Appendix A

Answers to Selected Exercises

Chapter 2: Systems

1. (a) The function of the grinder for its users is to grind coffee beans. (b) The environment of the system consists of its users, the electrical power supply, and the surrounding air. The interface to the user consists of the following interactions: accept an on or off transaction from the switch, switch light on or off, accept a volume of coffee beans, produce a volume of ground coffee. The interface to the electrical power supply is to draw electrical energy from the power plug, and the interface to the surrounding air is to produce waste heat. (c) The system is hybrid.

2. At the highest level, the interface consists of the transaction *sell grocery*. This is the way a branch organization would look at the store: the only relevant thing the branch organization wants to know about the store is that it sells grocery. At the next lower level, we observe interactions like *sell bacon* and *sell cheese*. This is the way the customer looks at the store: he or she wants to know which grocery can be bought at the store. At the next lower level, we can observe transactions like *enter shop*, *walk to shelf*, *get packet of cheese*, etc. This is the way an operations researcher may look at the store, who is interested in finding out the optimal placement of the shelves, of the goods on the shelves, etc.

6. The two diagrams represent different behaviors, because in diagram (a), the action c is nondeterministic: it may lead to one out of a set of two possible next states. From one of these states, action b can occur, and from the other d can occur. In diagram (b), the action c is deterministic: it leads to exactly one state, from which a choice between b and d can be made. Thus, the moment of choice is different in the diagrams.

Chapter 3: Product Development

1. (a) The client is the aircraft vendor. If the software is market-produced, the sponsor is the vendor of the software and the customer is the aircraft building company; otherwise the sponsor and customer is the aircraft building company. The user is the pilot of the aircraft.

   (b) The sponsor is the DBMS vendor. The client of the development process and customer of the DBMS is the buyer of the DBMS, the user is the person who must install and maintain the DBMS.

(c) The client and customer is the buyer of the software. The sponsor is the software vendor and the user is the library employee at the circulation desk.

(d) The client, sponsor and customer is the government in the form of the ministry of defense. The users are the officials who query the database.

2. (a) (1) Informal reasoning by managers. (2) Pencil and paper sketches. (3) Informal reasoning, performed by the designer about the likely consequences of certain design options. (4) Building a prototype. (5) Performing a trial production.

(b) (1) Informal evaluation after discussion by managers. (2) Informal evaluation after discussion by designers and managers. (3) Comparison with required properties by designers. (4) Performing a consumer experiment. (5) The evaluation criteria are not mentioned in the case study. Examples of criteria are repeatability, reliability and economic feasibility of the process.

3. Because business concerns are transformed into software requirements, this framework applies to the level of computer-based systems. *Elicitation* is the fact-gathering part of needs analysis, *specification* consists of analyzing the gathered facts and of synthesizing it into a requirements specification, and *validation* consists of simulation, evaluation and choice.

6. The finite number of observations of the disturbances were used as evidence for a model of Neptune and its orbit. This orbit contains infinitely many points. The step from the observations to this model is the inductive jump.

7. The correspondence with rational problem solving is as follows: **Problem analysis** corresponds to *suggestions* and *intellectualization*. That is, the subject becomes aware that there are other ways of doing things, that the current way need not be taken for granted, and makes the transition from unreflective and unquestioning doing things the current way to a disengagement, distancing from the current way of doing things, which opens the possibility of reflective thinking; and the subject then starts to analyze the current situation. **Solution generation**: *hypothesis*. **Estimation of effects**: *reasoning*. **Evaluation of effects**: *testing* the hypothesis by action. It is not clear from the description in the exercise whether this action is an experiment or the real thing. **Solution choice** is not listed explicitly in Dewey's process. The process can be viewed as a prescription for reflective action in which we alternate between reflection upon the current situation and performing an action. After the first action is performed, reflection upon the current situation can be viewed as part of the regulatory cycle (observe and evaluate the effects) as well as of a rational problem solving process that prepares for the next action.

8. *Scouting* and *entry* are pre-development tasks that precede the engineering cycle. *Diagnosis* corresponds to **needs analysis**. *Planning* corresponds to **synthesis of product specifications** and **Simulation of specified products**. Kolb and Frohman do not mention **evaluation of effects of simulations** or **choice of specification** explicitly, but these can be viewed as part if their *action* task. Their *evaluation* task is really part of the regulatory cycle. *Termination* is a post-development task that follows the engineering cycle as well as any applications of the regulatory cycle.

Chapter 4: Requirements Specifications

2. (a) In the first iteration, the documented objective was to preserve TANA market share. The alternatives considered were to search new markets for existing products, to develop new products for the same market, and to adjust the marketing mix. The likely effects of these alternatives were simulated and evaluated with respect to the objective by management. The discussion is likely to have been recorded in the form of minutes of a management meeting.

(b) The alternatives considered are listed in figure 3.7. The simulations were their own documentation, because they are paper and pencil sketches. Their evaluations are probably recorded as minutes taken at a meeting in which management evaluated the sketches against the marketing objectives.

Chapter 5: ISAC Change Analysis and Activity Study

2. Figure A.1 gives a solution. The activities are systems with local memory, which resemble the objects of object-oriented modeling. The arrows indicate messages sent by one object to another. This model is simpler than the one in figure 5.8, because it contains less interaction, and the interaction that it contains is essential for the functioning of the system. It has the disadvantage that data are distributed over different activities, whereas in fact they are located in one place (a paper or automated database). The diagram thus has less resemblance than figure 5.8 to the way that work is currently done in the circulation system.

4. Alternative 2 of the library case study (section 5.2.8, the store room alternative), has the same activity model as the current situation.

Chapter 6: Information Strategy Planning

4. See figure A.2 for an example. This is not the only solution; in fact, the tree may differ for different travel agencies.

5. See figure A.3 for one possible solution. A segment is characterized by a point of departure and a point of arrival. A scheduled segment in addition has particular departure and arrival dates and times, which are not represented in the diagram because they are attributes and not entity types. It is not clear from the exercise whether the segments of one flight must be consecutive in space and/or time. A reservation can profit from the price arrangements by reserving a number of segments such that a Saturday night falls in the time between departure from the starting point and departure from the destination. A complex reservation consists of a reservation for several segments. Each complex reservation is a reservation for one person. A complex reservation has a price that depends upon the departure and arrival dates of some of its segments. The price is not shown, because it is an attribute of complex reservation. Return flights have not been modeled explicitly. They can be defined as a view on $FLIGHT$ instances, defined by the predicate that the sequence of segments of the flight starts and ends in the same airport.

6. Example subject areas and entity types that belong to those areas are:

   - $CUSTOMERS$: $PERSON$
   - $FLIGHTS$: $AIRPORT$, $FLIGHT$, $SEGMENT$, $SCHEDULED\_SEGMENT$
   - $SALES$: $COMPLEX\_RESERVATION$

   The $FLIGHTS$ subject area corresponds to the products subject area of figure 6.14. Note that there is no reason to stick to the list of example subject areas of figure 6.14. Any partitioning in subject areas that the client agrees with, suffices.

7. See figure A.4. The matrix covers only two of the business areas of the travel agency, Sales and part of the Acquisition business area.

