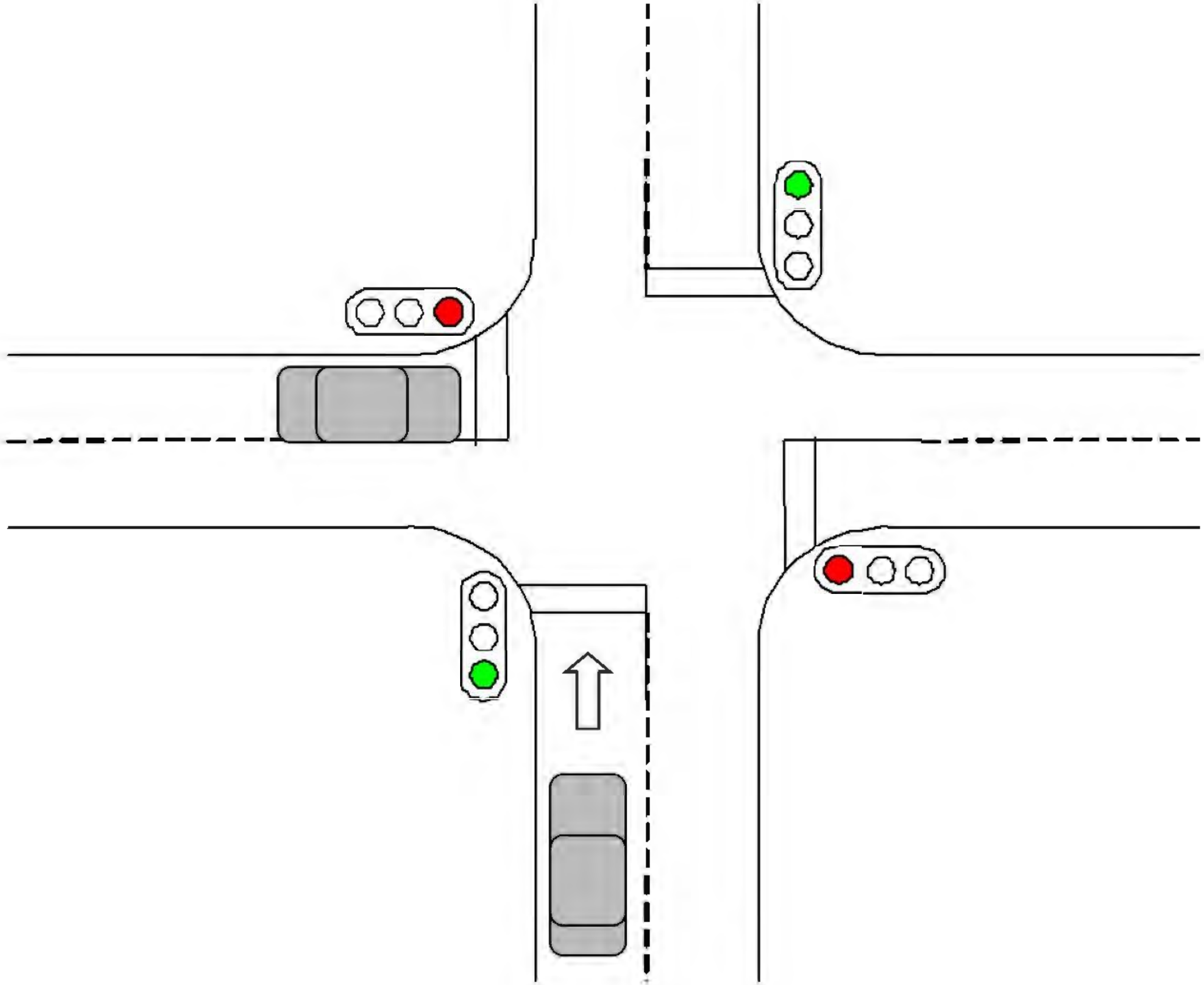
1. Systems are created for specified purposes
2. Systems have users
3. Systems interact with the environment around it
4. System boundary should be clearly defined
5. Systems are made by integrating components

Engineering to create systems



- Creation and application of information
- Fulfilment of human needs/desires
- Control use of resources

The Traffic Light – A system to control traffic at a junction



Components of a traffic light system

- Light posts
- Red, yellow and green lights
- Light sequence control (sub-system)
- Wiring
- Power

Engineering Design (from nature's principles) for the Traffic Light System

Brake distance required

Initial Speed = v_0

Deceleration rate = f

Deceleration force = F

Mass = m

Braking distance = x

$$v = v_0 - ft$$

$$v = v_0 - \left(\frac{F}{m}\right) \mathrm{t}$$

$$\mathrm{t} = \frac{m}{\mathrm{F}}(\mathrm{v} - \mathrm{v}_0)$$

Since v = 0 m/s.

