MESSAGE DEVELOPMENT IN THE BUILDING PROCESS

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New communication media offer new opportunities to exchange information between participants in a building project. A case study was done of a specific building project from the viewpoint of a company that produces concrete floors. An executable simulation model was used to create a formal description of the information exchange process. The output of the simulation is an activity schema, a message exchange diagram and a list of messages. The schemata give insight about the information flow and are a resource for developing a strategy for the introduction of electronic communication. The messages serve as a starting point for selecting a standardized electronic message or developing a special one.

1. INTRODUCTION

Every new communication medium that comes to the market offers a challenge for researchers to find appropriate applications. Fairly recent introductions are: telefax, floppy disk and electronic network. The major question is, what is appropriate in this context. To answer the question it is necessary to create a clear view about what we communicate and how we do this nowadays. To narrow the research field to the building industry, the question is adjusted to: 'Which information is being exchanged during a building project'. First a clear definition has to be created from the current information exchange process. From that we can search for opportunities to introduce new technologies such as electronic communication. Likely will new technology lead to rearrangement of the building process as a whole. To create a formal definition of the current process and to verify the effects of alterations on the whole process, a simulation tool for information exchange has been developed at the Eindhoven University of technology [Vries 1994]. The theoretical background of the simulation model is based on the Message Exchange Model [Vries 1995]. The *simulation model* is an executable process model of the information exchange process for a specific

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building project. A *building project* is defined by the begin and end state of the building product and by the building participants that are involved. A *building product* is defined by a list of objects and their aspects. Each *participant* is capable of executing a set of activities. An *activity* is defined by the required input and the produced output. Input and output in return are defined by lists of objects and their aspects. While executing the simulation model a list of messages is generated again consisting of object and their aspects.

In this paper a case study is presented of a company that produces concrete floors. The company wishes to know which part of the design and construction process could gain benefit from electronic transfer with other companies. The intermediate results of the following steps will be presented: (section 2) analyses of a specific recent realized building project, (section 3) simulation of the information exchange process using the simulation tool, (section 4) a set of tables and schemata showing the result of the simulation, (section 5) a discussion about the result of the simulation and the application of the results in practice and (section 6) a conclusion about the applicability of the simulation tool.

2. ANALYSES OF A BUILDING PROJECT

A specific building project has been selected as a reference project. In general all types of projects should be analysed. A project belongs to a specific *project type* if the contents of the information that is exchanged is determined by the building product and by the building participants that are involved. These two variables are the top level parameters of the simulation model. A building participant in this context is the role a building company plays in a specific building project. In the case study the design, the production and the deliverance of the floor slabs for the first floor of 30 houses was selected as the reference project. The floor production company considered the project as 'average' due to the project size, the product complexity and the role of the other participants. Because the role of concrete floor company is studied in more detail, it is divided into four departments.

All information that was produced during the project has been analysed to identify 'atomic' activities. About 25 document (letters, drawings, schemata, tables) were collected. From the documents and the interviews that were held with the employees in the floor company, a list of activities is reproduced. An 'atomic' activity in the message exchange model is a group of work items that can be advertised (in principle) outside the company. Because the simulation model does not include resource stores, activities that will return repeatedly during the process have to be entered separately (e.g. one day floor production). In the case study the following activities were distinguished per participant:

the sales department of the floor company

1. order acquisition

the design department of the floor company

2. floor dimensions design
3. strength analyses
4. reinforcement design
5. complete floor design

the production department of the floor company

6. one day floor production 1
7. one day floor production 2
8. one day floor production 3
9. one day floor production 4
10. one day floor production 5

the production preparation department of the floor company

11. production preparation

the main contracting company

12. order definition
13. floor openings indication
14. floor sequence indication
15. floor slab placement 1
16. floor slab placement 2
17. floor slab placement 3
18. floor slab placement 4

the structural design company

19. structural design verification

the transport company

20. floor stack transport 1
21. floor stack transport 2
22. floor stack transport 3
23. floor stack transport 4

the reinforcement production company

24. reinforcement production
25. reinforcement transport

After identifying the activities, each activity is defined by a list of input and output objects. A major problem is, that almost all documents contain more information then strictly required for their purpose. It is very important that only the required input and the produced output are added to the activity definition list. To create the correct list knowledge of the actual work that is done by the employees is indispensable. Three categories of object types are recognized:

1. physical building object type (e.g. door)
2. spatial building object type (e.g. living room)
3. labour object type (e.g. brick laying)

Object names are chosen close to common terminology. Each object type has a unique set of aspect types. Aspect type names are retrieved (if possible) from standards (e.g. fire resistance). The set of aspect types should enable each participant to map the objects from a message to the data structure of his company. Aspect types and object types are mutually exclusive. Thus, all entities that are not an object type, are an aspect type. The analyses of all documents and current activities will result in long lists of activity definitions for each participant. The lists can be stored using a word processor or even better, using a database.