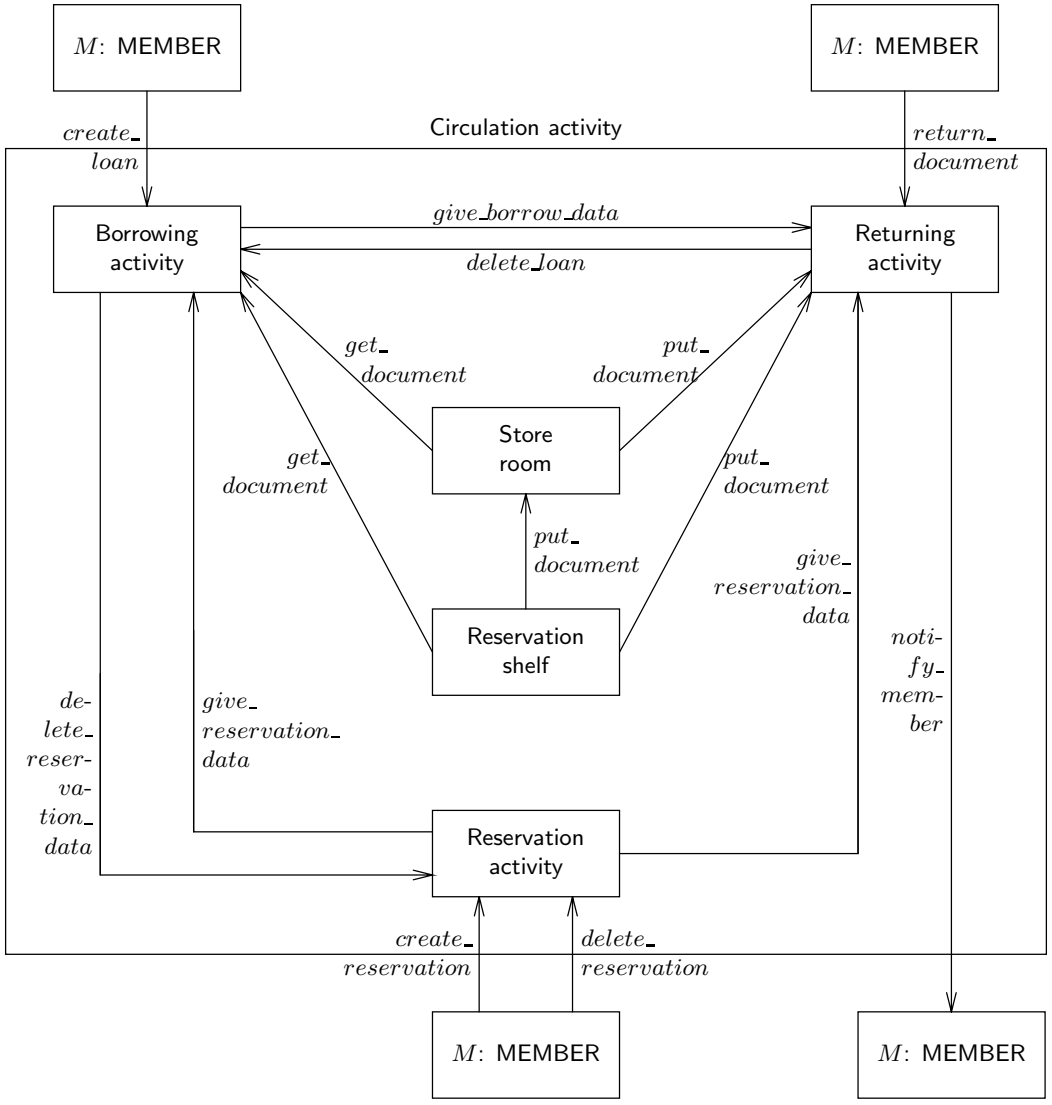


Figure A.1: An activity model of the circulation system that encapsulates memory in the activities.

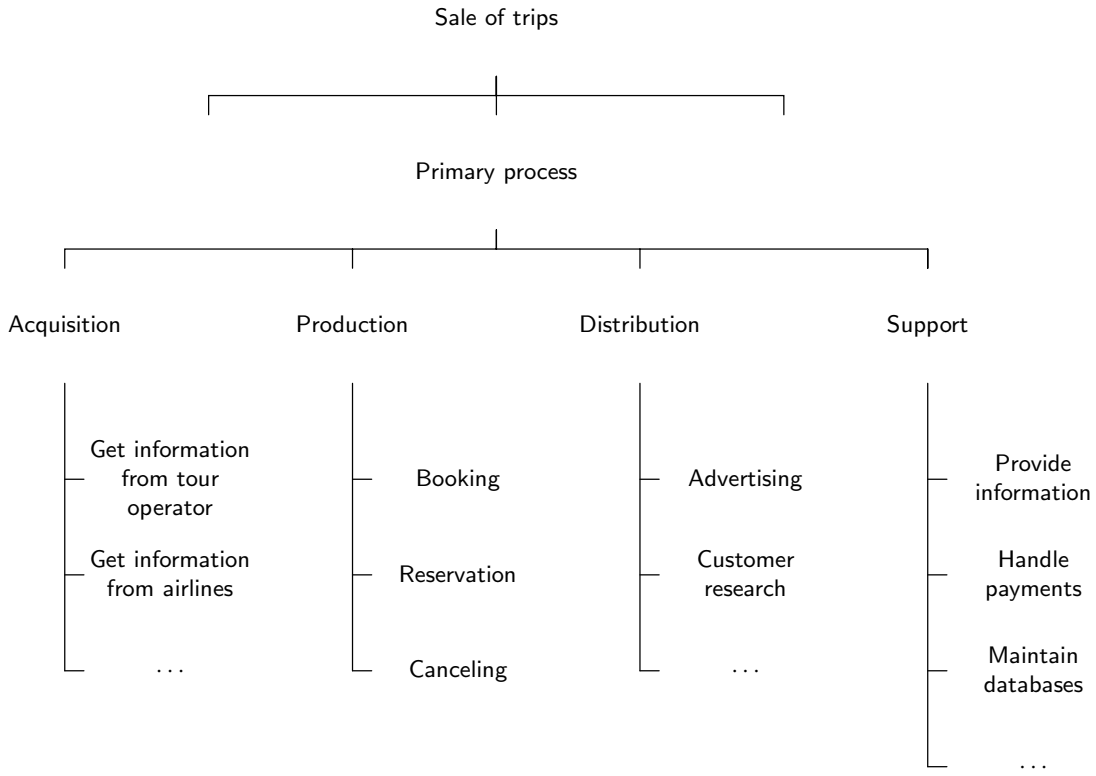


Figure A.2: A function decomposition tree of the primary process of a travel agency.

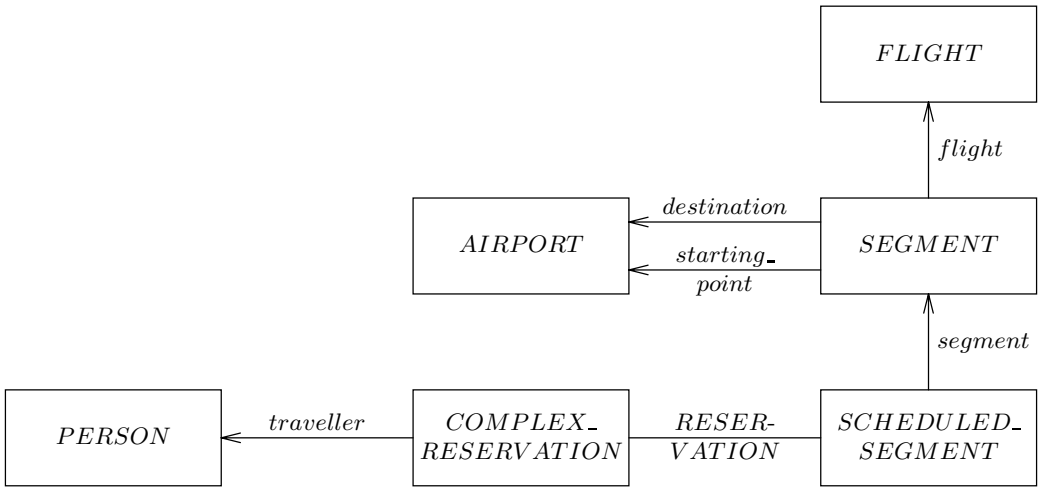


Figure A.3: An ER diagram of the UoD of a travel agency.