$$\mathrm{t} = \frac{m}{\mathrm{F}} \mathrm{v}_0$$

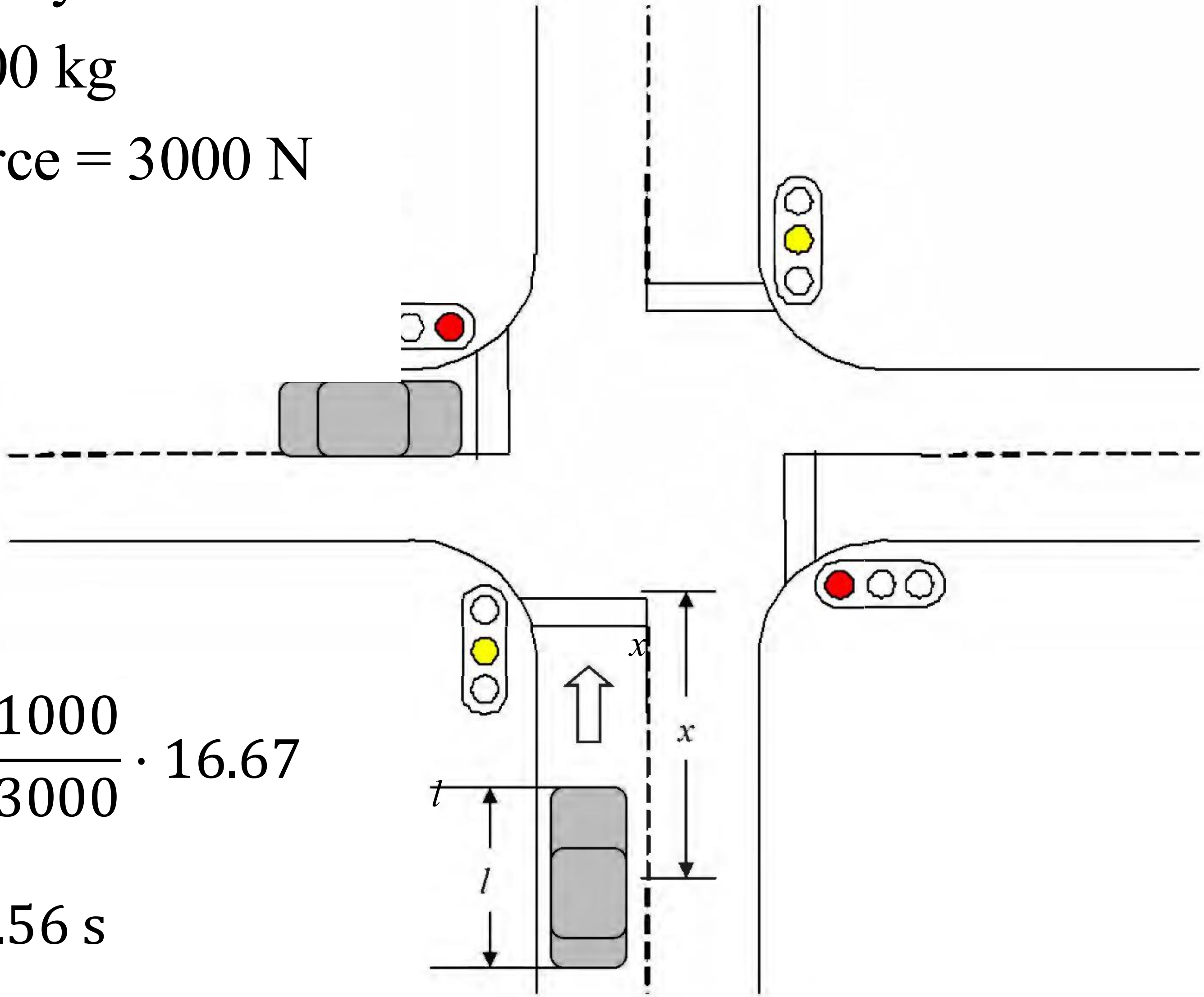
We are interested in the braking time (coming to a complete stop)

Car Approaching

Initial velocity = 60 km/h

Mass = 1000 kg

Braking force = 3000 N



$$t = \frac{m}{F} v_0 = \frac{1000}{3000} \cdot 16.67$$

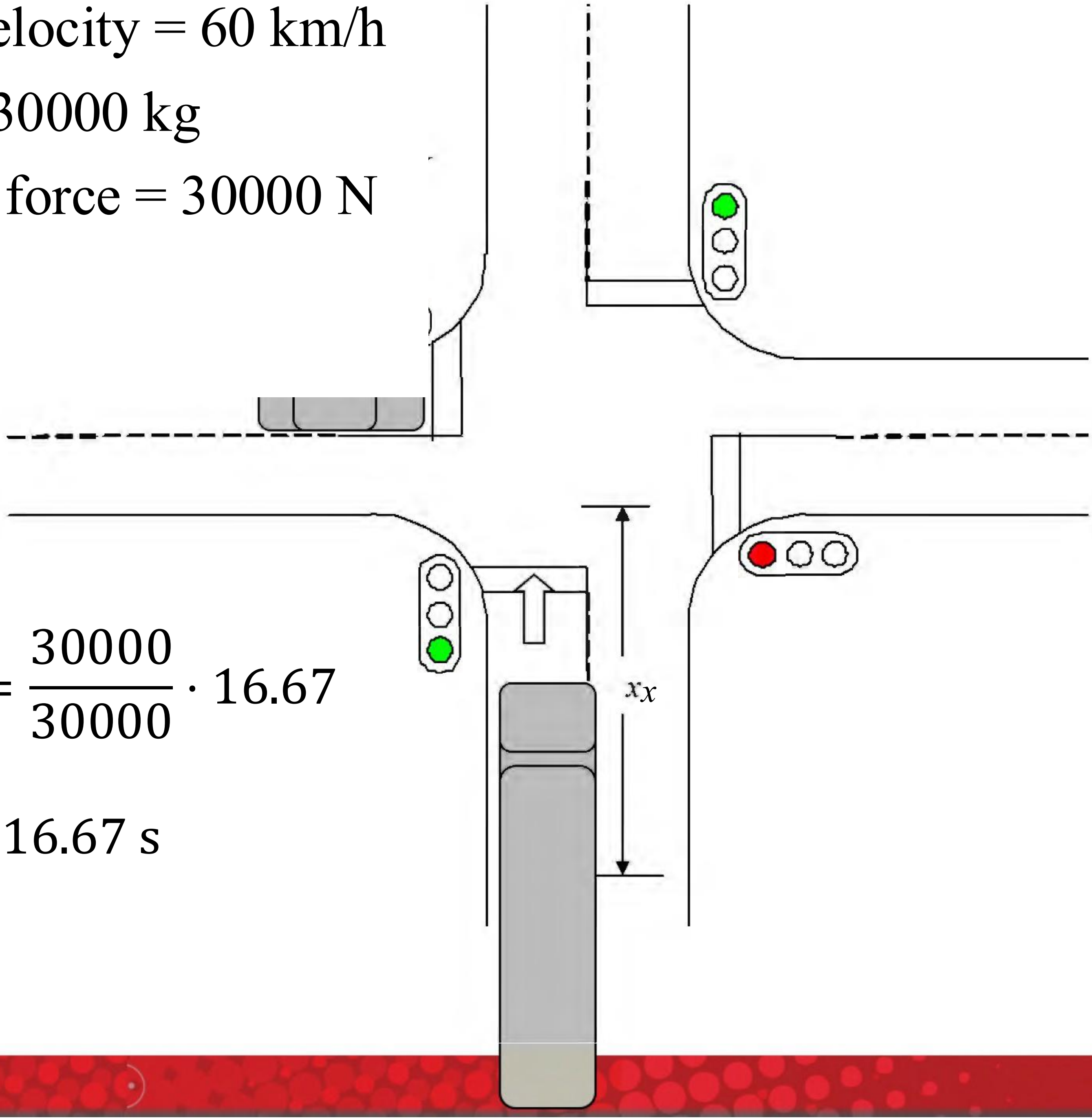
$$= 5.56 \text{ s}$$

Truck Approaching

Initial velocity = 60 km/h

Mass = 30000 kg

Braking force = 30000 N



$$t = \frac{m}{F} v_0 = \frac{30000}{30000} \cdot 16.67$$

$$= 16.67\ s$$

Principles of systems engineering observed

1. Systems are created for specified purposes
2. Systems have users
3. Systems interact with the environment around it
4. System boundary should be clearly defined
5. Systems are made by integrating components
6. Systems are designed by the application of engineering science knowledge

