HELSINKI UNIVERSITY OF TECHNOLOGY
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Construction Economics and Management

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PLANNING AND CONTROL IN CELLULAR NETWORK IMPLEMENTATION PROJECTS

Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering.

Espoo, August 1, 1998

Supervisor: Professor Jouko Kankainen
Instructor: Ilpo Luhtala, M.Sc.C.E

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ABSTRACT OF THE MASTER'S THESIS

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The aim of this research was to identify the procedures for planning and control in cellular network implementation projects. The thesis included an interview study that was meant to identify the main problems related to planning and control. Identified problems concern following main issues: the site process, the Work Breakdown Structure, the purchase packages, progress monitoring and control, network planning and site acquisition interworking, the teams and their work performance, information distribution and production planning and control.

The requirements for Project Management resulted from the problems, and the needed procedures for planning and control were based on General Project Management. The theoretical goal was to study Project Management and its knowledge areas, tools, techniques and procedures from the point of view of planning and control of project implementation. The procedures, methods and templates were tested and finalized in a project in Switzerland. The research method was observation through participation.

The main results of this thesis were the common site process model and its descriptions. Also the suitability of the model in practice has been shown. Furthermore, the documented models and templates for the project decomposition, the purchase packages, the project roll-out planning and control, the required teams, the meetings and flow of information were defined.

A turnkey project planning is a time-consuming process. Definition of required procedures should begin already during the tendering phase. There are lots of critical issues which have to be taken into consideration. Particularly, properly defined project decomposition, required teams, a site process with descriptions, a database and flow of information have an essential role in an effective project. The Project Top Management should be kept in NTC Managers' hands.

Production planning needs focusing and developing. In the future, it is important to take into account also repetitive cell production model and synchronized production model in choosing the correct production models for project implementation. By using multiskilled work groups it could be possible to increase the contents of work and to decrease the time of waiting between different work phases. NTC could aim for a situation, in which the production and material quality control is performed by the subcontractors according to their individual quality management systems.

Keywords: Project Management, telecommunications, cellular network, planning, control, implementation project, process, construction

TEKNILLINEN KORKEAKOULU

Rakennus- ja yhdyskuntatekniikan osasto

DIPLOMITYÖN TIIVISTELMÄ

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Diplomityön tavoitteena oli kehittää toimintamalleja matkapuhelinverkon toteutusprojektien suunnitteluun ja ohjaukseen. Tutkimukseen kuului teemahaastattelu, jonka tarkoituksena oli selvittää olemassa olevat suunnittelun ja ohjauksen ongelmat. Ongelmat liittyivät seuraaviin asioihin: tukiasemapaikan toteutusprosessin kuvaus, projektin osittelu, hankintapaketit, projektin etenemisen seurannan valvonta ja ohjaus, verkkosuunnittelijoiden ja tukiasemapaikkojen hankkijoiden välinen yhteistyö, tarvittavat tiimit ja niiden työsaavutukset, tiedon jakaminen sekä tuotannon suunnittelu ja ohjaus.

Vaatimukset projektin johtamiselle perustuivat havaittuihin ongelmiin. Teoreettisena lähtökohtana toimi yleinen projektinjohtokirjallisuus, jota käsiteltiin suunnittelun ja ohjauksen näkökulmasta, lähinnä projektin toteutuksen kannalta. Lopuksi osa toimintamalleista viimesteltiin ja testattiin todellisessa projektissa Sveitsissä. Tutkimusmenetelmänä oli osallistuva havainnointi.

Tutkimuksen keskeiset tulokset olivat yksittäisen tukiasemapaikan toteutusprosessin kuvaus ja sen soveltuvuus käytäntöön. Lisäksi tutkimuksen perusteella saatiin mallit projektin osittelulle, hankintapaketeille, projektin etenemisen suunnittelulle ja ohjaamiselle, optimaalisille tiimeille sekä kokouksille ja tiedon jakamiselle.

Turnkey-projektin suunnittelu on aikaavievä prosessi, jonka valmistelu tulisi aloittaa jo tarjousvaiheessa. Erityisesti projektin ositteluun, tarvittaviin resursseihin, prosessien määrittelyyn ja kuvauksiin, tietokantaan ja tiedonkulkuun tulisi kiinnittää erityistä huomiota. Projektijohdon tulee olla NTC:n omaan henkilökuntaa.

Toistuvan solutuotannon ja tahdistetun tuotannon toimintamallit tarvitsevat vielä lisäkehitystä. Käyttämällä monitaitoisia työryhmiä voitaisiin tehtävän työsisältöä kasvattaa, ja siten vähentää eri työvaiheiden välisiä odotusaikoja. Lisäksi aliurakoitsijoiden laadunvarmistusmenettelyihin on panostettava siten, että laatu varmistettaisiin ilman erillisiä tarkastusvaiheita. Laatutoiminnan kehittämisen tavoitteena olisi, että tarkastukset sisältyisivät osaksi työmenetelmiä.

Avainsanat: Projektin johtaminen, telekommunikaatio, suunnittelu, ohjaus, prosessi, toteutusprojekti, rakentaminen

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GLOSSARY AND ABBREVIATIONS

AM	Account Manager
BSC	Base Station Controller
BSS	Base Station Sub-system
BTS	Base Transceiver Station
CoSy	Complementary System
CPM	Critical Path Method
CS	Customer Services
CW	Construction Works
GSM	Global Digital System for Mobile Communication
HPAC	Heating, Plumbing and Air-Conditioning
JPP	Joint Planning Session
LBS	Location Breakdown Structure
LOB	Line-of-Balance
LOI	Letter of Intent
LOS	Line of Sight
MSC	Mobile Switching Center
NE	Network Element
NSS	Network Sub-systems
NTC	Nokia Telecommunications
PL	Product Line
PM	Project Manager
PMBOK	Project Management Body Of Knowledge
QoS	Quality of Service
RF	Radio Frequency
RFQ	Request For Quotation
SA	Site Acquisition
SAR	Site Acquisition Report
SARF	Site Acquisition Request Form
SITE	Building/room/street/tower/title of land where the equipment delivered by Nokia is to be installed as a part a telecommunication network.
SOW	Statement of Work
TI	Telecom Implementation
TRS	Transmission

Preface

The results and the contents of this thesis are an outcome of a study where several persons have contributed with guidance, knowledge and experience - not to mention their valuable time.

First, I would like to express my gratitude to Professor Jouko Kankainen. During this study Jouko has provided me useful advice that has contributed to the final outcome.

The study presented in this thesis was conducted at Nokia Telecommunications. I am grateful to my instructor Ilpo Luhtala, who instructed my master's thesis really professionally during the whole project. I would like to thank Pekka Koivu, who offered me the possibility to undertake the project and helped with practical matters. Exceptionally great thanks are owned by Jussi Ylinen, who helped to establish a network of personal contacts within the diAx project organization and gave important support during the testing phase in Switzerland. Special thanks are due to all people at Nokia Telecommunications who are cheerfully contributed with their experience, knowledge and insights.