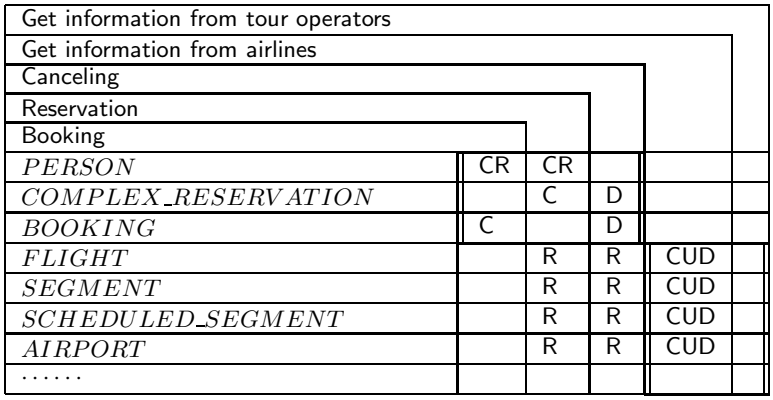


Figure A.4: Fragment of a function/entity matrix for a travel agency.

Chapter 7: The Entity-Relationship Approach I: Models

2. In the UoD, each existing airline has at least one existing flight. There exist cities without airports, addresses without people having that address, and flights and people without reservations. The only visible constraint is thus ≥ 1 at the $FLIGHT$ side of *airline*.

   In the system, each existing airline has at least one existing flight. We want to represent cities without airports, but we do not want to represent addresses without people. The other cardinalities are the same as in the UoD. Thus, we have ≥ 1 at the $FLIGHT$ side of *airline* and ≥ 1 at the $PERSON$ side of *address*.

4. The second one cannot be represented, because a cardinality constraint at the root of the arrow *supplier* says how many links can occur in which a single supplier s can occur. It does not and cannot say anything about the number of links in which s and a part p occur.

5. If attribute a is not applicable to some instances of entity type E_1, remove a from the definition of E_1 and define a specialization E_2 of E_1 for which this attribute is defined.

6. Replace a partial function by a relationship in diamond notation.

7. Define a relation $TRANSPORTED\_DELIVERY$ with components $COMPANY$ (playing role *transport_company*) and $DELIVERY$, which itself is a relation with components $COMPANY$ (playing role *supplier*), $PART$ and $PROJECT$.

8. Turn *LOAN* into an entity type. It then has its own identity and there can be arbitrarily many *LOAN* instances with the same member and document. The cardinality constraints that one member borrows at most 20 documents, and one document is borrowed by at most one member, are not expressible anymore in the diagram.

9. The referential integrity constraint allows the referring key to be *null*. A component of a relationship must never be *null*.

10. If a many-many relationship is transformed into one relational schema, it is not in the fourth normal form. A relationship not in fourth normal form contains two independently varying multi-valued facts. See also Kent [175].

11. - Less then 100 students follow course CS101 every year. This can be a descriptive regularity in the UoD. Treating this as a constraint on the system, we get a system that cannot be used in a situation where more than 100 students enroll for CS101. We

should only turn this sentence into a system constraint if we can be absolutely sure that the UoD regularity expressed by the sentence will never be falsified.

- Course CS100 is a prerequisite for course CS101. This may or may not be an official rule. If it is not an official rule, it is a descriptive sentence that expresses an observation made of the UoD. If we were to turn this into a system constraint, we would turn this observation into a UoD regularity that will never be falsified; which is a risky decision. If the rule is a UoD constraint and we want to enforce this by means of the system, we should turn it into a system constraint. Exceptions cannot be recorded. If the rule changes, we must then change the system specification.
- Students always follow CS100 before they follow CS101. This may be a consequence of a rule or a consequence of a habit of the students; which habit may follow from the fact that CS100 really is a prerequisite of CS101, even if the rules don't say so. The same considerations as above apply.

Chapter 8: The Entity-Relationship Approach II: Methods

1. The first one can be represented by adding the cardinality ≥ 1 at the root of the arrow $SALE \rightarrow CLIENT$. The other constraint says that the multivalued function $CLIENT \times SHOP \rightarrow\!\!\rightarrow PRODUCT$ defined by $SALE$ assigns at most two products to any particular $\langle c, s \rangle$ and this cannot be represented in the diagram.

4.
   - This is a car: Instance-type relationship.
   - A Ford is a car: is_a relationship.
   - A Ford is a type of car: Instance-type relationship, since "Ford" is now treated as the name of an individual.
   - A teacher is a member of staff: is_a relationship.

5. Add relationships $RECEIVE\_MARK\_FOR\_TEST$ and $FINISH\_TEST$ that represent the events of obtaining a result. The relationships $PRACTICAL\_REG$ and $TEST\_REG$ represent the events of registering for a practical and a test, respectively, and allocation of a *result* attribute to these events is a type error.

7. The key of the relational schema corresponding to a relationship can now have components that are themselves compound, and referential keys may now also be compound.

Chapter 9: Structured Analysis I: Models

3. (a) Material stores have only two operations: remove and add. Removal is a destructive read and corresponds to the effect of a read and delete operation on a data store. Addition corresponds to a creation operation on a data store. Data stores have non-destructive reads and additionally have an update operation, which is absent from material stores. Material flows move material items just like data flows move data items. However, if masses are manipulated (like water), then the flow is continuous and we need an additional notation to distinguish these from discrete flows. Material manipulations are physical processes that must be specified by means of notations from physics, chemistry, biology, etc. They can be discrete or continuous.

   (b) There is no difference with material manipulation. The dashed line is therefore superfluous and can be replaced by whatever notation is used for material flows.

Event	Response	Transaction
Member requests title reservation	Reserve title	Reserve title
Member requests cancellation of title reservation	Cancel title reservation	Cancel title reservation
Member requests to borrow a document	Lend document	Borrow document
Member requests to extend a document loan	Extend loan	Extend loan
Member returns a document	Accept document return	Return document
Document loan is overdue	Send reminder	Send reminder
Member loses document	Register document loss	Lose document

Figure A.5: Event list for the ciculation administration.

Chapter 10: Structured Analysis II: Methods

1. When a document borrow request is received, the administration must check whether it has been reserved (read access) and if so, whether the borrower is the reserver; if the borrower is not the reserver, the document cannot be borrowed, otherwise a reservation record must be deleted (write access). This is one data store access in which records may be read and updated at the same time.

3. See figure A.5.

4. 1. Feasibility study is a behavior specification process at the level of computer-based systems.

   2.(a)–(c) Structured analysis is a behavior specification process at the level of computer-based systems that makes the result of feasibility study more explicit.

   2.(d)–(i) This is a decomposition process that follows the engineering cycle. A computer-based system is decomposed into manual tasks and software systems. The observable behavior of the software systems is specified.

   3. Structured design is a decomposition process that decomposes software systems into modules.

   4. Structured programming is a decomposition process that decomposes software modules into executable parts.

5. 1. This is a behavior specification process at the level of computer-based systems. Needs analysis is already assumed to have taken place, as this task begins with understanding system objectives that are already previously identified.

   2. Building a processor environment model is a decomposition task as well as a behavior specification task for the units into which the system is decomposed.

   3. Specifying the human-computer interface is a behavior specification task at the level of software systems.

   4. Specifying a software environment model is a decomposition and behavior specification task, in which each unit is decomposed into software subsystems called tasks and the behavior of these tasks is specified.