Other components of a traffic light system

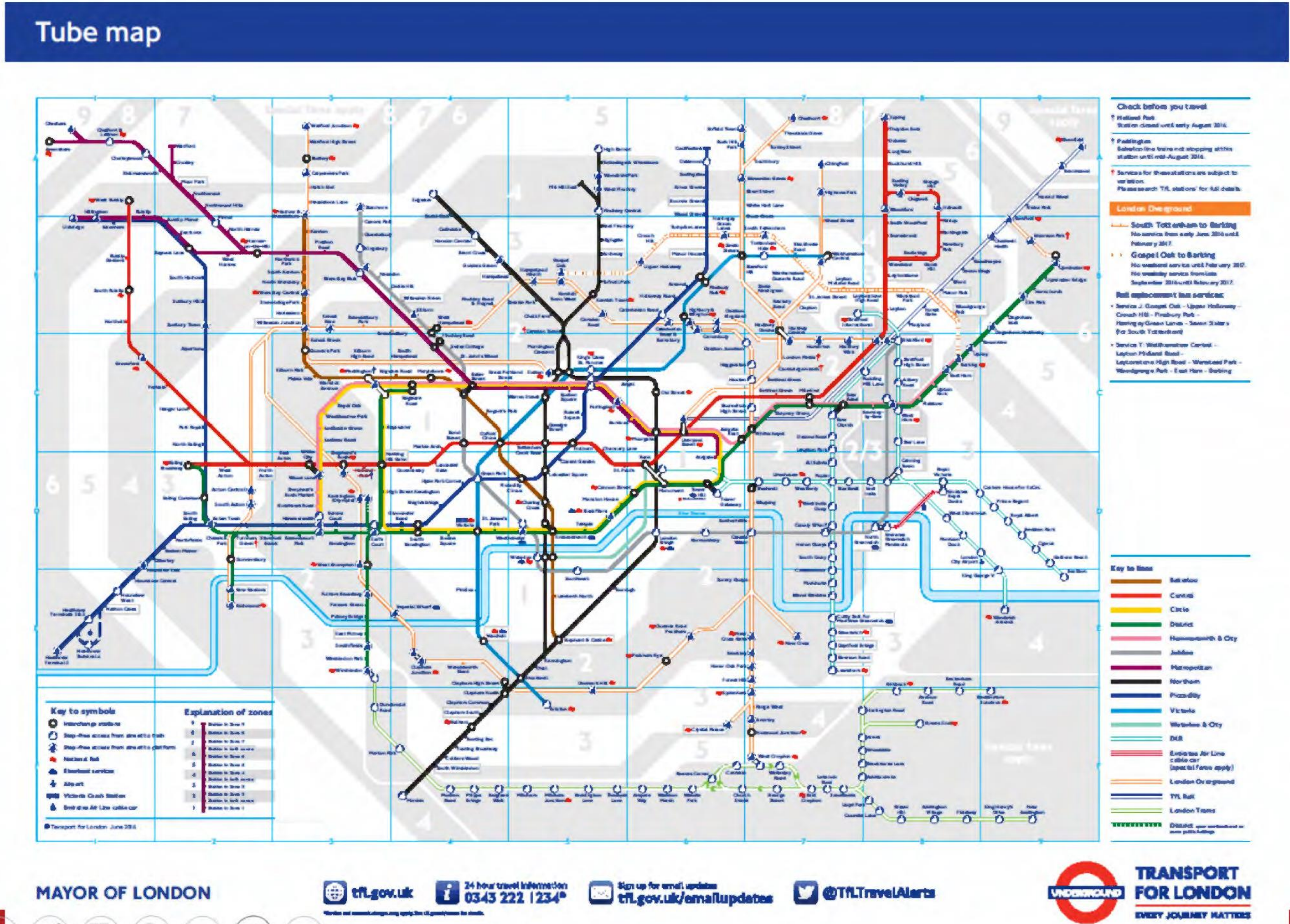
- Vehicles (registration, type, size)
- Drivers (licence, regulations)
- Road network (infrastructure planning, construction)
- Road maintenance
- Road regulations
- Other road users

Design and analysis of systems should not be isolated from external environment.