Finally, I would like to thank my girlfriend and my parents for their support and encouragement.

Espoo, August 1, 1998 Jani Kurtelius

1 INTRODUCTION

Nokia Telecommunications (NTC) is the leading supplier of GSM based cellular networks. In the last two years NTC has started to supply a GSM cellular network as a turnkey project. NTC can be compared to a design-construct contractor, which takes full responsibility for the management and implementation of the whole project.

In this thesis a turnkey project is a telecommunication system delivery including network planning, site acquisition, design and permitting, construction works, installation, commissioning and integration services. The goal of the turnkey project service is to manage the whole system delivery with quality, on schedule, within budget and in accordance with the customer's functional objectives.

Network planning service provides a network plan to the customer for coverage, capacity and quality according to the customer's requirements. Network planning is a continuous process, that consists of radio network planning, transmission network planning and fixed network planning. *Site acquisition service* identifies and procures the telecommunications equipment sites for the operator. *Design and permitting service* prepares needed drawings and documents for all permits and for site implementation. *Construction works service* constructs the sites needed for the installation of telecommunication equipment. *Installation* and *commissioning services* comprise detailed planning of the installation site, installation, and commissioning of the equipment. *Network integration service* incorporates new network elements, additional capacity and new services into the total network concept.

A GSM cellular network is composed of the following main elements:

- A Mobile Switching Centre (MSC) is a main element of the Network Sub-systems (NSS).[1] It is a digital switch, that controls the connection of the calls to each other

[1] Kaaranen, H., 1995, p. 10

and controls the base station sub-system. The MSC routes calls to and from different kinds of public and private telecommunication networks.[2] [3]

- A Base Station Controller (BSC) is the central network element of the Base Station Sub-system (BSS).[4] It handles connections from one Base Transceiver Station to an other, by performing locating, paging and handover procedures.[5]
- A Base Transceiver Station (BTS) is usually referred to 'a radio base station' or 'a site' is a part of the Base Station Sub-system, where most of the radio-related functions are performed.[6] [7] It is a basic building block and a key link in the GSM cellular network. [8] The BSS is comprised of both BSCs and BTSs.[9]

In the GSM cellular network BSCs are linked together by the MSC. The BTSs are connected via microwave link, or 2 Mbit cable connection to the BSCs, or they are linked together BTS to BTS by using microwave links or cables.[10] The basic structure of a GSM cellular network is illustrated in Figure 1.

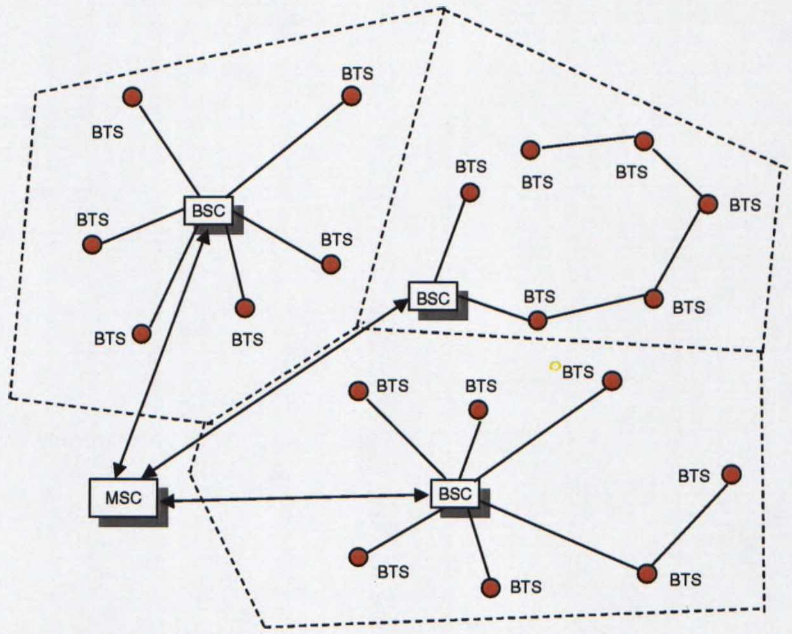

Figure 1 *The basic structure of a GSM cellular network. (Compare: Lynross Training & Consultancy, Introduction to Telecommunications, 1997, Chapter 4, p.7)*

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2 Lynross Training & Consultancy, 1997, chapter 4, p. 5
3 Laitinen, M., 1994, p. 9-11
4 Kaaranen, H., 1995, p. 19
5 Greger, B., 1994, p. 131
6 Kaaranen, H., 1995, p. 19
7 Greger, B., 1994, p. 132
8 Woolery, J., 1994, p. 593
9 Laitinen, M., 1994, p. 11
10 Lynross Training, 1997, Chapter 4, p. 3

A project may include hundreds of individual sites. In general, it can be said that the cellular network project is a large project, in which numerous almost similar small projects take place simultaneously. The labor and equipment resources are shared with all these small projects. The typical model sites in a cellular network project are shown in Figure 2.

"RURAL SITE"

Tower and shelter or outdoor BTS

"ROOFTOP SITE"

Antenna stands and shelter,
indoor / outdoor BTS

Figure 2 *Typical model sites in a cellular network project.(Source: Jani Kurtelius' photo collection, 6th of June 1998, Switzerland)*

Production is based on implementing several similar model sites. Production planning is made by using these model sites.

The objective of this research was to define the procedures for planning and control in cellular network implementation projects. The thesis included interview study, that was meant to identify the main problems related to planning and control. The requirements for Project Management resulted from the problems, and the needed procedures for planning and control were based on General Project Management.

2 GENERAL PROJECT MANAGEMENT

2.1 Problems and Principles Related to Project Management

The most difficult aspect of managing small projects is the problem of dealing with many projects at once, some of which are in the design and procurement phase, some of which are under construction, and some of which are just being started up.[11]

The organizational problems, problems related to procedures for planning and controlling the project, project management techniques and using standard approaches are typical problems for project management. The lack of a realistic budget for both time and money may be one of the basic problems. Many small projects usually have to compete for the attentions of a fixed, limited pool of resources. [12] [13] [14] The most commonly re-occurring problems are listed in Table 1.