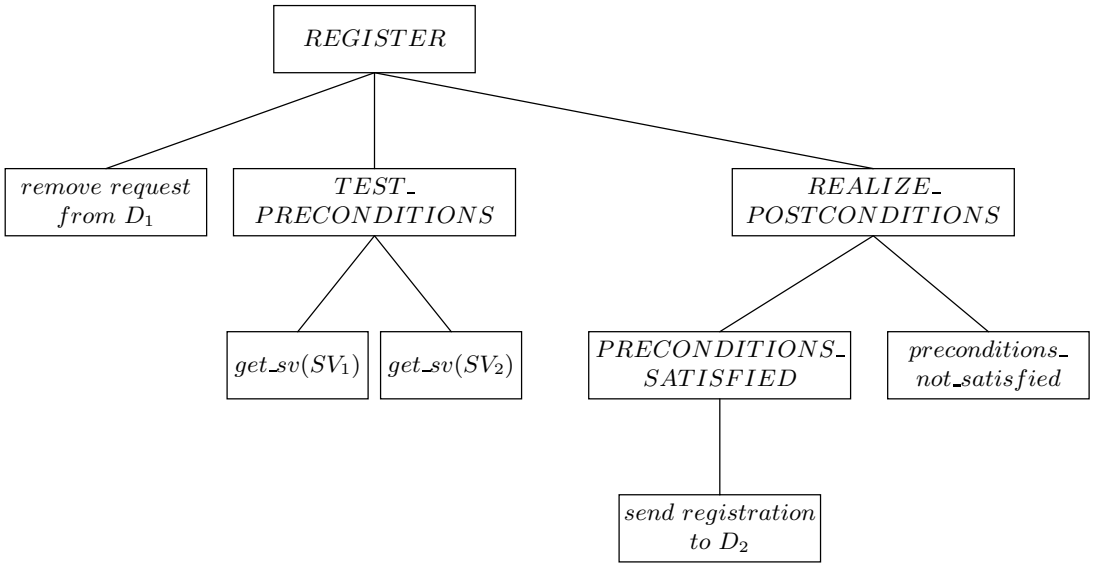


Figure A.6: Outline of a PSD for the $REGISTER$ function.

5. Structured design is a decomposition of tasks into units of code.

Modern structured development decomposes software systems into tasks, and tasks into modules, where classical structured development decomposes software systems into software modules immediately.

Chapter 11: Jackson System Development I: Models

1. Input: A registration request of student s for test t.
   Precondition: s and t exist and the *register* action can occur in the life of t.
   Postcondition: The registration request has been removed from D_1 and a registration record has been sent to D_3.

   Precondition: s or t do not exist or the *register* action can occur in the life of t.
   Postcondition: The registration request has been removed from D_1 and a refusal has been sent to D_2.

   Figure A.6 gives an outline of the $REGISTER$ PSD.

2. The $REPORT$ subtree of the $LATE$ PSD is a short-running version of $LATE$. The connection cardinality must be changed so that the ≥ 0 cardinality is on the $LATE$ side.

   To turn $ACCT\_HISTORY$ into a long-running function, make the short-running function one iteration in a process that is triggered by the arrival of a *historical_query*. The connection cardinality changes so that one $ACCT\_HISTORY$ instance is connected to many $ACCOUNT$ instances.

3. This requires addition of a JSD entity $REGISTRATION$. In ER terms, this is a relationship between the ER entity type $STUDENT$ and the ER entity type $TEST$. The *register* action is the creation action for this relationship. The $REGISTER$ function of figure 11.21 is a function process that performs the input transactions in which this creation action is executed. The PSD of $REGISTRATION$ is trivial and consists of a sequence *register*;

perform; *mark*. We should add the *perform* action to the *TEST* life cycle as well. The *REGISTRATION* life cycle then shares all its actions with the *TEST* life cycle but enforces an ordering per test–student pair.

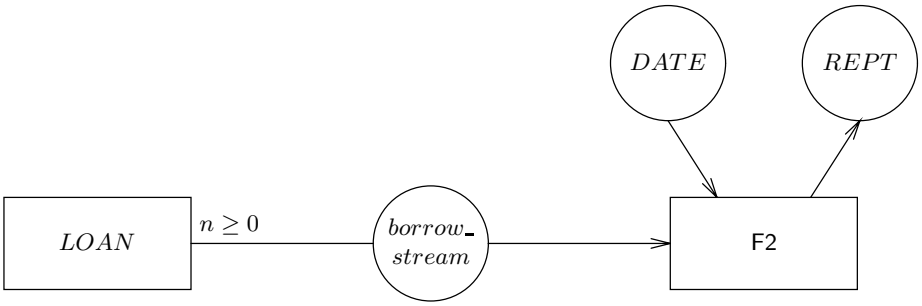
4. What is required is that allocation must be a synchronous communication between *ROOM* and *ALLOCATE* instances. Turn the data stream D_2 into a controlled data stream that locks a *ROOM* instance, observes the state of the instance, and then updates the *ROOM* instance.

Chapter 12: Jackson System Development II: Methods

1. This requires a periodic function process that scans all outstanding reservation processes and cancels those that are past their final date. The connection with the reservation processes must be by controlled data stream, because the deletion is conditional upon the state of the deleted processes.
2. The structure of *D_RESERVATION* is the same as that for *T_RESERVATION*. There are now two *res_borrow* actions, *t_res_borrow* and *d_res_borrow*, and the normal *borrow* action has an extended precondition that tests that none of these other cases is true.
3. The *FINE* life cycle now starts with a *lose* action and continues with an iteration over *lose* and *pay* actions. A fine is only created upon the first document loss.
4. This is a historical query that is periodically triggered by a temporal event. It is therefore a long-running function. Because it is a historical query, we cannot scan model processes on their current state using a state vector connection, but we must keep a log of the relevant action occurrences in a data stream. In addition, the function process will take input from the clock, to be able to notice the end of a week. The system network and a possible process structure for the periodic borrowing report function are shown in figure A.7. This process assumes that there is always at least one borrowing in a week. If this assumption cannot be made, a provision for a null report must be added, similar to the *null* action of F1. The *LOAN* process must be extended with the action *add borrow to borrow_stream* immediately after the *borrow*(and *borrow_res* actions (figure 12.7).

Chapter 13: A Framework for Requirements Engineering I: Models

1. (a) There is not enough information to put any other constraint in the model than $n \geq 0$.
   (b) A possible subject area *PRODUCT_OBJECTIVE* is the tree whose root is *GOAL*. The rest is then part of the subject area *PRODUCT_ENVIRONMENT*.
2. Figure A.8 gives a possible trace of a model containing one student s, one course c and one test t. Each column shows a history of an object, with the earliest action occurrences at the top. Synchronization by common actions is indicated by horizontal lines. Actions in the history of different objects not connected by a horizontal line may occur in any order (compatible with the synchronization points). The student receives a mark twice, without doing a test in between. This possibility remains when there are many students, many courses and many tests.
4. (a) Figure A.9 shows part of a specification of a simulation of a data stream. The connected processes are represented by external entities. The data store contains records labeled by a sequence number, that indicates the sequence in which they were put in. It