System (vehicle) constraints

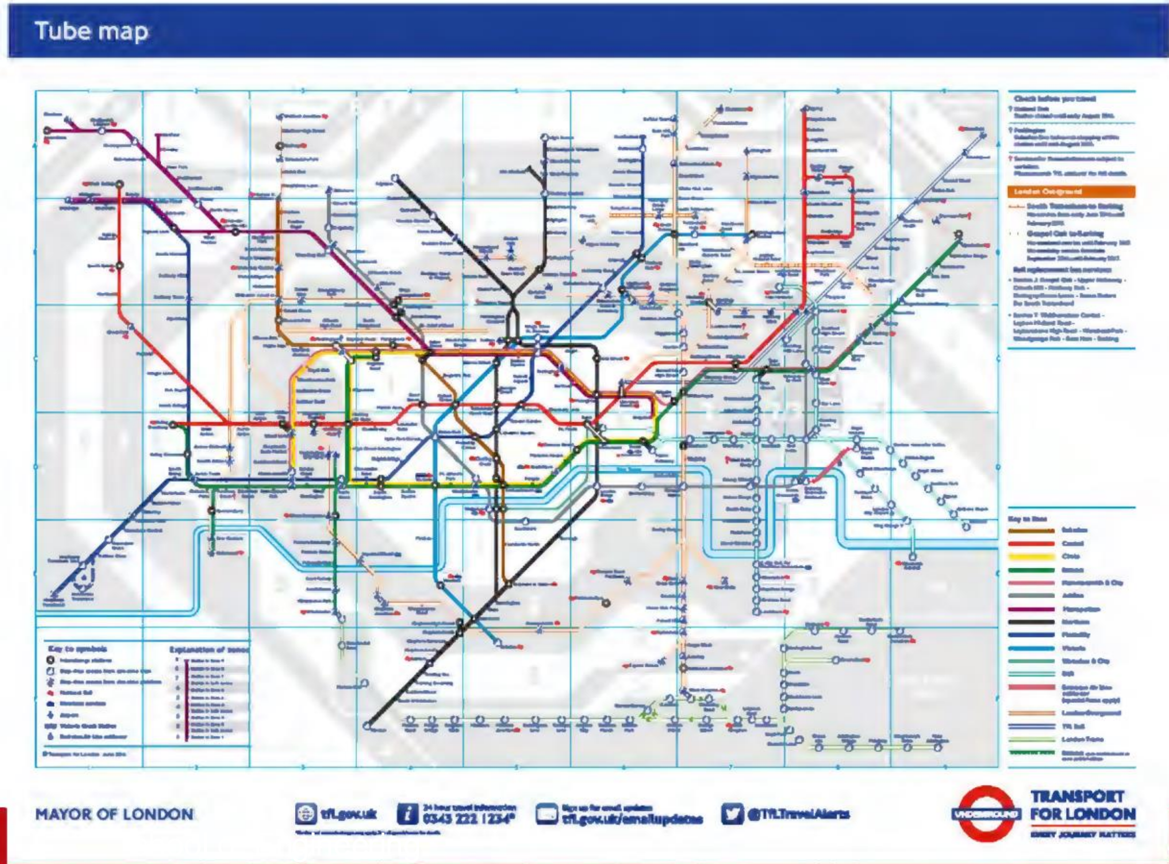
An Engineering System – Transport Infrastructure

A system of built over 150 years



Observations on London Tube System

- Stations – individual components supporting flow of passengers
- Network – cooperation to achieve one goal – passengers to destinations
- Operations – according to rules, commands (track control), timing
- Other components:
  - Ticket
  - Signal
  - Maintenance
  - Power supply
  - Human
  - Security of track
  - Storage (parking)



Systems Engineering driven by science

- Wind farm
- Renewable energy
- Environmental
- Water
- Air conditioning
- Traffic planning
- Logistics
- Medical emergency
- Disaster management

System engineering tasks are often not repeated

Principles of systems engineering observed

1. Systems are created for specified purposes
2. Systems have users
3. Systems interact with the environment around it
4. System boundary should be clearly defined
5. Systems are made by integrating components
6. Systems are designed by the application of engineering science knowledge
7. Systems engineering tasks are often not repeating

Some major engineering disciplines

- Civil Engineering
  - infrastructure related stuff
  - Design and monitor civil projects
- Mechanical Engineering
  - Thermo systems, energy
  - Hydro systems, pumps, valves, water flow, water treatment
  - Clever mechanisms
- Aerospace Engineering
  - Aerodynamic analysis, air flow around objects, propulsion
  - Aircraft structure, composite (s.g. 1.1 to 1.2, plus honeycomb)
- Electrical Engineering
  - Power distribution
  - Wiring
  - Electrical safety

What about other engineering disciplines?

- Automotive Engineering
- Environmental Engineering
- Chemical Engineering
- Structural Engineering
- Systems Engineering
- Sustainable Systems Engineering

Principles of systems engineering observed

1. Systems are created for specified purposes
2. Systems have users
3. Systems interact with the environment around it
4. System boundary should be clearly defined
5. Systems are made by integrating components
6. Systems are designed by the application of engineering science knowledge
7. Systems engineering tasks are often not repeating
8. Systems development and operations are multi-disciplinary