The problems are mainly related to scheduling, work planning, quality, contracts, cost control and health and safety when subcontractors are used on projects. The problems in cost control and health and safety are often a consequence of the problems in scheduling, quality and contracts. [15]

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[11] Westney, R., 1985, p. 5
[12] Westney, R., 1985, p. 6-9
[13] Westney, R., 1989, p. 79
[14] Lorenzoni, A., 1980, p. C.6.2-C.6.3
[15] Kankainen, J. and Särkilahti, T., 1992, p. 11

Table 1 Re- occurring problems in projects. (Compare: Pelin, R., Projektin suunnittelun ja valvonnan menetelmät, 1988, p. 15)

managing the situation as a whole	insufficient resources	tight schedule
budgets are set from incomplete planning	organization changes in the middle of project	there are task that are not anybody's responsibility
project management is too impulsive	same persons simultaneously in different project	lack of documentation on earlier projects' real durations
ill defined allocation and responsibilities	lack of time	accurate predicting of schedules
inefficient project meeting	timely allocation of human resources for a specific project	decision making lags behind the requirements of the schedule
continuous change of project data	allocation of resources too uneven	not enough planning
the project managers have too little power	not enough experienced project managers	cost surveillance lags behind

According to the Project Management Institute; *Project Management* is defined as the application of knowledge, skills, tools, and techniques to project activities in order to meet or exceed stakeholder needs and expectations from a project. Project management consists of nine knowledge areas that are divided into component processes as illustrated in Figure 3.[16] These knowledge areas provide a basic structure for understanding project management.

The focus of this thesis is to study Project Management and its knowledge areas, tools, techniques and procedures from the point of view of planning and control of project implementation.

16 Project Management Institute, 1996, p. 6

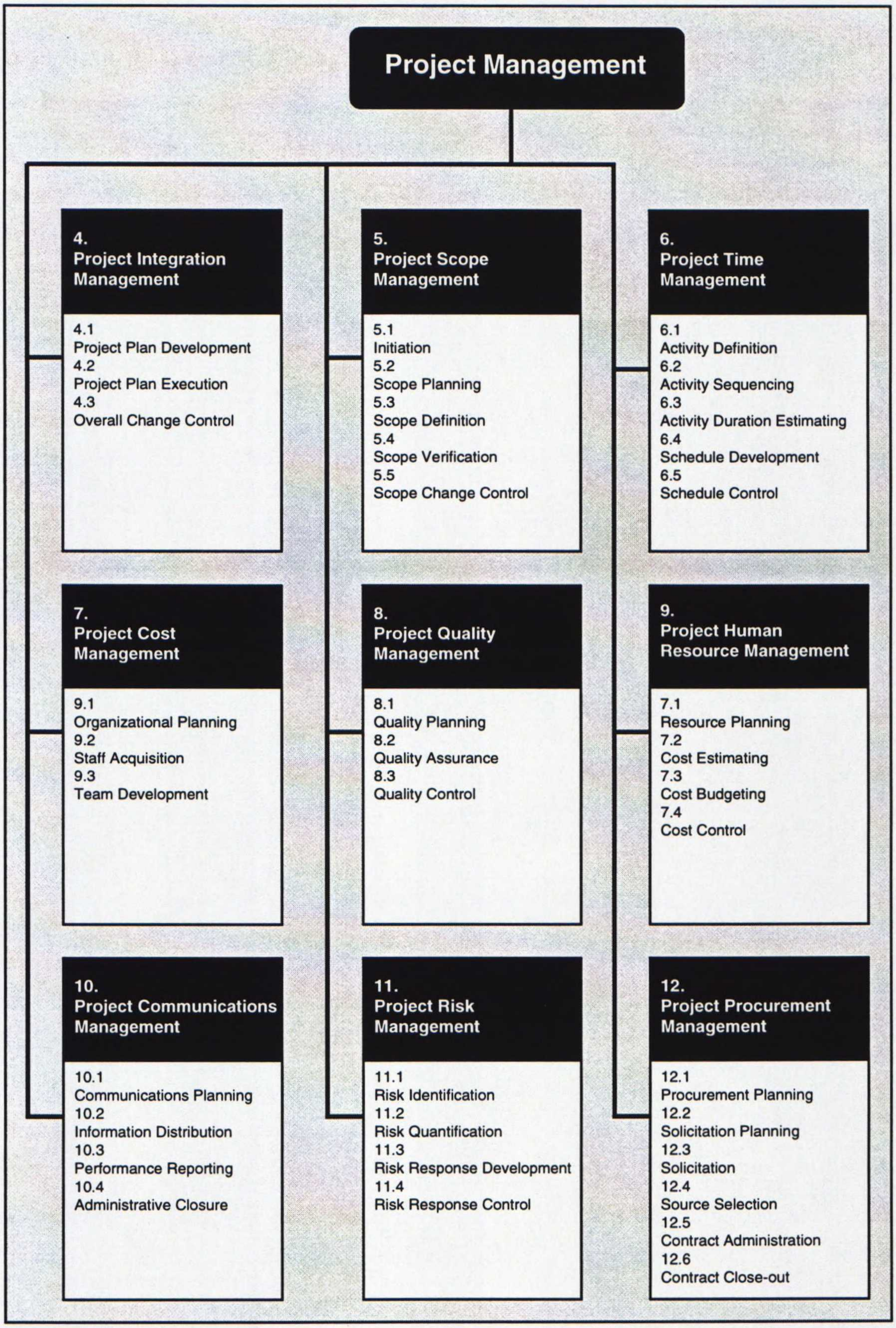

Figure 3 Overview of Project Management Knowledge Areas and Project Management Processes. (Source: PMBOK, Project Management Institute, 1996, p. 7)

2.2 Project Management Knowledge Areas

2.2.1 Integration Management

Project integration management includes processes required to ensure that the various elements of the project are properly coordinated. The processes are project plan development, project plan execution and overall change control.[17] [18]

Project plan development combines the results of other planning processes together and puts them into a document. It can be said that the project plan is the cornerstone of project management. It is used to guide project execution and project control.[19]

Overall change control is composed of three main functions. The first one is to influence the factors which create changes to ensure the changes are beneficial. The second one is determining that a change has occurred. The third function is to manage the actual changes when and as they occur.[20] Changes to the project's target have to be made only with the approval of the customer.[21] Even so, the operational changes can be made by the Project Manager.