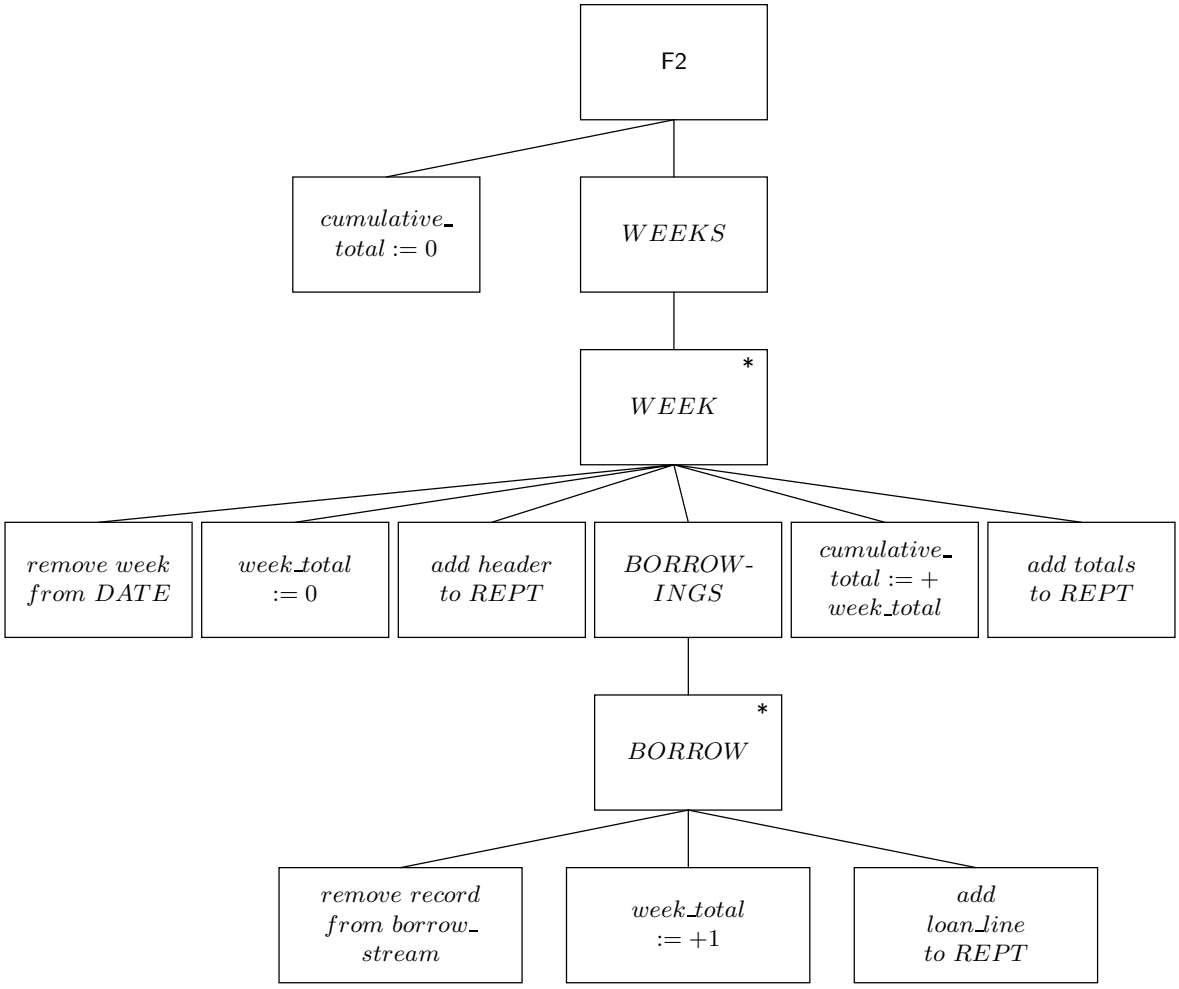


Figure A.7: System network and process structure for the periodic borrowing report.

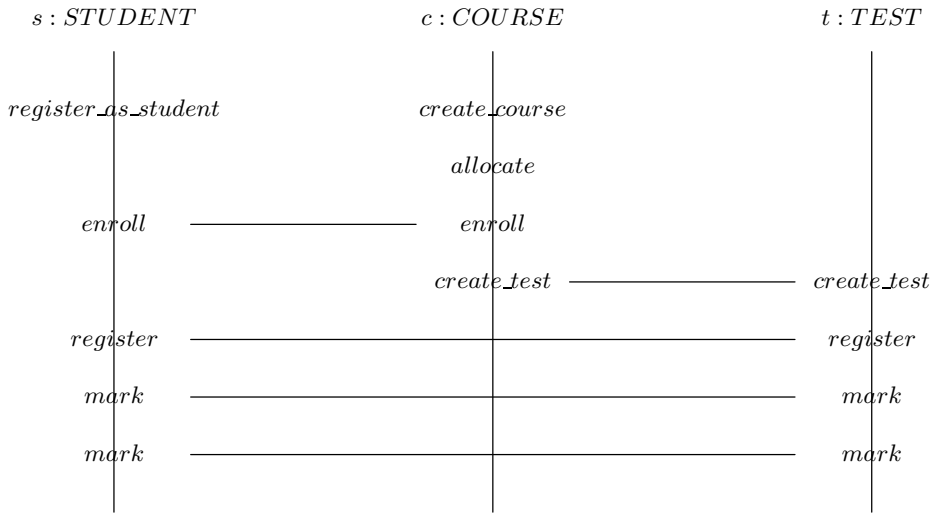


Figure A.8: A possible history of the student administration.

starts with the next sequence number to be given out and then contains the set of records written to it but not yet removed. This model cannot simulate the case where records are not stored but passed immediately, because addition and removal are then one atomic action. In the DF simulation, they are two atomic activities (functional primitives) performed in sequence. Moreover, The DF simulation cannot adequately represent the cardinality of the data stream connection.

(b) Figure A.10 shows a simulation of a controlled data stream. Records are passed immediately, depending upon the current state of the receiver. The conditional update is a functional primitive and is therefore atomic. (Just like the controlled data stream connection in JSD, it may have to wait till the observed process sends it its state vector.) However, it cannot represent the cardinality of the connection.

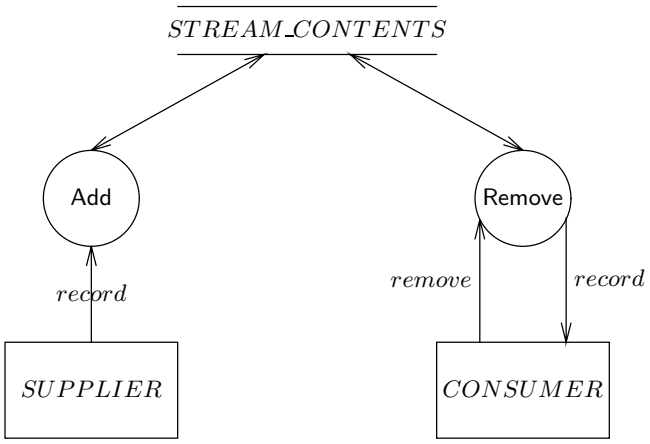
5. (a) Each JSD entity type corresponds to a JSD entity type or to a relationship. To complete it, we should check whether there are relevant actions in the remaining ER entity types and relationships.

(b) Each functional primitive corresponds to a JSD action in the UoD model. There are some minor differences in naming, due to the difference in perspectives of JSD and DF modeling, that can be easily resolved.

(c) Figure A.11 contains the DF diagram and the minispecs. The minispecs use pseudocode that is sufficiently clear for a programmer to code the functions.

Chapter 14: A Framework for Requirements Engineering II: Methods

1. As explained in subsection 12.2.1, the action allocation table omits all R's because these represent the testing of preconditions. As indicated by the action allocation heuristics in

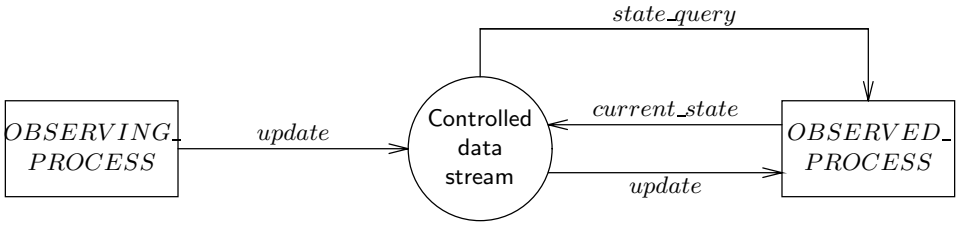


$STREAM\_CONTENTS = next\_sequence\_nr + 0\{record\}next\_sequence\_nr - 1$
$next\_sequence\_nr = NATURAL$
$record = sequence\_nr + \cdots$
$trigger =$ "Remove record"

Add
Read $record$ from $SUPPLIER$,
read value of $next\_sequence\_nr$ from $STREAM\_CONTENTS$,
write value of $next\_sequence\_nr + record$ to $STREAM\_CONTENTS$
increase $next\_sequence\_nr$ by 1 and
write it to $STREAM\_CONTENTS$.

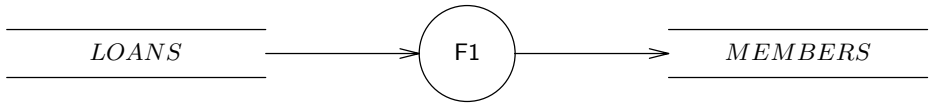
Remove
Read $trigger$,
Read $record$ with highest $sequence\_nr$ from $STREAM\_CONTENTS$,
Remove this $record$,
Write it to $CONSUMER$.

Figure A.9: A DF simulation of a data stream.



Conditional update:
Read $update$ from $OBSERVING\_PROCESS$,
write $state\_query$ to $OBSERVED\_PROCESS$,
read $current\_state$ from $OBSERVED\_PROCESS$,
if $current\_state$ satisfies the update condition of the controlled data stream
then write $update$ to $OBSERVED\_PROCESS$.