The last part of the preparation for the simulation is the product begin and end state definition. In the case study the project starts with a request from the main contractor to the floor company to calculate the cost of the design, production and deliverance of the floor slabs. The project ends when all floor slabs are in place on the building site. Product begin and end state definition are performed analogue to the activity definitions.

3. SIMULATION OF THE INFORMATION EXCHANGE PROCESS

Before using the simulation model an agreement has to be defined between all participants. An *agreement* enables the control of the information flow. It contains: a list of participants, for each participant a list of activities, for each activity a list of input objects and a list of output objects. Additionally the activity type and the execution time is defined for each activity. Activities are divided into two types: tasks and requests. An activity of type *task* is defined if new data are generated. An activity of type *request* is defined if information is retrieved that is already available.

To create an executable simulation model all parameter values (product begin and end state, participants, participants' activity definitions, agreement) are 'bound' with the model. The parameter values are enclosed in the ExSpect [Hee 1989] text and then recompiled. After compilation an executable model of the building project is available. Executing the model means that participants will start activities themselves or at other participants in order to reach the end state of the building product. To start an activity at another participant, a message containing a task is sent to him. On receipt of a task an activity is executed if all required information is available. Otherwise a message will be sent to another participant to obtain the missing information. After execution of an activity a reply is sent with the desired data.

Using the simulation model takes two steps to generate the required data for the construction of the schemata. To start with, a *first order agreement* is defined simply by copying all activity definitions from the participants. Additionally all activities become of type 'task' and get an execution time of one unit. While executing the simulation model, a check is made against:

- completeness

Incompleteness means that the requested information is not available at a certain moment during the project. This problem requires adjustment of the activity definition.

- consistency

  Inconsistency means that a participant works with out-dated information at a certain moment during the project. This problem can be solved by introducing an activity of type request that delivers the actual information at that time.

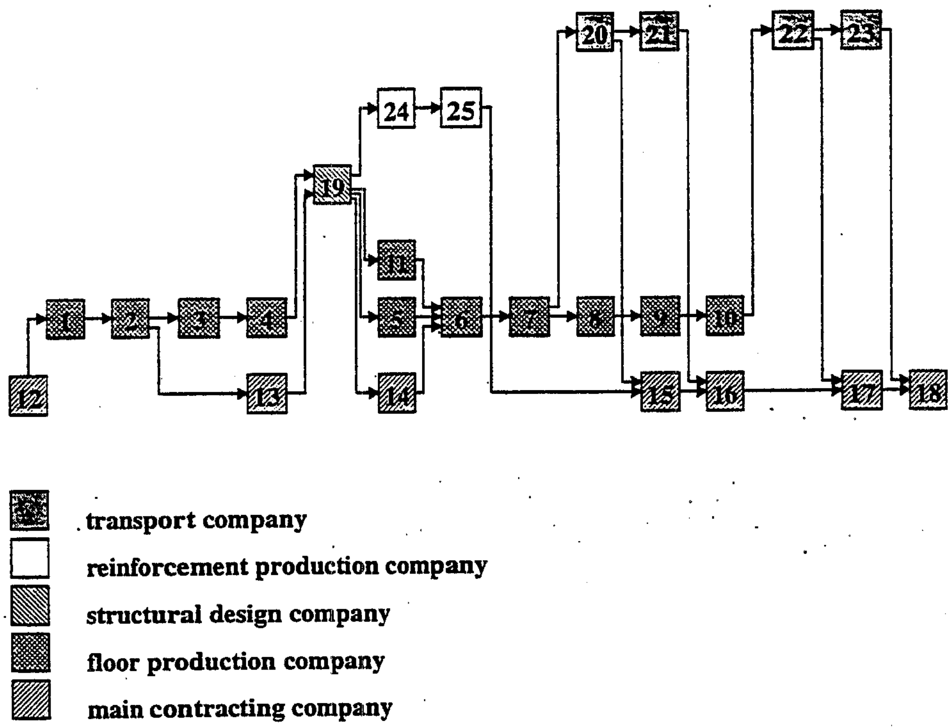
Next step is to create *a second order agreement* in accordance with the project organization (e.g. subcontracting). The organizational structure of the project controls the information flow between the participants. The first order agreement is adjusted by:

1. grouping sequences of activities into one new agreement activity definition
2. removing output from the agreement activity definition that will by produced by subcontracting
3. removing input from the agreement activity definition that will be retrieved as already available information

4. RESULTS OF THE SIMULATION

The simulation of the building project will result in a list of messages that are exchanged between the participants. Each message contains: the sender name, the recipient name, the activity name, the time the message was sent, the objects and their aspects with a time stamp and the message sequence number. These data are used to create the following schemata:

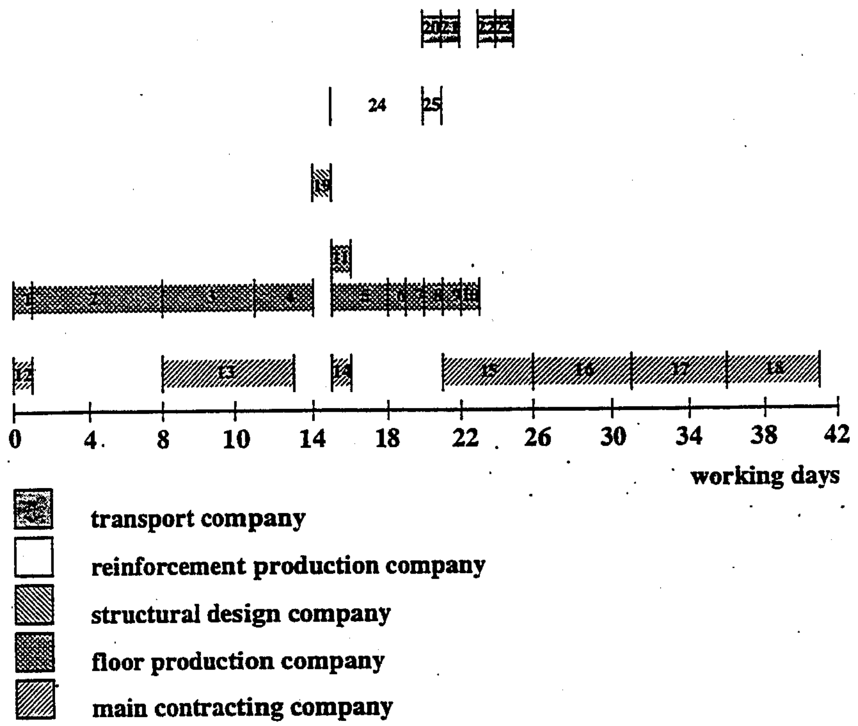
FIGURE 1. Activity network



An activity network shows the information flow between activities. The activity network is deduced from the list of messages that is generated from the first order agreement. All activities take equal time to execute and each activity will be started by the participant the initiated the project. The activity network is modelled as a PERT network. The most important property of the network is that an activity can only start executing if all input channels contain the required information. The squares symbolize the activities, whose sequence numbers can be found in section 2. The arrows symbolize the channels through which the information flows from one activity to another. Since the case study is focused on information exchange between participants, all departments of the floor production company are concentrated into one company. The channels that have our special interest are the channels that connect activities between two different participants. From the activity network becomes clear:

- which activities are interdependent
- which activities can take place concurrently
- which bottle necks exist in the information flow
- which activities have to be reexecuted if already accepted information is changed