2.2.2 Scope Management

Project scope management includes the processes required to ensure that the project includes all the work required to complete the project successfully. These major processes are initiation, scope planning, scope definition, scope verification and scope change control.[22]

Initiation commits the project organization to begin the next phase of the project. Scope planning develops a written scope statement as the basis for future decisions. It is composed of product analysis, benefit per cost analysis and alternatives identification. It identifies both the project objectives and the major project deliverables for an agreement between the project team and the customer. [23]

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[17] Project Management Institute, 1996, p. 39

[18] International Stardard ISO 10006, p. 7-8

[19] Project Management Institute, 1996, p. 39

[20] Project Management Institute, 1996, p. 44

[21] Gerrand, J., 1996, p.23

[22] Project Management Institute, 1996, p. 47

Scope definition involves dividing the project into manageable activities systematically. The result is a Work Breakdown Structure (WBS).[24] It is a key method for project success. WBS can schedule dates, budget cost and staff assignments for each element.[25]

Scope verification is the process of formalizing acceptance of the project scope by all parties (sponsor, customer, etc.). Work products and results have to be reviewed to ensure that all were completed correctly and satisfactorily. This conditional acceptance has to be documented and distributed.[26]

Scope change control includes managing changes to the project scope and to the project plan. The intent, extent and impact of the changes have to be analyzed and accepted before changing the scope.[27] Scope changes often require adjustments to cost, time, quality, or other project objectives.[28]

2.2.3 Time Management

Project time management includes processes that are required to ensure timely completion of the project. These main processes are activity definition, activity sequencing, activity duration estimating, schedule development and schedule control. These processes have interaction with each other and with the processes in other knowledge areas. In some case they can be tightly linked together so that they can be viewed as a single process.[29]

Activity definition identifies the specific activities that have to be performed so that the project objectives will be met.[30] Activity sequencing involves identifying interrelationships and logical interactions and dependencies among activities. Activity duration estimating involves defining the durations for each activity.[31]

Schedule development consists of analyzing activities and their sequences, activity durations and resource requirements, to create the project schedule by using different

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[23] Project Management Institute, 1996, p. 49-51
[24] International Stardard ISO 10006, p. 9
[25] Project Management Institute, 1996, p. 52-56
[26] Project Management Institute, 1996, p. 56-57
[27] International Stardard ISO 10006, p. 8
[28] Project Management Institute, 1996, p. 58
[29] Project Management Institute, 1996, p. 59
[30] Project Management Institute, 1996, p. 59
[31] International Stardard ISO 10006, p. 10

kinds of production models. At the same time, resource requirement is updated.[32] The resource requirements are reconciled by changing the timing of the non-critical activities.[33]

Schedule control involves controlling the realization of the project activities and the progress of the project. Deviations from the schedule have to be identified, analyzed and if significant, reported for action.[34]

2.2.4 Cost Management

Project cost management is composed of processes required to ensure that the project is completed within budget. The major processes are resource planning, cost estimating, cost budgeting and cost control.[35]

Resource planning defines both resources and their quantities which are required to produce the various project activities. These resources are then scheduled over the time span of the project. The resource planning process is closely co-ordinated with cost estimating.[36]

Cost estimating involves developing cost estimates for the project and it is linked to the Work Breakdown Structure. Cost budgeting is based on the cost estimates and schedules. The budget has to be in a form suitable for project cost control. Cost control includes controlling costs and deviations from the project budget.[37]

2.2.5 Quality Management

Project quality management consists of processes required to ensure that the project will satisfy the needs for which it was undertaken. The main project quality management processes are quality planning, quality assurance and quality control.[38]

[32] Project Management Institute, 1996, p. 59
[33] Kimmons, R.,1990, p. 81
[34] International Stardard ISO 10006, p. 11
[35] Project Management Institute, 1996, p. 73
[36] Project Management Institute, 1996, p. 75
[37] International Stardard ISO 10006, p. 11-12
[38] Project Management Institute, 1996, p. 83

Quality planning involves identifying which quality standards are relevant to the project and how to satisfy them. It is one of the key processes during project planning. Quality assurance is all the planned and systematic activities implemented within the quality system to provide confidence that the project will satisfy the quality standards. Quality control involves monitoring project results to determine if they comply with the quality standards and identifying ways to eliminate causes of unsatisfactory results.[39]

2.2.6 Human Resource Management

Project human resource management is composed of processes required to make the most effective use of the people involved with the project. These major processes are organizational planning, staff acquisition and team development.[40]

Organizational planning involves identifying, documenting and assigning project roles, responsibles, and reporting relationships.[41] Staff acquisition involves acquiring and assigning sufficient personnel with appropriate competence to suit the project needs.[42] Team development includes developing individuals and group skills to enhance project performance.[43]

2.2.7 Communications Management

Project communications management consists of processes required to ensure timely and appropriate generation, collection, dissemination, storage, and ultimate disposition of project information. The major processes are communications planning, information distribution, performance reporting and administrative closure.[44]

Communications planning includes planning the information and communication system of the project. It takes into account the needs of the project and of the individuals involved in the project.[45] Information distribution involves making needed information available to project organization members and other parties in a timely manner. Performance reporting includes status reporting, progress measurement and

[39] Project Management Institute, 1996, p. 83-89
[40] Project Management Institute, 1996, p. 93
[41] Project Management Institute, 1996, p. 94
[42] International Stardard ISO 10006, p. 14
[43] Project Management Institute, 1996, p. 99
[44] Project Management Institute, 1996, p. 103
[45] International Stardard ISO 10006, p. 16

forecasting. Administrative closure consists of verifying and documenting project results to formalize acceptance of the product of the project by sponsor or customer. [46]

2.2.8 Risk Management

Project risk management includes the processes concerned with identifying, analyzing and responding to project risks. The processes are risk identification, risk quantification, risk response development and risk response control.[47]

Risk identification involves determining risks in the project. An identified risk has to have a person assigned with responsibility for managing the risk. Risk quantification includes evaluating the probability of risk occurrence and the impact of risk on the project. Risk response development involves developing plans for responding to risks. Risk response control consists of implementing and updating the risk plans. The project's risk situation has to be monitored and reports on risks has to be part of progress evaluations. [48] [49]

2.2.9 Procurement Management

Project procurement management is composed of the processes required to acquire goods and services from outside the performing organizations. The major processes are procurement planning, solicitation planning, solicitation, source selection, contract administration and contract close-out.[50]

Procurement planning includes determining what to procure, how to procure, how much to procure and when. Solicitation planning involves documenting product requirements and identifying potential sources. Solicitation involves obtaining information (bids and proposals) from prospective subcontractors on how the project can be met. Source selection includes choosing the most qualified subcontractors from all the candidates. Contract administration is the process of ensuring that the subcontractor's performance meets contractual requirements.[51] The most essential and central issue for controlling the subcontractors' work and the suppliers is to create the sufficient conditions for

[46] Project Management Institute, 1996, p. 106-109
[47] Project Management Institute, 1996, p. 111
[48] International Stardard ISO 10006, p. 16-17
[49] Project Management Institute, 1996, p. 111-121
[50] Project Management Institute, 1996, p. 125
[51] Project Management Institute, 1996, p. 125-131

controlling in the contracts between main contractor, subcontractors and suppliers.[52] Contract close-out involves both product verification and updating of records to reflect final results and achieving of such information for future use.[53]

2.3 Tools and Techniques for Project Planning

2.3.1 Work Breakdown Structure

A Work Breakdown Structure (WBS) means breaking down the project into the project elements and activities that organizes and defines the total scope of the project. Work not mentioned in the WBS is outside the scope of the project.[54]

The WBS is used both as a planning tool and as a reporting tool. In the planning phase it gives a detailed presentation of the project and in reporting it is used as a structure for reporting the project status.[55]

The project can be broken down into smaller, more manageable elements from different perspectives. The most commonly used viewpoints for project division and planning are as follows: [56] [57] [58] [59]

- Physical break down, which presents a hierarchical view of project's physical elements. It is the basis for the division of the project.
- Functional break down, which divides the project into different functional elements; for example: a data transfer system and a control system.
- Project break down from the production point of view, which divides the project elements into the work packages and further more into activities, work phases and types of work.
- Location Breakdown Structure (LBS), which splits the project into subprojects according to their geographical locations.

