
Conceptual Systems Design

Discusses early design activities in the systems engineering process

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Slide 1

Requirements and Design

- For complex computer-based systems there is no clear boundary between requirements (what the system should do) and design (how the system should do it).
- In general, a high-level design is developed from an abstract specification and this design then constrains the more detailed specification of the system.

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Design/specification activities

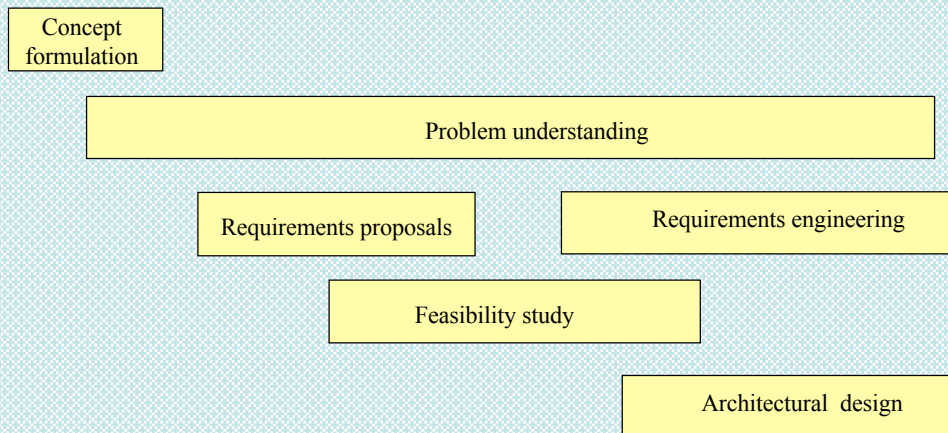
- Concept formulation
- Problem understanding
- High-level requirements proposals
- Feasibility study
- Requirements engineering
- Architectural design

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Process overlaps

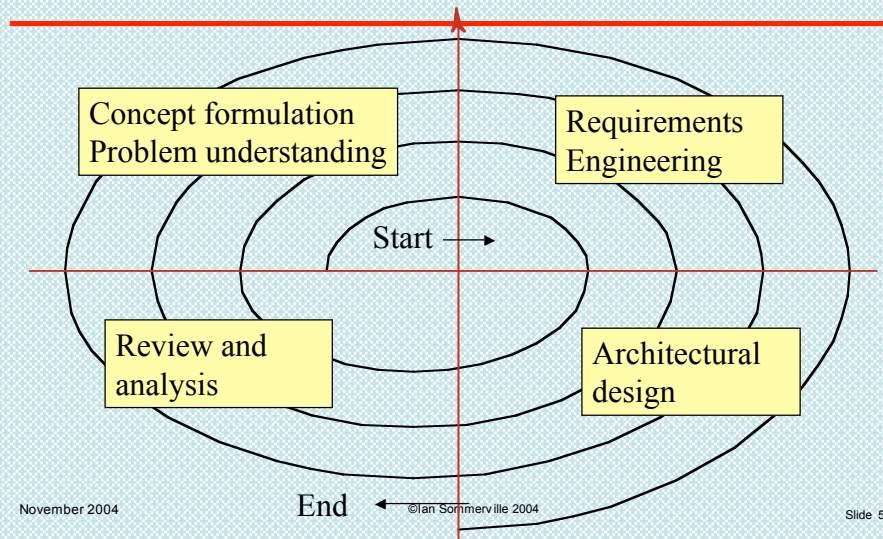


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A spiral model of conceptual design



Concept formulation

- The concept for a system of some type is proposed in response to some perceived problem.
- This concept is generally proposed by people who are outside of the systems engineering process e.g. senior management in a company, politicians or civil servants, pressure groups, etc.
- The concept is usually influenced by factors which influence the thinking of these people such as political and economic benefits.

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The traffic problem

- Problem
 - Road traffic growth is accelerating so that the number of vehicles is outstripping the road capacity. This is particularly true for motorways
 - It is difficult both politically and financially to build more motorways. Even when this happens, there is evidence that it leads to a growth in motorway usage
- Some way must be found of reducing traffic growth.
- One possibility is to increase road travel costs to encourage people and goods to use alternative forms of transport. This would reduce the number of journeys made, pollution and congestion.

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Solution concept

- A road pricing system could be applied to motorways so that a cost per mile (or km) charge is incurred by all motorway users.
- Other solutions have political drawbacks
 - Increasing fuel costs mean that non-motorway users subsidise motorway users.
 - Large subsidies to other forms of transport to encourage alternative use are not allowed because of European rules on competitiveness.
 - Flat-rate increases e.g. of road tax penalises low volume users of the road system.
 - Flat rate charges means that high mileage users are subsidised by low mileage users.

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Problem understanding

- The process of understanding why the problem has arisen and the impact that the proposed concept is likely to have.
- This process should involve, primarily, domain experts rather than systems engineers although some systems engineering input is essential.
 - For the road pricing system, it would include transport specialists, statisticians, civil engineers, environmental experts, etc.
 - For a packaging system (for example), it would include manufacturing specialists, packaging suppliers, supply managers, etc.