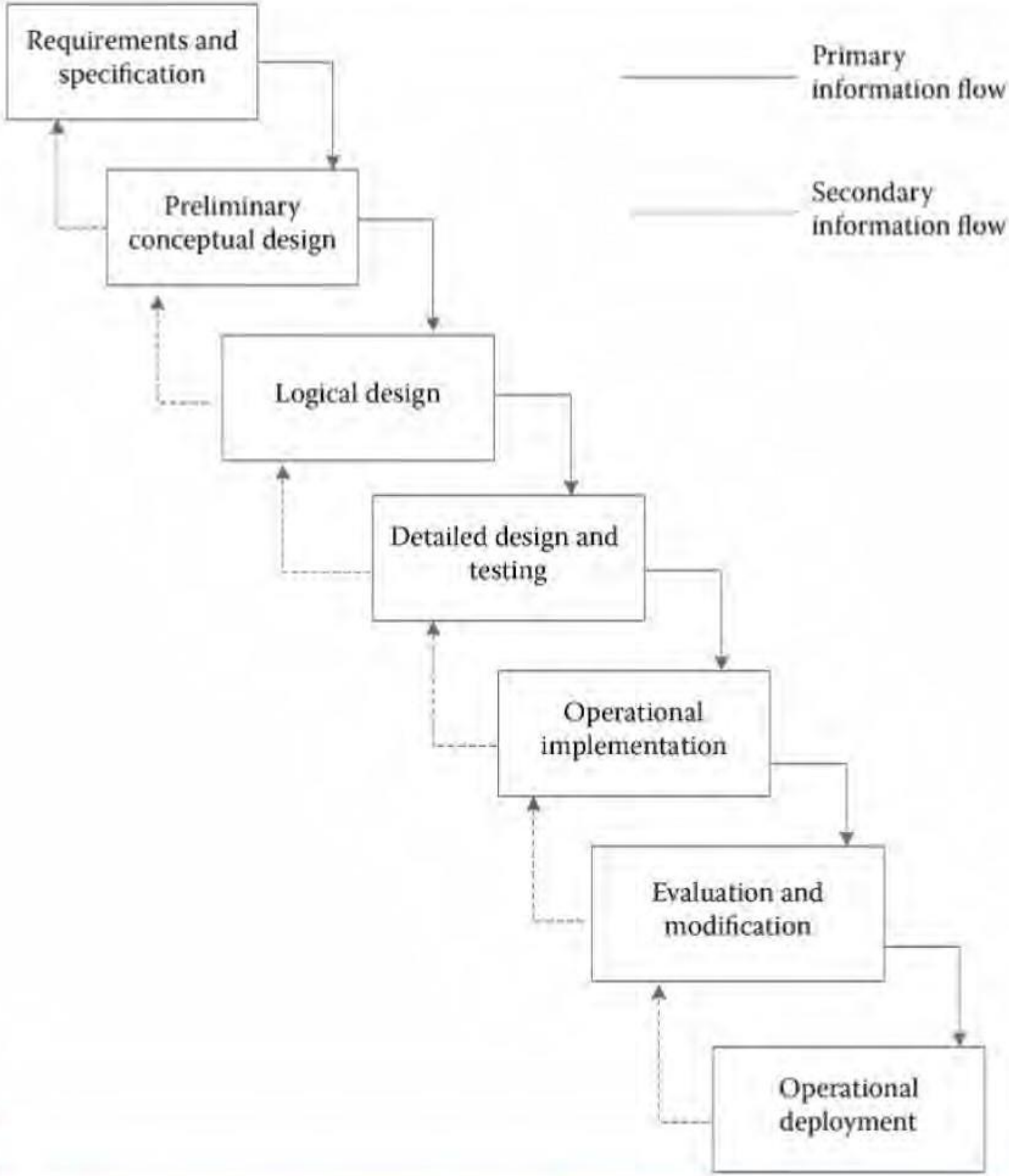
Characteristics of a system

- Systems are created to fulfill user needs
- Systems are made up of components
- Components can be sub-systems, i.e. systems by themselves
- Components and sub-systems may not be used all the time but they are required when the system requires to do something that the components are capable of
- Components and sub-systems are designed by specialist engineers

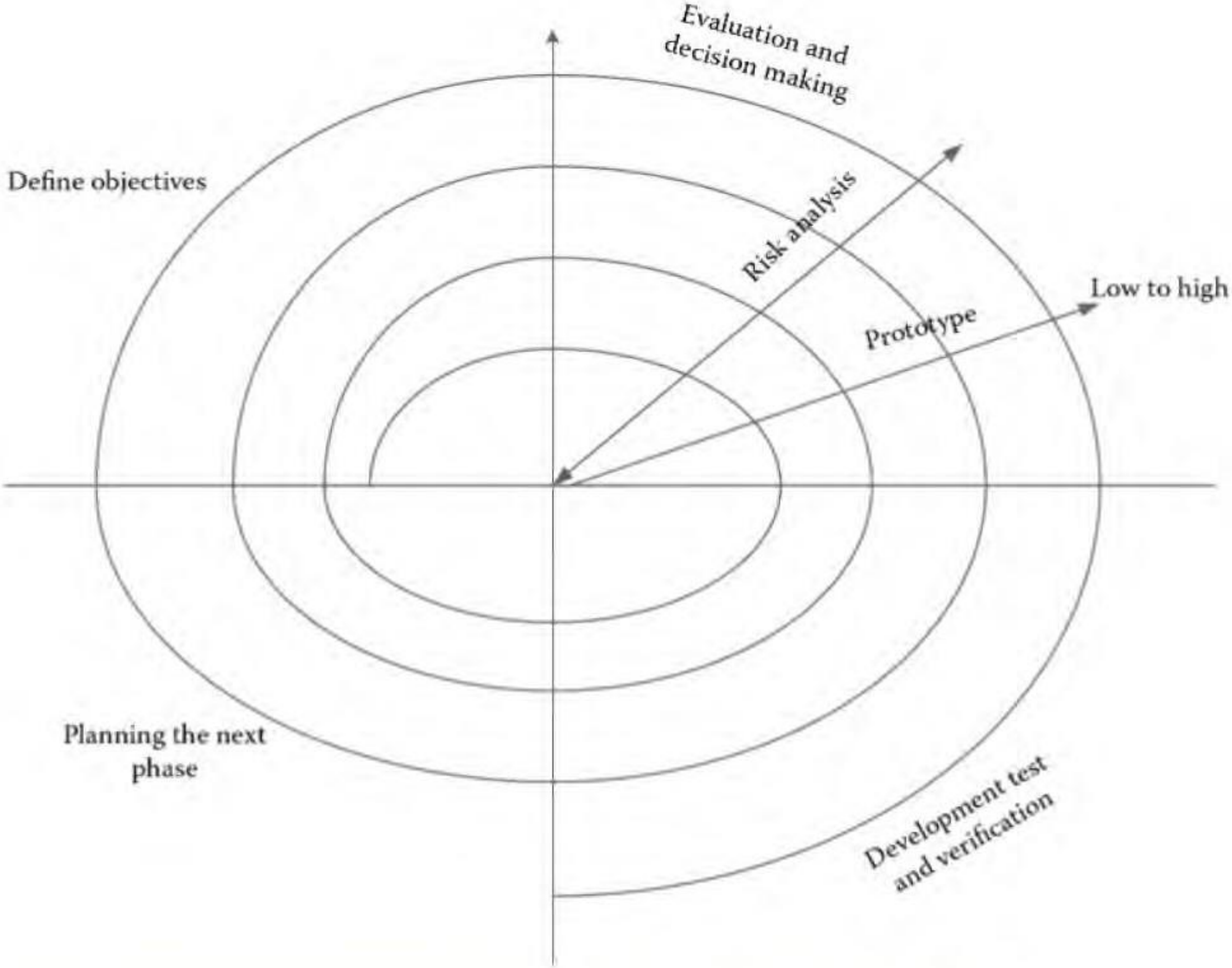
System Design Process

- Every system needs to be designed. The primary goal is that the system runs correctly FIRST time when it is put into operation.
- To ensure system design process to achieve the right-first-time goal, many system design process models have been used to guide planning the process.
- The process plan organises design activities according to relationships understood by the models, and the inter-relationships between different deliverables.
- Engineers use these models to provide a management structure to control design efforts.