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52 Luhtala, I.,1992, p. 19
53 Project Management Institute, 1996, p. 133
54 Project Management Institute, 1996, p. 54
55 Wysocki, R., Beck, R. and Crane, D., 1995, p. 125-126
56 Pelin, R.,1996, p. 117, 129
57 Erke, J., Lindholm, M. and Kankainen, J., 1998, p. 44-50
58 Project Management Institute, 1996, p. 56
59 Wysocki, R.,Beck, R. and Crane, D., 1995, p. 114-119

- Project break down from the procurement point of view, which means that the project is divided into planning and purchase packages. The 'planning packages' and 'purchase packages' can be performed by either one or several subcontractors.
- Organizational Breakdown Structure (OBS), which shows the relationships between work elements and organization units. The structure is matrixed within the project organization chart.
- Cost Breakdown Structure (CBS), which break downs the project into different cost accounts according to an account map.
- Project break down from the different phases point of view, which divides the project into different consecutive phases. The typical phases are, for example: project design, implementation and maintenance.

The whole project's data management should be based on the project's basic WBS. Further work breakdown structures use the basic WBS as a starting point. The principle connections between the basic WBS and the other breakdown structures are shown in Figure 4.[60] [61]

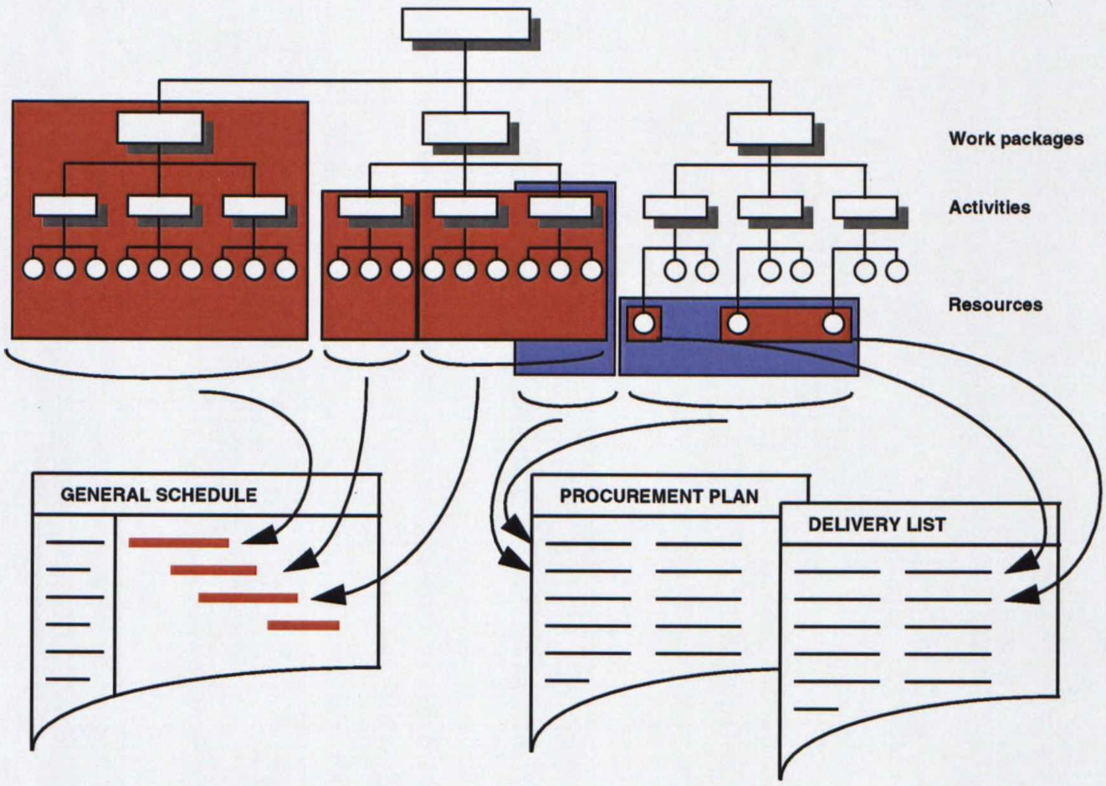

Figure 4 An example from the principle connections between the basic WBS and the other breakdown structures. (Compare: Kiviniemi, M., Rakennusprojektin osittelu tuotannon näkökulmasta, Rakennustekniikka, No. 6 1989, p. 303)

[60] Kiviniemi, M., 1989, p. 303
[61] Erke, J., Lindholm, M. and Kankainen, J., 1998, p. 51-59

In the basic WBS, the project is broken down into structural elements which are decomposed further into work packages.[62] A work package represents the lowest manageable part of the work. The work packages are the basis for all project work.[63] Each WBS element has to have a schedule, a budget and a person responsible for its preparation.[64] [65]

From a production point of view there are different approaches to breaking down a project. These main approaches are shown in Figure 5.[66]

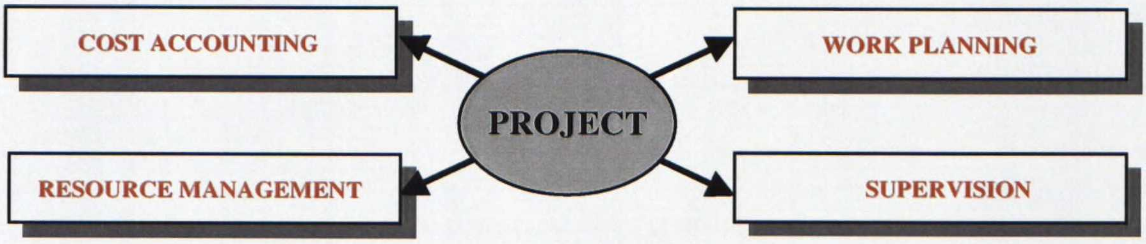

Figure 5 *The main approaches to breaking down a project. (Compare: Kiviniemi, M., Rakennus-projektin osittelu tuotannon näkökulmasta, Rakennustekniikka, No. 6 1989, p.302)*

The best way to generate the WBS is to make it part of the Joint Planning Session (JPP). The main steps of building the WBS within the JPP session as follows:[67]

1. The planning team agrees on the approach to build the first level of the WBS.
2. The planning team creates the Level 1 activities.
3. Divide the planning team into groups, one for each Level 1 activity.
4. Each group agrees on the approach to build the remaining WBS.
5. Each group reports their WBS to the team.
6. The planning team critiques and discusses the group presentations and completes the WBS.