Figure A.10: A DF simulation of a controlled data stream.



F1:
Each day at 9:00 do:
search $LOANS$ for records with $date\_last\_reminded \leq today - 6\ weeks$,
for each of these,
read $pass\_nr$ of member from the record,
write $suspend$ to this member in $MEMBERS$.

Figure A.11: DF diagrams and minispecs of F1.

figure 12.3, testing the state vector of an entity type is not sufficient reason for allocating the action to that entity.

Chapter 15: Development Strategies

2. (a) To generalize to arbitrary client-driven development, replace the programming task by the construction task.

   (b) To change it into a market-driven strategy, the acceptance test is performed by the marketing department. Often, this is followed by β testing at selected customer sites, after which a release follows.

3. (a) Specification of required properties, performed during the initial stages of development.

   (b) Planning, performed during the initial stage of development.

   (c) Producing a user's manual is part of product development when the product to be delivered consists not only of executable software but is an installed system. It is performed during the implementation stages, starting from architectural design.

   (d) This is part of architectural design, as a preparation for the selection of algorithms in the next stage.

   (e) This is part of the programming task.

   (f) This is a task belonging to organizational implementation of the developed product.

   (g) This is part of the coding task, performed during the initial stage of development.

   (h) This is part of architecture design and performed during the corresponding stage.

5. Just like evolutionary development, the craftsman changes his design (1) in small steps and (2) in response to a mismatch between the product and user requirements that is experienced in actual use. However, (3) in evolutionary development, the product is then changed to reduce this mismatch. Wagons are not so easily changed as software is, and in general the learning experience led to an incrementally changed design for the *next* wagon to be built. In this respect, wagon-making is more truly evolutionary than evolutionary software development. Evolution is the property that *populations* adapt themselves to their ecological niche. As a metaphor, this is more accurate for traditional wagon-making than it is for software development. (4) A second difference is that there is no global product idea, part of this is then worked out. At any point in time, there are already wagons in use. (5) A third difference is that no global design of the wagon is ever made. This means that no global change to the design can be planned, nor can the likely effects of such a change be estimated.

Changes must be local and only incrementally different from designs that are known to work from experience.

The difference with experimental development is (6) that the customer requires a robust product. The livelihood of the customer depends in part on the quality of the product, so the customer doesn't want any surprises. This is another explanation for the incremental nature of design changes.

6. (a) ETHICS only contains product development tasks.

   (b) The entire ETHICS method deals with the social system level. The two questions that it tries to answer are: 1. How can the efficiency and job satisfaction needs of the organization unit be met? and 2. How do we decompose the organization unit into social and technical subsystems so that these needs are met?

   (c) ETHICS contains an exact match with the engineering cycle: tasks 1 to 9 correspond to **needs analysis**. Tasks 10 and 11 correspond to **synthesis**, **simulation** and **evaluation**. Task 12 corresponds to **choice**. This ends the correspondence with the engineering cycle. In terms of our development framework, task 13 is a decomposition task that brings us to a lower level of aggregation.

   Task 14 implements the design and task 15 evaluates the implementation. Thus, tasks 13, 14 and 15 correspond to the regulatory cycle.

7. (a) All tasks that say which documents must be written and whom to consult at which point in time are process management tasks. In particular, the *assemble report* tasks are process management tasks.

   (b) **Social system level**: feasibility study and requirements analysis. **Software system level**: requirements specification. **Decomposition of software system**: investigate technical system options (410, 420). **Software subsystem level**: specify logical design. **Software subsystem decomposition**: physical design.

   (c) Feasibility study and requirements analysis are two iterations through the engineering cycle at the social system level. After the preliminary cycle (feasibility study), requirements analysis performs a thorough needs analysis (investigate current environment), generates solutions, simulates and evaluates these (cost/benefit analysis and impact analysis in task 210) and chooses one.

   Requirements specification does not match to the engineering cycle. It can be viewed as a conceptual modeling task, in which a vaguely specified solution is modeled more explicitly. This is a descriptive activity; the normative questions have been dealt with in requirements analysis (task 2).

   Task 4 (investigate technical system options) is a decomposition that follows the rational problem solving cycle.

   Task 5 (specify logical design) is a conceptual modeling task at the level of software subsystems.

Chapter 16: Selecting a Development Strategy

5. (a) *Spiral method.* The growth envelope is limited, understanding of the requirements is high and robustness of the system must be very high. Depending upon available product alternatives, transformational development or waterfall development are possible options.

   Euromethod. Although this is an embedded system and not an information system, it is nevertheless illuminating to apply the Euromethod heuristics. The initial state

is that there exist requirements for the current generation of control systems. These are well-understood and the project aims at reimplementing these systems using new technology. According to figure 16.6, this should be performed in several adaptations. Due to the high safety requirements and the strategic importance of of the system, risk must be reduced to a minimum. It is decided to perform two adaptations, one in which a global system design is produced and a second one in which this design is implemented.

In both adaptations, the complexity of the manipulated information is low; however, the target domain factor more suitable to this domain is the complexity of the control structure of the system, and this is complex. Furthermore, the strategic importance of the system is high, which increases the uncertainty about the system. Complexity and uncertainty are further increased because the complexity of the target technology is high and the technology is novel. Uncertainty arises in the project domain as well, because the *development* technology is complex and relatively unknown: the company's engineers have little experience with computer technology. All of this leads to the selection of an incremental construction strategy: Requirements are known but will be implemented incrementally for each of the two adaptation processes. Note that the second adaptation process (from global design to implementation) can start as soon as the first process delivered its first increment of the global design and that from that point onwards, there will be two parallel adaptation processes until the global design is finished.

In this example, Euromethod leads to a more conservative advise than the spiral method. This is mainly due to the larger number of factors considered by Euromethod, which leads to a sharper focus on the project risks and thus to more risk-avoidance.

(b) *Spiral method.* The growth envelope is large and the understanding of requirements is low. Robustness of the system must be high and there is, at the higher levels of network technology, no technology of reusable components. (At the lower levels, standard network software is available on the market.) Architecture understanding is low. The spiral method heuristics lead to risk reduction followed by waterfall as one possible strategy, and the full spiral method as another. Due to the high robustness desired of the system, risk reduction followed by waterfall is chosen.

Euromethod The difference between initial and final state leads to a decision to perform more than one adaptation. One possible sequence would be the production of an information system change study first, the production of a global design next, the production of a tested system next, and finally the production of an installed system. For any of these adaptations, the information system complexity factors all score on the high side; the information system uncertainty factors all score on the uncertain side. Due to the many different systems in operation, the complexity of the computer system is high. The uncertainty about the computer system is medium to low, for all computer technology to be used in the project is commercially available. The complexity of the project task is high and the uncertainty of the project is medium to high. The number of interfaces is potentially high. Project uncertainty is also increased by the potential dependency on subcontractors and on other IS adaptations. Given the complexity and uncertainty about the target domain as well as about the project, the project manager would do well to keep the complexity and novelty of the development technology low. In the face of all of this uncertainty, the Euromethod heuristics recommend evolutionary construction.

The difference with the spiral method recommendation can be explained by the fact that risk reduction, recommended by the spiral method, is *always* recommended by Euromethod (we did not treat risk reduction in chapter 16). Furthermore, the sequential

nature of the waterfall process is also present in the Euromethod advice to perform several adaptations in sequence. The Euromethod advice can be viewed as a refinement of the spiral method advice by recommending evolutionary construction.

Appendix B

Cases

B.1 The Teaching Administration

A teaching administration maintains data about courses, practicals, tests, examinations and students. Each course and each practical is given regularly and there are one or more tests for each course. An examination consists of a number of tests. The examination is done by doing these tests. Examinations are done once every month and consist of a ceremony in which students receive proof of having passed the examination. When a student hands over proof of having done these tests with sufficient result, he or she has the right to participate in the ceremony.