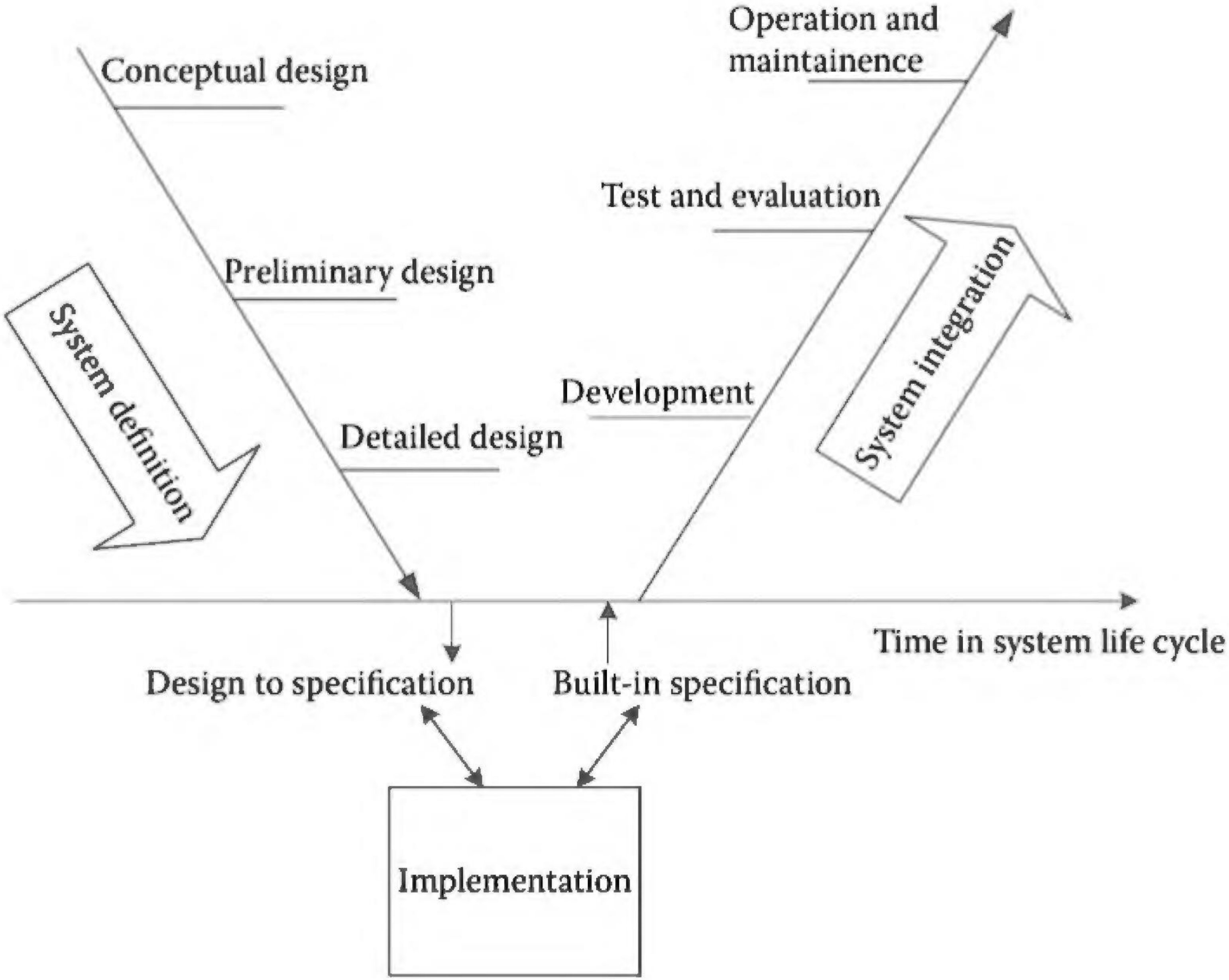
Design Process Model – Waterfall Model



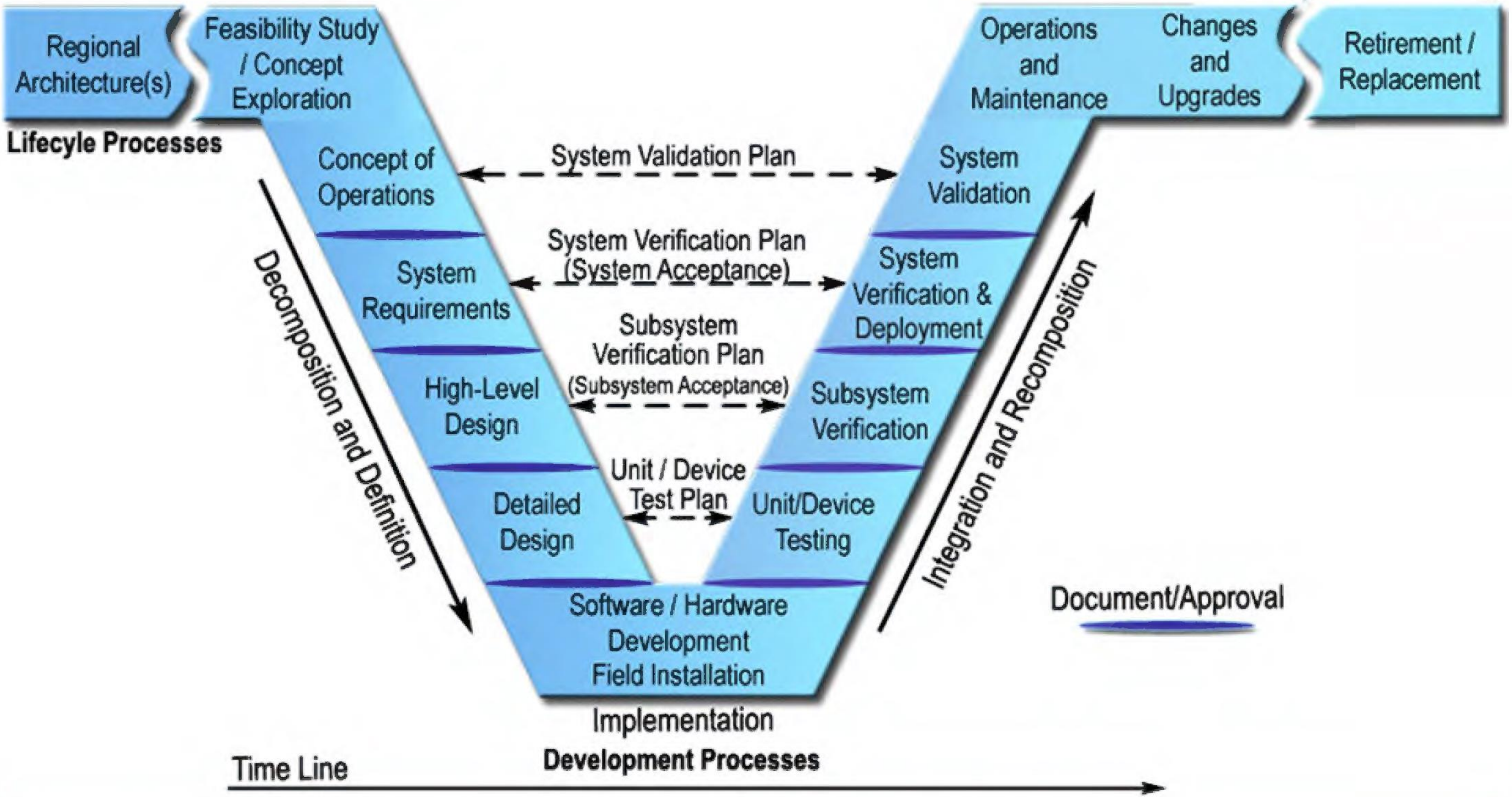
Design Process Model – Spiral Model