62 Erke, J., Lindholm, M. and Kankainen, J., 1998, p. 5

63 Kimmons, R.,1990, p. 51

64 Project Management Institute, 1996, p. 54-56

65 Kimmons, R.,1990, p. 51

66 Kiviniemi, M., 1989, p. 301

67 Wysocki, R.,Beck, R. and Crane, D., 1995, p. 126

2.3.2 Organizational Structure

The project organization is consistent with the Work Breakdown Structure. The WBS divides the project into organizationally clear responsibilities. Each WBS-element has to have a clear division of tasks or a person in charge.[68] The structures of the project-based organizations are divided into three categories:[69] [70]

- A functional organization is shown hierarchically where specific functions of a business are grouped into specialist departments that provide a dedicated service to the whole organization.
- A Projectized organization includes the project team, which usually remains as a multidisciplinary unit and is moved from one project to another as each project is completed. The project manager has a great deal of independence and authority.
- A matrix organization is a mixture of functional and projectized characteristics in which individuals, groups and managers continue to work within their specialist function departments, but are assigned to work under the direction of a project manager who is not their line manager. They are responsible to the project manager for their project work and to other functional managers for activities that are not related to the project.

A modern project organization involves all these structures together at various levels.

2.3.3 Schedule Planning

A correct Work Breakdown Structure provides a perfect setting for schedule planning. The project schedules are presented at the different hierarchical levels, which are linked together by two clear and precise milestones. The schedules are broken down into more and more detailed subschedules up to the work package level. The schedule structure should follow the project coding system. [71]

The principle of hierarchical levels in schedules is shown in Figure 6.

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[68] Pelin, R.,1996, p. 128
[69] Project Management Institute, 1996, p. 19-20
[70] British Standards Institution, 1996, p. 9-11
[71] Pelin, R.,1992, p. 90-91

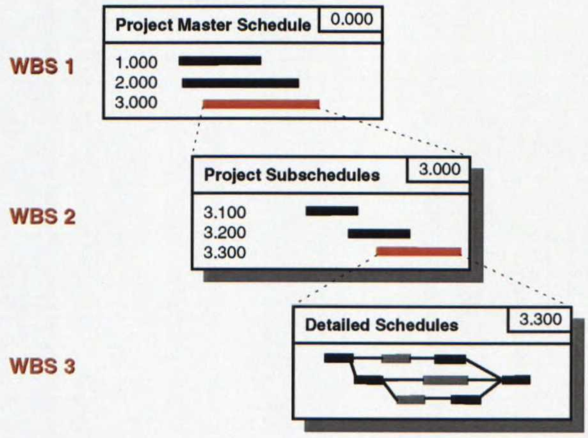

Figure 6 *The principle of hierarchical levels in schedules. (Compare: Pelin, R., Projektihallinnan käsikirja, 1996, p. 123)*

The project master schedule includes the whole project and is presented in summary form. It is based on experiences from other projects and can be the basis for other projects in the future. It shows the summary of the major milestones and processes of the project. The project master schedule is used as a communication tool. The project master schedule remains unchanged if there have not been any radical changes in the scope of the project or major uncontrollable postponements to the work phases.[72]

Critical Path Method (CPM)

Classic planning and project management methods for single projects are based on the project network techniques.[73] The project networks give a clear graphical picture of the dependencies between project activities. The project can be viewed from a high-level and detailed-level simultaneously.[74] So, to be effective for small projects, networks must be kept simplistic.[75]

The Critical Path Method is a network analysis method for scheduling purposes and programming operations.[76] CPM can be used if a large number of activities should be scheduled and constraints are known. It shows the whole project or one part of it as a graphical portrayal. The CPM is based on using nodes that are interconnected by arrows. Either the nodes or the arrows represent functional dependencies between the activities. Each arrow represents one required activity in the project. The node represents the event or the milestone when it can be said that the activity has been

[72] Kimmons, R.,1990, p. 65-66
[73] Westney, R., 1989, p. 79
[74] Wysocki, R.,Beck, R. and Crane, D., 1995, p. 164
[75] Westney, R., 1985, p. 22
[76] Westney, R., 1985, p. 33

completed.[77] Each event must have an activity before and after it, aside from the starting event of a network and the final event of the diagram.[78] In the network, logical restraints called 'dummies' can be used to maintain the logic of a certain situation where the use of an activity arrow would not allow this.[79]

The CPM consists of the following basic phases:[80]

1. Define the scope of work of the project
2. Break the project down into activities
3. State the assumptions on which the plan and schedule will be based
4. Assign expected durations for each activity
5. Define activity constraints and illustrate a network
6. Calculate critical path and float
7. Schedule activities
8. Optimize plan

Figure 7 shows a basic sequence of five activities represented by CPM.

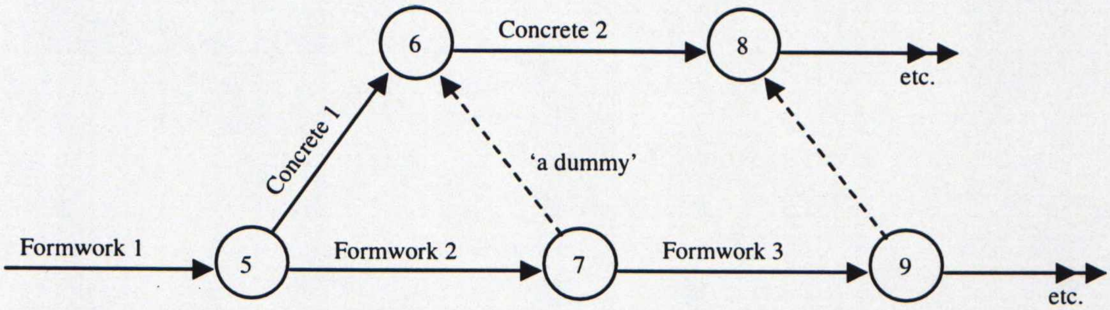

Figure 7 An example of CPM. (Source: Roy Pilcher, Principles of Construction Management, 1992, p. 284)

The critical path is the longest path through the diagram between the starting event of a network and the final event of the diagram.[81] The Critical Path Method tells us what we should concentrate on at any time during the project, and where resources can be used most effectively.[82]

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[77] Pilcher, R., 1992, p. 274-275
[78] Wysocki, R.,Beck, R. and Crane, D., 1995, p. 154-156
[79] Pilcher, R., 1992, p. 279-280
[80] Westney, R., 1985, p. 39
[81] Wysocki, R., Beck, R. and Crane, D., 1995, p. 159
[82] Kimmons R., 1990, p. 77