To be able to do a test for a course, a student must register for the test. Each test has two or more supervisors, who check that the test participants are registered for the test. Students must register for a test at the teaching administration. One day before the test is conducted, the teaching administration produces a list of test participants, and this is given to the supervisors. When students come to a test unregistered, they are sent by the test supervisor to the teaching administration to register. The student receives a late registration slip from the administration, which he or she can show to the supervisor as proof of registration.

There are members of staff, called counselors, whose task it is to monitor student progress and help students when there are problems with their progress. Every six months, the results of all students are aggregated in a report and discussed by student counselors. Students whose progress is too slow, are called to their counselor for advice. In addition, each student receives an advise about study continuation after his or her first year of study. Every year, each student receives a report about his or her results so far.

B.2 The University Library

The functions of the Free University Library are (1) to acquire documents containing information that is of use for scientific research and education, (2) to catalog these documents, (3) make them available, (4) preserve them, and (5) to act as custodian of the documents it acquired. The collection is made available not only for the Free University but for any scientific research or education at all. Other universities and colleges have the right to use

the library, and as a matter of fact do so. The only prerequisite for getting registered as a library user is showing a valid proof of identity, so private individuals can use the library as well. However, most users are students or staff at the Free University.

The library is divided into departments that more or less reflect the structure of the university in departments. Thus, there is the Biology library for the faculty of Biology, the Mathematics and Computer Science library for the Faculty of Mathematics and Computer Science, etc. Department libraries are located close to the Faculty they serve. Department libraries are grouped together into Scientific Area libraries. For example, there are α, β and γ areas. Libraries in one scientific area have a common administration.

A user is someone who has a reader's pass. Any student or employee can acquire a pass, as well as citizens who are not otherwise related to the university. A group of employees can also acquire a pass, called a "group pass". There should be one person accountable for the actions of this group, but any member of the group can borrow a book.

The library acquires a wide diversity of items, such as books, journals, series (e.g. the Springer Lecture Notes in Computer Science), Proceedings, internal reports from their own or from other universities, unpublished reports from research laboratories, Ph.D. theses, maps, microfiches, videotapes, old manuscripts, newspapers, microfilms, etc. Some of these are acquired for students (often several copies), most of these are for research purposes. Books themselves can come into a great variety of forms, such as multivolume works, multi-edition works, and even works that appear as one volume in one edition and as several volumes in the next — after which only volume 1 goes through successive editions.

Most books can be lent to users, but some can only be read in special rooms. Similarly, old volumes of journals, when bound, can be borrowed, but loose issues cannot be borrowed. Borrowable items receive a unique code so that they can be traced to a borrower.

A user can borrow a book for three weeks. Researchers can in addition borrow it for three months. At the end of the allowed lending period, a user should return the book or else renew the borrowing. Renewal can only be done when there is no reservation for the book. If a user does not return of book or does not renew the lending period, action is only taken after 1 extra week, by sending him or her (or them) a reminder. So a user is reminded of his obligation to return the book 4 weeks after it was borrowed. If it is not yet returned or renewed, a second reminder is sent after 7 weeks. After the second reminder, the user has still one week to respond. If one week after the second reminder there is no message from the user, he or she must pay a fine of Dfl 70 and is not allowed to borrow any more books until the book is returned and the fine is paid.

Any user can reserve books that are currently borrowed by someone else. He or she will receive a message when the book is available and the library will hold the book for ten days so that this user can borrow the book. If the book is not fetched after ten days, the book is returned to the shelf. There can be at most one reserver for a book.

If a user loses a book, he or she has to report this to the administration, who will issue an invoice for the price of the book. If a user loses a pass, the pass is registered as lost and the library will issue a new pass at no cost. If the lost pass is found, the user has to return it to the library. Journal issues can be lost as well. Since issues are not lent to users, this cannot be attributed to any particular reader.

For some years now, the library experiences problems that cause increasing hindrance to library staff as well as users and that hinder the library in the realization of its primary function, making scientific documents available to its users. An unknown number of books and journal issues is lost or stolen, and often it is not known which of the two is the case.

Sometimes, a book registered as present cannot be found on its shelf and there is no record of it being borrowed to anyone. On the other hand, a book registered as borrowed or even as stolen may be found on a shelf. There are no reliable statistics of the use of documents and of their availability, such as the ratio between reservations and borrowings. Availability of documents is further decreased because some users, especially University staff, lend books for months or even years without bothering to return them.

These problems have budgetary consequences, for lost or stolen documents must be replaced and the costs of this are added to the normal costs of paying for journal subscriptions and the acquisition of books. In the coming years, the library budget for the university is not likely to increase, to put it mildly. In view of cuts in university funding by the government, the budget will probably decrease in the next few years. At the same time, scientific publishers start new journals almost every month, and tend to double the subscription rate every few years. Most subscriptions are in US dollars, and due to fluctuations in the dollar rate, this price increase may pass unnoticed in some years and hit extra hard in other years.

Some faculties chronically overspend their budget by simply refusing to terminate subscriptions. Especially faculties of "old" sciences such as Chemistry, Physics and Mathematics have some very expensive reference journals and in addition a wide assortment of subscriptions that cover some specialities within their science very well. However, those faculties argue that they have a minimal subscription portfolio already, and that termination of more subscriptions would endanger the quality of their scientific research, which is of a high level. All faculties, young and old, argue that they only have subscriptions to a fraction of the available journals, and that it would be irresponsible to terminate even one of them. For some of the older faculties, some of these subscriptions were started in the nineteenth century and the library and faculties all agree that it would be a shame to terminate such a subscription. However, they disagree on whether this implies that these subscriptions therefore should not be terminated, no matter what the budgetary consequences.

There are no competitors which aim at the same part of the market, and the library is a non-profit organization, so performance cannot be measured in terms of profit. The long-term objective of the library is to improve the level of service currently provided to the user, and to look for possibilities to provide new services. As part of the realization of the first objective, organizational measures are taken that aim at making more efficient use of the financial means at the disposal of the library than is done now. These measures are described below.

As part of the realization of the second objective, the possibilities for providing new services are being studied. There is a national EDI network for university libraries and public libraries of which the library is not yet a part. Access to this network would allow the users to find literature fast and request it from the appropriate library anywhere in The Netherlands. Possibilities for extending this kind of service by connecting to a European network are also considered. In addition, the library catalogue should be made available online to users, and there are plans to provide entry into the catalogue by terminals installed at the library itself, through a modem connection, and through the local area network of the university.

To eliminate some problems experienced by the library, and reduce others, the library is reorganized. To spend the library budget more efficiently, all double subscriptions to journals should be terminated, so that for each journal, there is at most one subscription owned by the University. Similarly, books already present in the University library in one department should not be bought by another, unless there is good reason to do so.

Journals cannot be borrowed anymore, neither in single issues nor in bound volumes. All library departments get photocopiers so that papers from journals can be copied without borrowing them.

To reduce theft, documents that can be borrowed are marked in an indelible way, and ports with sensors are installed at the entry of each library.

An IS should be installed that supports library staff in the stricter enforcement of library rules. For example, the borrowing limit of three weeks will be strictly maintained, and to support this enforcement, a report should be produced each week on documents who are borrowed for longer than their allowed lending period, together with a standard letter that is sent to the user. In addition, once every year, all users are to be sent a list of lost or stolen books, so that they become aware of the problem.

Appendix C

An outline of some development methods

C.1 ETHICS

ETHICS (Effective Technical and Human Implementation of Computer-Based Systems) is a sociotechnical system development method, developed by Enid Mumford of the Manchester Business School in the late 1970s and early 1980s [237, 235]. A **sociotechnical** development method is a method to develop a system that consists of of a human subsystem and a technical subsystem. Sociotechnical development is oriented to developing both subsystems in an integrated way, so that the integrated system functions in an optimal way. This development strategy has its background in studies done in the 1950s on the relationship between social structure and technology in organizations [347]. Emery and Trist [95] give a brief introduction to sociotechnical development. Bostrom and Heinen [47] give an introduction to sociotechnical ideas for system developers and apply these ideas to an analysis of success and failure factors of information system development. ETHICS is a sociotechnical development method oriented towards information systems at the operational level of an organization. Pava [256] shows how sociotechnical ideas can be applied to the development of strategic information systems.