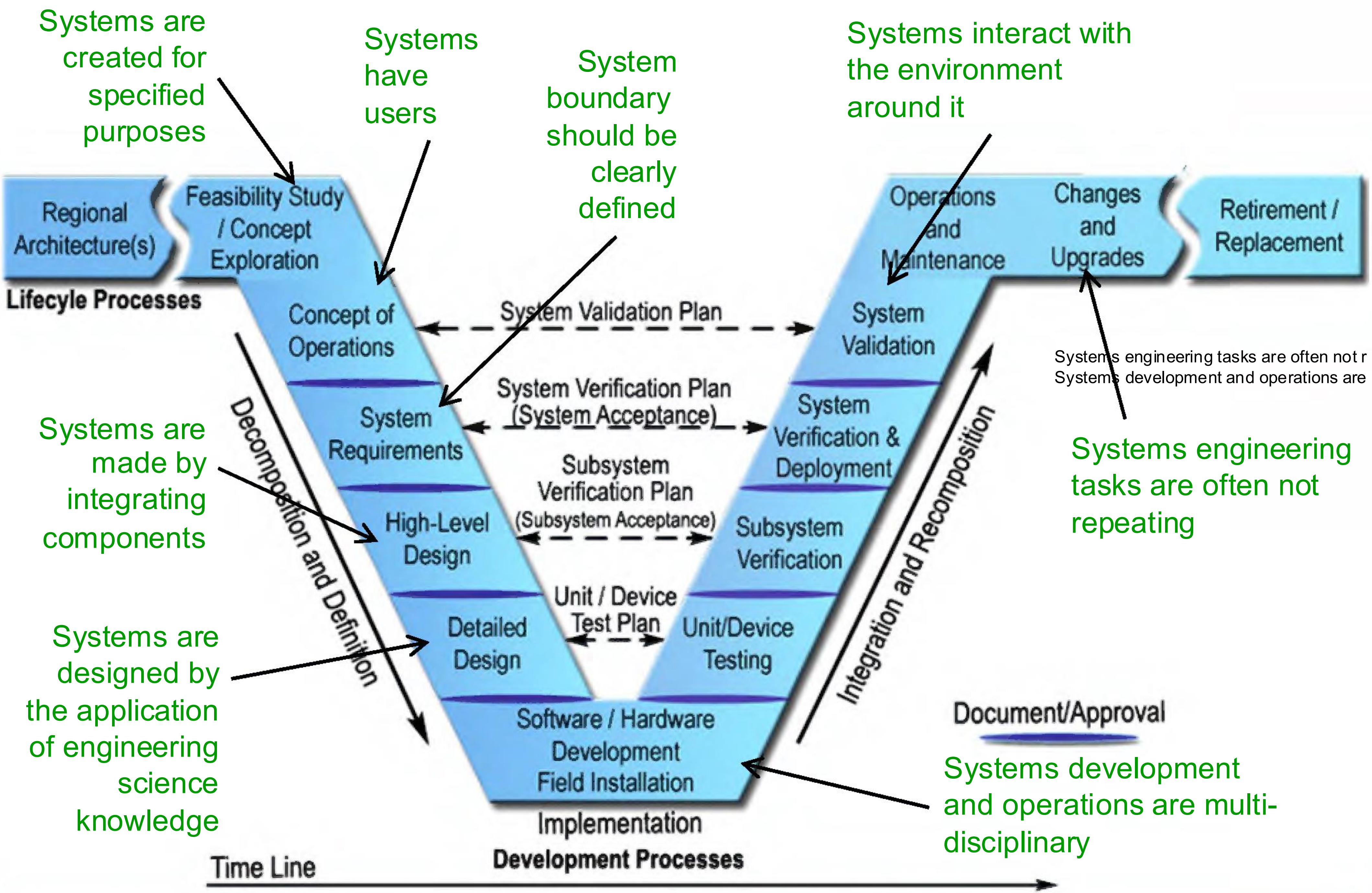
Design Process Model – V Model



Systems Engineering V Lifecycle Model – International Council on Systems Engineering (INCOSE)