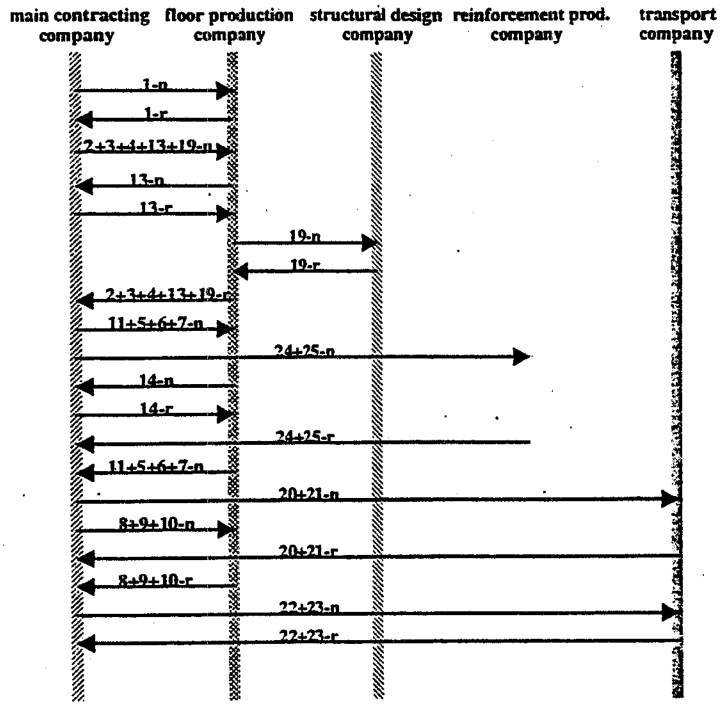
FIGURE 2. Time schedule



The time schedule shows for each activity the number of working days and the starting time. An important property of the simulation model is that it will execute an activity as soon as the required information is available. The activity numbers can be found in section 2. From the time schedule becomes clear:

- the earliest time an activity can possibly start
- which activities form the 'critical path' (in combination with the activity network)

FIGURE 3. Message scenario



A message scenario shows the sequence of messages between participants. The message scenario is created from the second order agreement. Messages carry the activity number of the activity that they started with a '-n' (new) extension or the activity number of the activity that produced the result with a '-r' (reply) extension. Activity sequences are grouped in one message if no intermediate information exchange with other participants occur. Grouping of activities is indicated with a '+' sign. Subcontracting is introduced to achieve that the floor production company is responsible for getting the floor openings indications and for verification of the floor design by the structural design company. In the message scenario the subcontracting activities are added (with the '+' sign) to the actual activities. The message scenario starts at the top. Some messages that are presented one after another, actually are sent concurrently (e.g. 11+5+6+7-n and 24+25-n). Otherwise the schema would have been unreadable.

As a result of the simulation the contents of each message is known. As an example the contents of the message that started the floor openings indication activity at the main contractor and its reply is listed below. Apart from the object types and their aspects, 'new' messages contain an 'operation' attribute. To present the message contents the table format is used. The implementation format may differ from the table format.

TABLE 1. Example message-new: floor openings indication

object	aspect	operation
opening	size	update
opening	location	update
wall	location	none
wall	geometry	none
wall	material	none
stair	geometry	none
stair	location	none
floor slab	geometry	none
floor slab	geometry	none
outlet	location	update
outlet	type	update

TABLE 2. Example message-new: floor openings indication

object	aspect
opening	size
opening	location
outlet	location
outlet	type

5. INTERPRETATION AND APPLICATION OF THE RESULTS

Though the project is just a sample of a building project, it very well demonstrates the possibilities of the simulation environment. Each of the schemata will be discussed in comparison with the current situation. At the same time opportunities for using Information Technology are indicated.

5.1 Activity network

The information flow through an activity network is normally not realistic from an organizational view. The network shows interdependencies between activities that are executed by corporations that never communicate directly in the current situation (e.g. structural design company and reinforcement production company). Although the network shows the most direct flow of information through the network, the drawback is that the participant who initiates the process is also responsible for its continuation. In practice the principal of a project (the main contractor) hands over part of the management of the process to other participants.

A number of activities can execute concurrently, hereby resources are not taken into consideration. In current practice almost the complete process is executed sequential. Concurrent execution of activities requires (more) status control of information and of subcontracting activities. To enable status control a project store containing the actual information about the building product, and a message store containing the messages that are sent and received are required. Information flow between activities within a participant (or company) does not necessarily mean that these activities reside at different people or different applications. On the contrary, human resource management and management of other resources (e.g. apparatus) is complete separated from the business process. The activity network can help to introduce concurrent engineering, because it describes the business process in an explicit way and the shows possible concurrences between activities.

Removing bottle necks from an activity network is a major challenge. Most striking is the bottle neck that is formed by the structural design verification (19). The complete floor design and strength analyses must be verified by an independent specialist. Formally the structural engineer merely should perform the verification, but in real practice it turns out that he will also update the input data with the actual information from the main contractor. The most drastic and effective solution for removing the bottle neck is the elimination of the verification activity. The main contractor and the floor company could agree upon a quality assurance for the complete floor design. Instead of the structural design company, the floor company takes full responsibility. Before creating the complete floor design a request message is sent to the main contracting company to get the actual information.