<u>Line-of-Balance (LOB)</u>

A Line-of-Balance is a specialized scheduling technique for construction. It was derived from the manufacturing industry, in which work is truly repetitive.[83] The other good example for which line-of-balance is particularly well suited to include construction projects such as high-rise buildings.[84] [85]

The purpose of the Line-of-Balance technique is to balance the rate of the activities, and to schedule the activities to eliminate interference. This is done by adjusting the rate of production for each activity. This will approximate a common rate of production for all activities by delaying the start of those activities that proceed faster than the activity immediately proceed it.[86]

Time buffers between activities at the same stage, and stage buffers between activities at different stages are used to maintain a constant production rate for the work group working on the activity.[87] The horizontal distance between two lines at any stage represents the time buffer between the activities during that stage. The vertical distance between lines represents the stage buffer between the two activities at a particular time. The slope of each line represents the production rate for each activity. Figure 8 shows typical flowline curves of repetitive activities, which represent the movement of the activities' work group from one stage to another. [88]

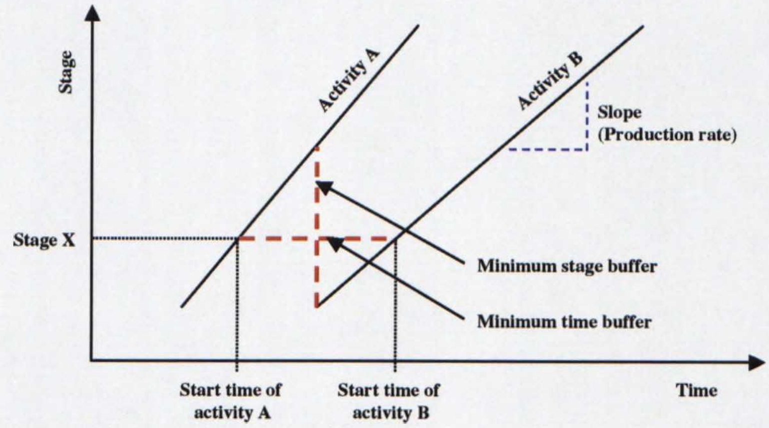

Figure 8 *Typical flowline curves of repetitive activities. (Source: Al-Harbi, K., Selim, S. and Al-Sinan, M., A multiobjective linear program for scheduling repetitive projects, Cost Engineering, Vol.38 / No.12 1996, p. 41)*

[83] Neale, R. and Neale, D. 1989, p. 24
[84] Reda, R. 1990, p. 316
[85] Pilcher, R., 1992, p. 348-349
[86] Neale, R. and Neale, D. 1989, p. 38
[87] Reda, R. 1990, p. 319

Bar Chart

A bar chart is one of the most common ways to represent and plan simple project schedules. If there is small number of activities, the bar chart can be used as a main schedule. The bar chart shows the basic relationships between activities, which should always be based on network logic. It gives a good basis for resource scheduling.[89]

Bar charts only relate the listed activities in a time scale, they do not indicate activity interdependence or variations in rate of progress.[90] The activities are listed and the time-scale is presented horizontally. The bars represent the needed time for when the work will proceed on the activities. The bars can be linked together by logical connections and their relationship is shown with vertical lines (links).[91]

Figure 9 shows an example of a basic bar chart.

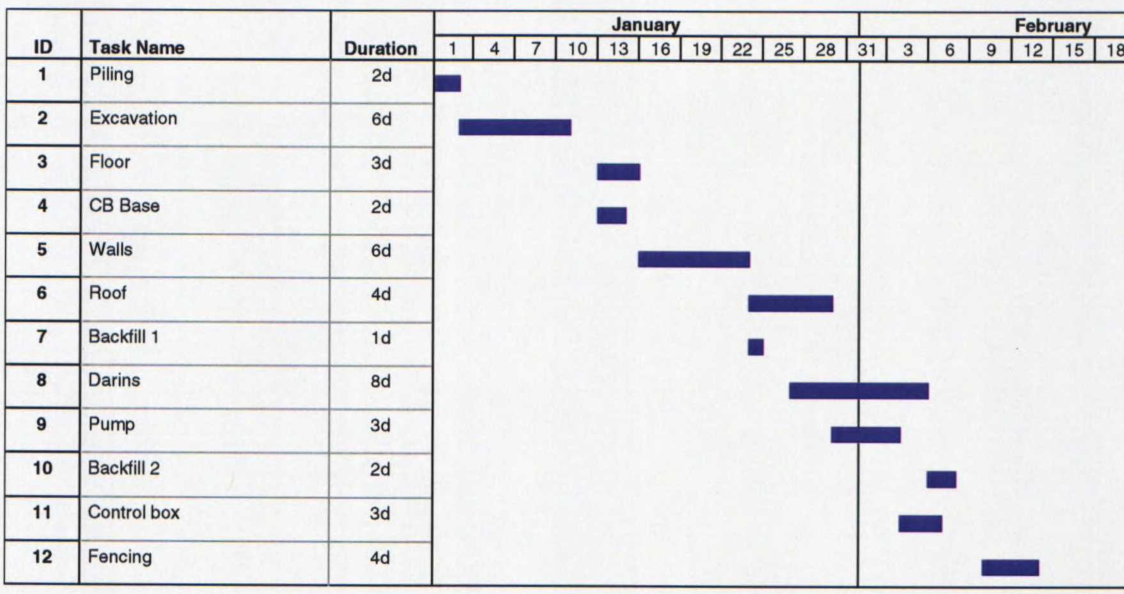

Figure 9 *An axample of a basic bar chart. (Compare: Neale, R. and Neale, D., Engineering Management - Construction Planning, 1989, p. 62)*

Milestone charts

The Milestone charts are similar to bar charts, but identify the scheduled start or completion of major deliverable and key milestones.[92]

An example of a milestone chart is presented in Figure 10.

88 Al-Harbi, K., Selim, S. and Al-Sinan, M., 1996, p. 41

89 Pelin, R. 1996, p. 153-154

90 Project Management Institute, 1996, p. 28

91 Neale, R. and Neale, D. 1989, p. 28-29

92 Project Management Institute, 1996, p. 70

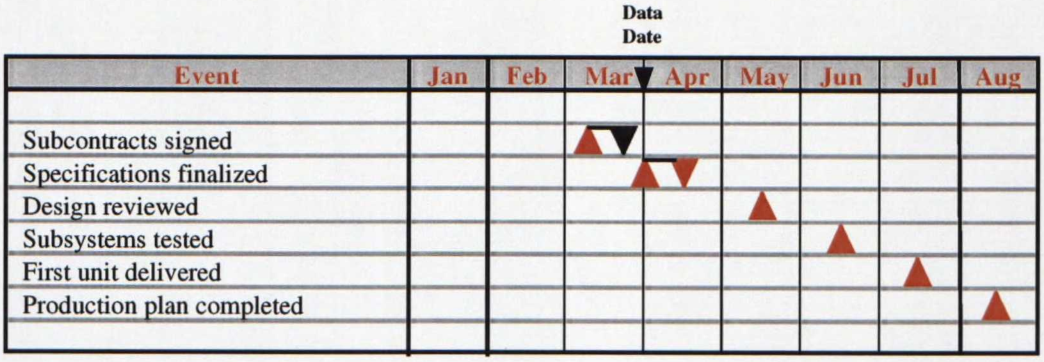

Figure 10 Milestone chart. (Source: Project Management Institute, 1996, p. 70)