ETHICS can best be viewed as a development method for organization units, with equal emphasis on the job satisfaction aspect, the workflow aspect and the information aspect of the unit. Most of the method is spent in requirements determination, which follows a rational choice cycle. Work design and implementation involves designing and implementing a (new or renovated) information system, but there is no specific advice of ETHICS about this.

ETHICS is a participative method that follows the consensus model. The efficiency needs and job satisfaction needs are collected and diagnosed by means of questionnaires given to all people who work in the organization unit. Decisions are made by involving all workers in the unit, who should all support the decisions. The decision about the change option should be verified with the appropriate management authorities.

An outline of the ETHICS method is given in figure C.1.

1. Determine the reasons for change.
2. Determine the boundaries of the organization unit to be developed.
3. Describe the organization unit as it currently is.
4. Define the key objectives of the unit.
5. Define the key tasks performed in the unit.
6. Determine the *information needs* of these tasks.
7. Collect the accidental problems with the current organization of work in the unit, i.e. problems that are due to the way the workflow in the unit is currently implemented. Diagnose these problems. The underlying problems are called *efficiency needs*.
8. Collect information on job satisfaction problems in the current organization of work. Diagnose these, and call the underlying problems *job satisfaction needs*.
9. Use the information needs, efficiency needs and job satisfaction needs to determine the change objectives of the development process.
10. Generate and evaluate organizational change options.
11. Generate and evaluate technical change options.
12. Merge the technical and organizational options and choose one.
13. Make a detailed work design for the chosen option.
14. Implement the work design.
15. Evaluate the new situation.

Figure C.1: Outline of the ETHICS method.

1. **Feasibility study**. Find out if the development of a computer-based system would provide benefits that justify the cost of the development process.
2. **Classical structured analysis**.
   (a) Specify the current system, allowing physical details.
   (b) Specify the current essential system by eliminating all physical details.
   (c) Transform this into an essential model of the desired situation.
   (d) Generate alternative physical implementations of the new system.
   (e) Quantify each alternative by a cost/benefit analysis.
   (f) Choose an option.
   (g) Propose a budget for the chosen option.
   (h) Plan the rest of the project.
   (i) Package the resulting documents into a structured specification.
3. **Structured design**.
   (a) Derive structure charts for the design and add control.
   (b) Design the module structure of the system.
   (c) Package the resulting documents into a structured design specification.
4. **Structured implementation**.

Figure C.2: Outline of classical structured development.

C.2 Structured Development

There are several versions of structured development that can be classified as **classical structured development** and **modern structured development**. In classical development, the current system is reverse engineered to retrieve an essential system model, which is then re-engineered to a model of the desired system. In modern developmemt, the desired system is modeled using event partitioning, without assuming that a current system has been modeled first. Figure C.2 gives an outline of the classical method as proposed by DeMarco [84]. Figure C.3 gives an overview of the modern structured analysis as described by Goldsmith [118].

C.3 SSADM

SSADM (Structured Systems Analysis and Design Method) is the standard method prescribed by the UK government for carrying out development projects for computer-based systems [14, 91, 98]. It assumes that there is a strategic information plan for the business and gives a number of steps that lead from a global information strategy to an implemented information system. SSADM uses structured techniques from a number of other methods, including Entity-Relationship modeling, Structured Analysis and Jackson System

1. Build an essential model of the desired system.
   - 1.1 Build a context diagram.
     - (a) Understand the purpose of the system.
     - (b) Identify the external entities.
     - (c) Define the data flows entering and leaving the system.
     - (d) Check the context diagram.
   - 1.2 Build an event list.
   - 1.3 Build a behavioral model.
     - (a) Build a DFD, an ER diagram, and state transition diagrams (not treated in this volume).
     - (b) Integrate the diagrams.
     - (c) Divide the diagrams into levels.
     - (d) Complete the data dictionary.
     - (e) Add implementation constraints.
2. Build a processor environment model.
   - 2.1 Allocate data transformations and data stores to available processors.
   - 2.2 Document the allocation by means of allocation tables.
3. Specify the human-computer interface.
4. Build a software environment model.
   - 4.1 For each processor, allocate behavior to standard software already available on the processor.
   - 4.2 Allocate remaining behavior to execution units.
   - 4.3 Document the allocation by means of allocation tables.
5. Build a code organization model.
   - 5.1 Translate each DFD into a structure chart.
   - 5.2 Complete the traceability tables that show allocation of transformations to modules.

Figure C.3: Outline of modern structured development.

Development. SSADM assumes that there is a project board which monitors the information strategy of the business and to which the project team executing the SSADM process reports. Every step in the feasibility study is verified with the project board.

SSADM consists of 5 tasks, called *modules*, each of which is divided into one or more tasks called *stages*, which themselves are devided into a sequence of *steps*. Figures C.4 and C.5 give an outline of SSADM. The construction, test and operation tasks are not part of SSADM.

Feasibility study

0. Feasibility

   010 *Prepare feasibility study.* Define scope of the project, identify stakeholders and problem areas, create a high level model of data and activities.

   020 *Define the problem.* Identify the activities and information necessary for the business unit to meet its objectives, identify those aspects of current operations where improvement is required, identify new features of the system, identify nonfunctional requirements.

   030 *Identify feasibility options.* Draw up a list of minimum requirements, to be met by all options. make a list of up to six business system options and up to six technical system options. Combine, trim down to about three, document these and do a cost/benefit analysis and impact analysis of these. Identify preferred option and assist project board and users in selection.

   040 *Assemble feasibility report.*

Requirements analysis

1. Investigate current environment.

   110 *Establish analysis framework.* Review output from feasibility study, identify target users, plan the project.

   120 *Investigate and define requirements.* Investigate current system operation, including frequencies, volumes, etc. Identify intended users and identify opportunities for improving current system, as well as desired functions and data not currently provided.

   130 *Investigate current processing.* Create a data flow diagram of current processing. Identify shortcomings of current processing with users and add to requirements.

   140 *Investigate current data.* Create an entity model of current data. Identify shortcomings of current data with users and add to requirements.

   150 *Derive logical view of current services.* Make logical model of current processing and data.

   160 *Assemble investigation results.*

2. Investigate business system options.

   210 *Define business system options.* Make a list of requirements, define up to six business solutions, cut down to three with user, describe each of these and do a cost/benefit analysis and an impact analysis.

   220 *Select business system option.* Present to project board, record choice made and complete description of this choice.

Figure C.4: Feasibility study and requirements analysis in SSADM.

Requirements specification.

3. Specify requirements.

   310 *Define required system processing*. Transform logical model of current processing to agree with selected option. Define user roles and correlate role with new processing model.

   320 *Develop required data model*. Transform logical model of current data to agree with selected option and with new processing model.

   330 *Derive system functions*. Identify update and enquiry functions, specify I/O interface of each function, cross-reference with user roles and identify critical dialogues.

   340 *Enhance required data model*. Normalize data of selected functions and verify the result with logical data model.

   350 *Develop specification prototyping*. Create prototypes of dialogues, reports, screens and access paths for selected functions. Test with users and iterate if necessary.

   360 *Develop process specification*. Identify for each entity in the logical data model which events create, update or delete it and define a life cycle of events for the entity. Include parallelism, interaction and abnormal termination. Specify all entities affected by an event and define enquiry access paths.

   370 *Confirm system objectives*. Ensure that all functional requirements are met and that all non-functional requirements are defined.

   380 *Assemble requirements specification*.

Logical system specification

4. Investigate technical system options.

   410 *Define technical system options*. Identify ways to implement requirements.

   420 *Select technical system option*.

5. Specify logical design.

   510 *Design user dialogues*.

   520 *Define update processing model*.

   530 *Define enquiry processing model*.

   540 *Assemble logical design*.

Physical design

6. Specify physical design

   610-... (Details omitted)

Figure C.5: Requirements specification, logical system specification and physical design in SSADM.

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Index