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Impact assessment

- To understand the impact of a proposal, we need to look at the underlying causes of the problem
- Factors contributing to the growth in traffic
 - Increased individual prosperity means more private cars
 - Reduction in subsidies for public transport
 - Development of automated stock control systems and centralised warehouses
 - Transport privatisation leading to reduced quality of service
- Impact of motorway pricing
 - Remove hidden subsidies for road users
 - Reduce congestion hence shorten journey times
 - Environmentally acceptable
 - Increased cost of goods

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High-level requirements definition

- This process is concerned with eliciting very general high-level requirements (what the system must do) and system constraints (limitations on how this will be done).
- It will involve senior decision makers and people involved in the management of the processes where the system will be deployed such as senior traffic police, local authorities, etc.
- Requirements at this stage will be vague - they should not exclude particular solutions.

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Road pricing system

- High-level requirements
 - The system must provide a facility whereby cars travelling on motorways pay a fee which is proportional to the distance travelled.
 - The fee charged should be settable by the government of the day and may vary from place to place and time to time in the system.
- Constraints
 - The system must not introduce additional traffic delays.
 - The system must be run without subsidy.
 - The system should be run by a non-governmental authority.
 - Use of the system should not require modification by a garage of existing vehicles.
 - The system should be introduced within 5 years.

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Feasibility study

- The objective of a feasibility study is to investigate, in depth, possible ways to implement a road pricing system.
- Stages of a feasibility study include
 - Assessment of existing systems
 - Technology assessment
 - Solution proposals
 - Cost/benefit analysis
- On completion of the feasibility study, a decision is made on a preferred solution.

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Assessment of existing systems

- Other systems of the same or similar types which have been introduced elsewhere should be examined and various questions asked:
 - What has been the practical experience of introducing these systems?
 - What problems are there in introducing and operating these systems?
 - What are the differences between the context of these systems and the planned system context?
 - Can all or part of these existing systems be reused?

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Technology assessment

- What kind of hardware might be needed to implement a road pricing system?
 - Is this hardware available commercially?
 - Would special-purpose hardware have to be designed and manufactured?
- What software would be needed?
 - Are off-the-shelf software solutions available?
 - Can existing hardware/technology meet the performance demands of the system?

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Hardware

- Vehicle presence sensors
 - Detect a vehicle in a traffic lane. Must work in all weather conditions and at night
- Vehicle identification system
 - Identify individual vehicles with a high level of reliability
 - Must work in all weather conditions and at night
 - Must not be high cost or require permanent fitting to the car
- Hardware for collecting charges from drivers

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Software

- General purpose database system for payment collection.
- On board, real-time system for managing car identification.
- Real-time charging system.
- Other database systems for identification, exemptions, offender tracking, etc.

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Design proposals

- Normally, there are several possible potential system designs that could solve the problem. These will each have their own advantages and disadvantages.
- Various techniques such as brainstorming may be used to develop potential solutions.
- Each possible design proposal should be described in sufficient detail to allow a cost benefit analysis to be carried out.

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Road pricing system options

- Toll 'gates' on motorway
- Satellite position reporting

- Number plate recognition system.
- Transponder-based identification

- Centralised periodic billing
- Direct debits
- Real-time payments
- Pre-payment

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Satellite tracking

- The position of each vehicle is continually tracked by a satellite positioning system and the actual motorway usage is computed.
- Advantages
 - Needs only simple hardware on slip roads
 - Would allow system to be extended to other types of road at low cost
- Disadvantages
 - Technology is untried on such a large scale
 - Needs new GIS software to determine motorway usage
 - Needs in-car hardware to send position to satellite

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Number plate recognition

- Equipment is installed at each tolling station to record and recognise each car's number plate
- Advantages
 - No on-board vehicle equipment is needed.
 - No need for real-time response from the system.
- Disadvantages
 - Cost feedback to driver before payment is impossible.
 - Centralised vehicle registration information is unreliable and incomplete.
 - Can't deal with vehicles from outside the UK.
 - May have problems operating in bad weather.
 - Loss of privacy for the driver.

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In-car transponder

- Each car broadcasts its registration when it passes a tolling station. This is detected then the driver is billed.
- Advantages
 - Cheap and fairly simple on-board equipment
 - No need for real-time response
 - Based on well-tried technology
- Disadvantages
 - Real-time payment is impossible
 - Needs backup system for cars without transmitters

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Smart-card system

- Each vehicle has a pre-paid debit card. When it passes a tolling station, the toll is debited from the card.
- Advantages
 - Pre-payment of road tolls. Fewer billing problems.
 - Easier to anonymise - need not be based on car registration.
- Disadvantages
 - Needs real-time response with new technology.
 - Needs backup identification system.

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Cost/benefit analysis

- Each proposed solution is considered and, based on its advantages and disadvantages, an estimate of the costs of developing that solution and the associated benefits is made.
- Ideally, one solution should have the lowest costs for the greatest benefits and this should be chosen. In practice, however, some more subjective judgement may have to be made.
- Once a decision has been made on solution technology, then the system architecture can be designed.

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Key points

- Conceptual systems design is the process of realising a conceptual design for the system that will be the basis for deriving the system requirements and architecture.
- Key activities include
 - Concept formulation and problem understanding
 - High-level requirements proposals
 - Feasibility study
 - Requirements engineering
 - Architectural design