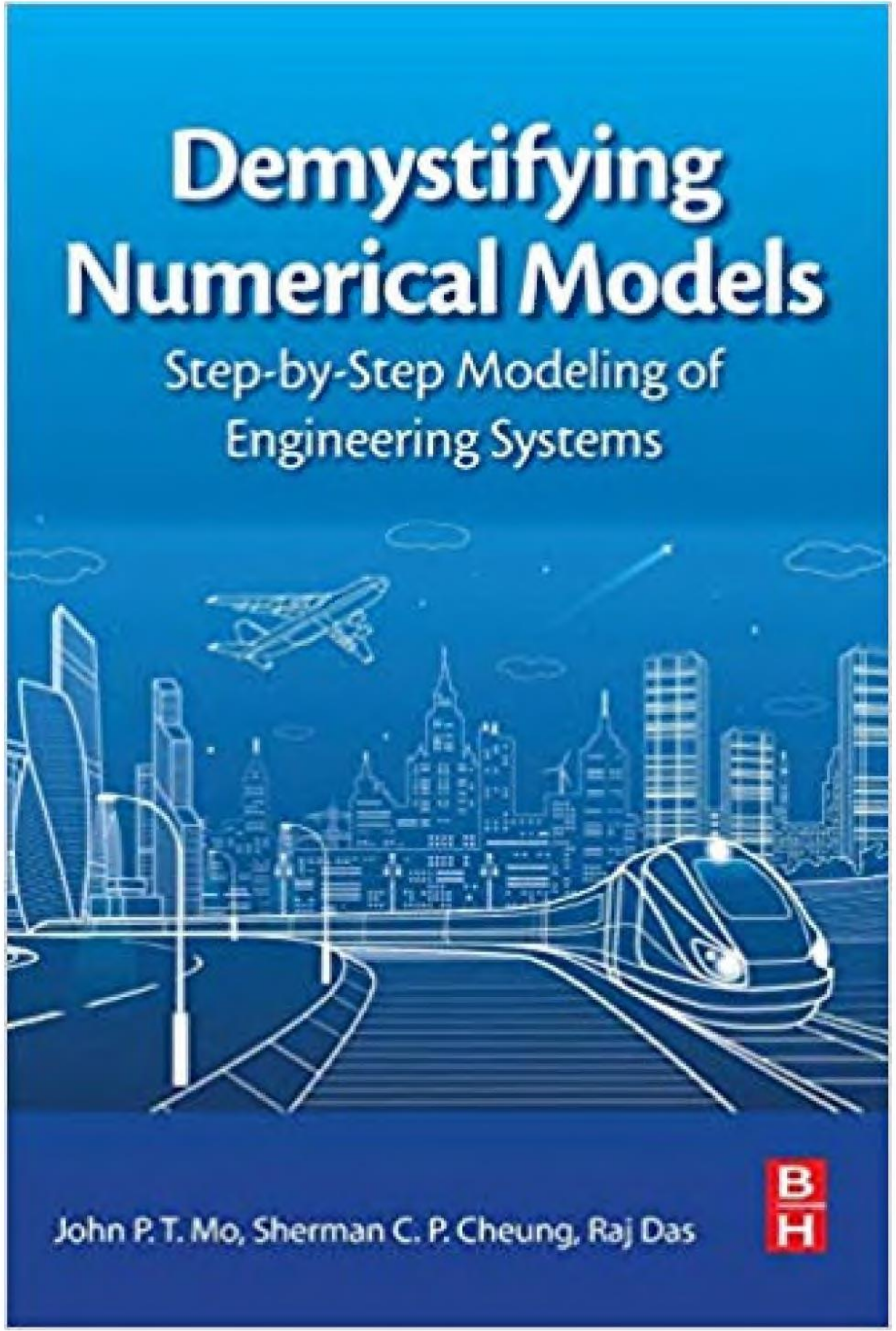


SE V Lifecycle Model implements principles



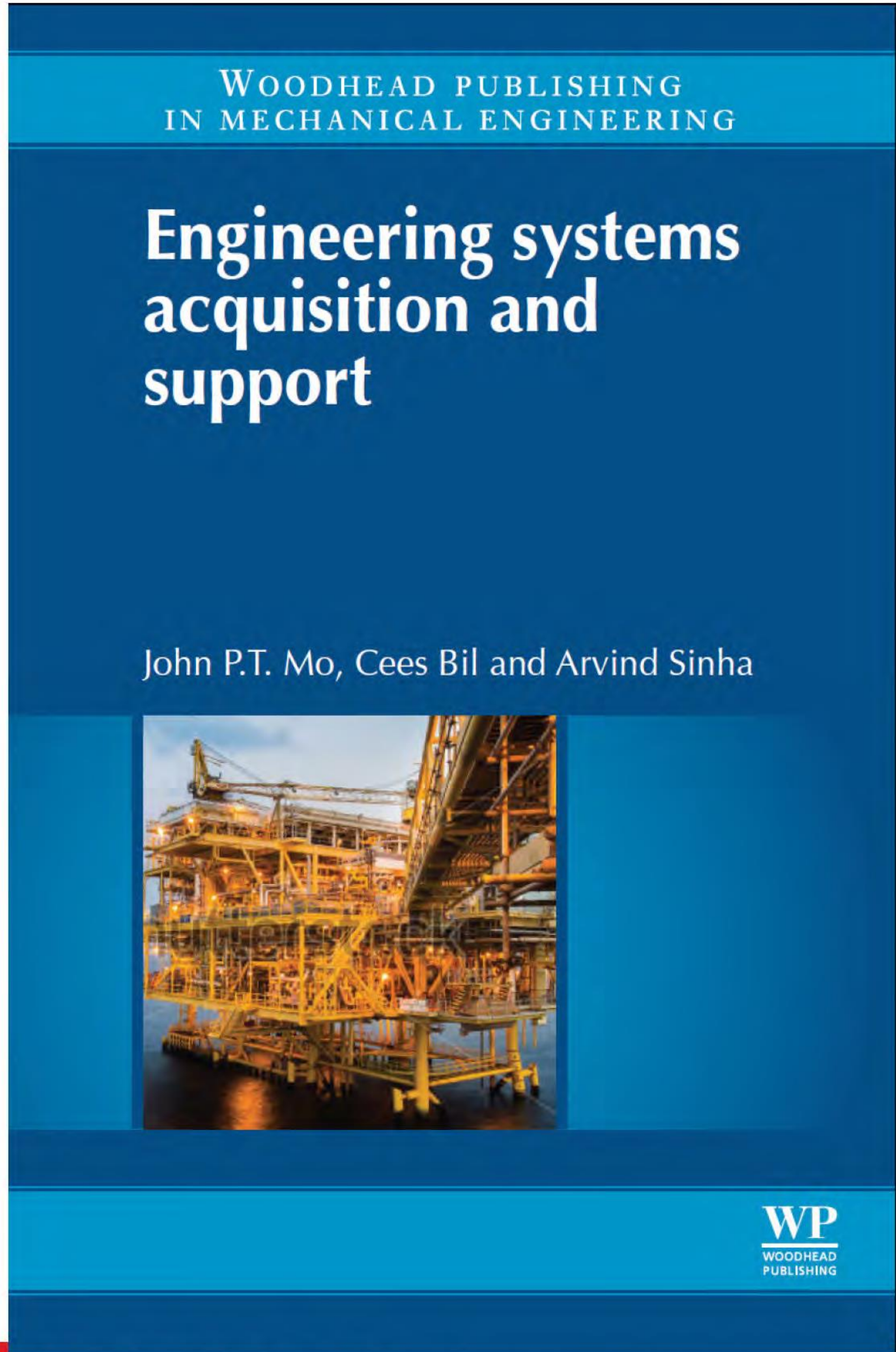
Reading

- Chapter 1 – Introduction to Engineering Systems



Further Reading

- Chapter 2 – The Lifecycle of Complex Engineering Systems



Questions?

RMIT UNIVERSITY