Consequences of disturbances in a project can easily be traced. During a building project corrective information often reaches a participant after finishing his task. In the simulation model the information exchange process executes smoothly without these kind of disturbances. Disturbances can be simulated also, but it is not possible to predict all kind of disturbances. A more straightforward approach is to look for the first appearance of an afterwards updated object in the information flow. In other words, all messages are searched to find a particular object/aspect combination. The object/aspect combination with the earliest time stamp determines the first activity that needs to be restarted. From the activity network can be deduced which activities depend on this activity.

5.2 Time schedule

Scheduling of activities can be used to optimize the process. The time schedule shows that the floor dimensions design (2) is a time consuming 'critical' activity. Speeding up will directly result in a shorter project time. On the other hand is a shorter production time (11,5,6,7) useless, because it is overruled by the reinforcement production and transport (24,25). After the first stack of floor slab has been transported, the production department can slow down because the main contactor cannot place the floor slab at such speed.

The total project time can be reduced by concurrent execution of activities. Some activities (e.g. reinforcement production) start executing in the simulation model earlier then people are used to. Because the current process is executed sequential, information is 'kept behind' until it is impossible to continue without communication with another participant. The time schedule shows that there are plenty of opportunities to reduce the total process time by executing activities concurrently.

Some activities gain much benefit from electronic communication. The time schedule is based on the amount of time that is spent per activity in the current situation. From the information exchange point of view it is interesting to known which percentage of the execution time is spent on input and output. The percentages are roughly (0, 25, 50,75 percent) estimated [Table 3]. In general input is more time consuming in the beginning of the project, because text and drawings are created from scratch. Afterwards information is extended and added. 'Critical' activities that could gain much profit from electronic input are 'strength analyses' and 'structural design verification'. In the case of strength analyses, a FEM (Finite Element Method) application could be considered that can share data with the floor design system. In the case of structural design verification there is actually no new information generated. Verification can highly be automated if the message that is received by the design verification company could serve as input for (another FEM) computer application. A 'non-critical' activity like 'floor openings indication' can be reduced in time if electronic transfer is available instead of redrawing and retyping information.

TABLE 3. Time spent in input/output

activity	working days	percent. input/output
order acquirement	1	50
floor dimensions design	7	25
strength analyses	5	50
reinforcement design	3	25
complete floor design	3	25
one day floor production	1	0
production preparation	1	25
order definition	1	50
floor openings indication	7	50
floor sequence indication	1	0
floor slab placement	5	0
structural design verification	1	75
floor stack transport	1	0
reinforcement production	6	25
reinforcement transport	1	0

5.3 Message scenario

The message scenario resembles current practice quite a lot, with a few differences:

1. In the simulation model every activity is immediately followed by another activity. In reality there will exist delay times, because for instance there are not enough resources available or because of disturbances (section 5.1). For this reason 'confirm' messages can be inserted to confirm the receipt of the message and to convey the delay time.
2. Messages contain information about abstract and physical objects. If a message merely contains information about physical objects, then instead of transferring the message, the physical object can be transferred. This situation occurs if a stack of floor slabs is transported from the floor production company to the building site. Instead of sending a message containing new information about the location of the floor slabs, the main contractor receives the floor slabs on the building site. The accompanying messages can be skipped (20+21 and 22+23).
3. In current practice the floor production company arranges the transport instead of the main contracting company. From the activity network it shows that the management of the transport should reside at the main contracting company. In the message scenario the transport is arranged by the main contracting company on call, increasing his flexibility in the construction management. As a consequence this may lead to more storage room at the building production company.

5.4 Message contents

The simulated message contents is unstructured, but can serve as a starting point for selecting a standardized message structure (e.g. EDIFACT based or STEP based) or development of a customized message. The 'standard' message should contain all object types that also exist in the message from the simulation model, or an equivalent object type. If a one to one mapping is not possible then additional mapping rules are necessary to transform the standard message data structure to the company data structure. Using standardized messages is probably the most (cost) efficient method of introducing electronic information exchange. However, especially unique products like buildings are hard to standardize. At a detailed level of information it may be necessary to develop one's own messages. Creating a message data structure from the simulated message means introduction of more semantics by adding relationships (specialization, association) and constraints.

6. CONCLUSION

For those companies that are still in doubt whether they should use electronic communication media, the simulation model can help to give more insight on the current situation and to develop a strategy for the implementation. Many companies are still working on smoothing the information flow inside the company. However, as this case study shows, the communication inside a company strongly interferes with the external communication. If an explicit description of the information exchange process is available then a strategy can be developed how to implement electronic communication. The strategy allows for selecting message data structures and transfer media based on implementation independent results from the simulation model.

7. REFERENCES

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