The important events and stages are described by milestones. Typical milestones are start or completion of an activity, order time, delivery time, inspection, acceptance and decision.[93]

2.3.4 Production Planning

Traditionally, in the construction sector, schedule planning has been done without taking into consideration the production model of implementation. Planning techniques are only facilities that are used for producing the schedule based on a certain production model. However, schedule planning should be based on, and performed together with the chosen production planning model. [94] The objective of production planning is the completion of the project within the established time limits according to the plans, contracts, regulations and work quality objectives.[95]

Production planning of the whole project is divided into (Figure 11):[96]

- Cost planning (Budgeting)
- Schedule planning
- Procurement planning
- Logistics planning

Different production plans are made in parallel.

93 Pelin, R. 1996, p. 153-154
94 Toikkanen, S., 1995, p. 10
95 Compare. Koski, Hannu, 1995, p. 10
96 Toikkanen, S. & Särkilahti, T., 1997, p. 6

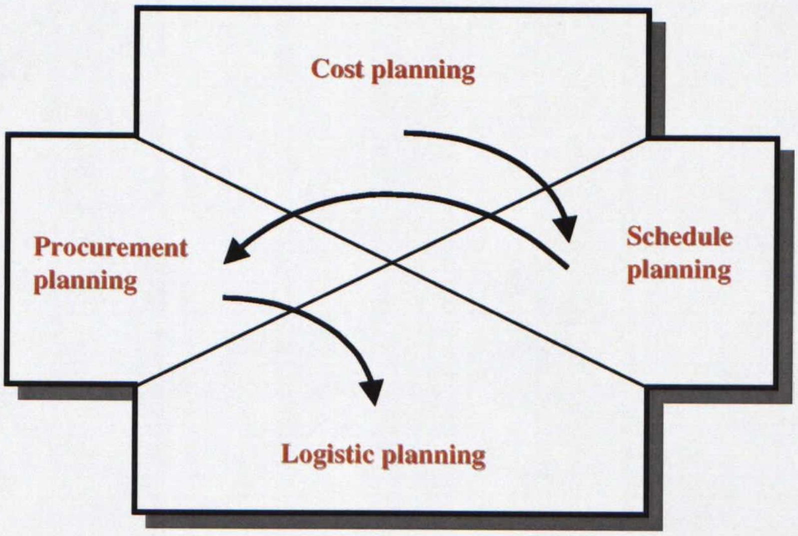

Figure 11 *The main areas of the entire project's production planning. (Source: Toikkanen S., and Särkilahti T., Hankintojen suunnittelu ja valvonta, 1997, p. 6)*

Production planning is a chain, which is planned in three phases at the project level. These main phases are:[97]

1. Tender phase
2. Start-up phase
3. Implementation phase

During the tender phase, production planning aims at determining the main production methods and resources for the project, and at defining other essential points contributing to the preparation of the cost estimate. The most important plans are:[98]

- list of activities by location
- bills of quantities
- preliminary production plans
- cost estimate

During the start-up phase, production planning includes the preparation of the organization, time and resource plans, numerous special production plans, and undertaking preconstruction operations. The project budget and budgetary objectives are calculated on the basis of the project cost estimate and schedules.[99]

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97 Compare. Koski, Hannu, 1995, p. 12
98 Koski, Hannu, 1995, p. 12-13
99 Koski, Hannu, 1995, p. 12

The implementation phase includes scheduling at different levels, schedule control and updating, cost control, meetings and negotiations.[100]

Because of the characteristics of telecommunications production in this thesis, there are three types of production models presented. These production models are (Figure 12):

- Repetitive cell production model
- Synchronized production model
- One of a Kind -production model

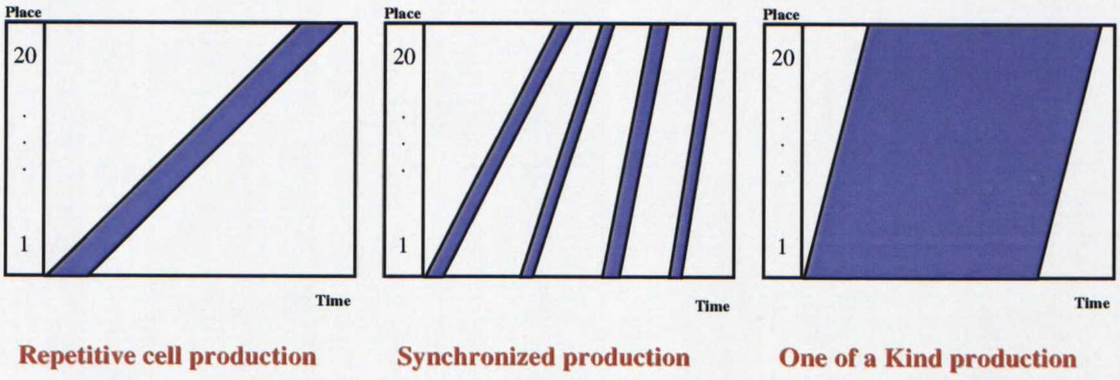

Figure 12 Different production models in building construction. (Compare: Toikkanen, S., Licentiate's Thesis, Just On Time Manufacturing at the Repetitive Construction projects, 1995, p. 17 and Särkilanti, T. and Kiiras, J., The Taskplanning of a Construction Project, 1996, p. 13)

Repetitive Cell Production Model

Repetitive project production is planned and controlled by the cell production model. The aim of the repetitive cell production model is to limit executed time required per work area and achieve steady production rate and high productivity.[101]

The Finnish JOT is based on the Japanese Kanban[102] [103] [104]- and American Just In Time[105] [106] (JIT) -production and has been adjusted to the conditions in Finland. The contractors have good experience in JOT-production in repetitive renovation projects and metal industry in Finland, England and USA. For example, productivity at the

100 Koski, Hannu, 1995, p. 64
101 Toikkanen, S. & Kiiras, J., 1994, p. 1
102 Japan Management Association, 1986
103 Schonberger, R.,1982
104 IVF-RESULTAT 82610, 1982
105 Hay, E., 1983
106 Japan Management Association, 1986

repetitive renovation projects has improved from 20-30 %.[107] The typical results of JOT-production in the composition industry are:[108]

- smaller warehouses
- shorter lead-times
- better productivity
- better quality

These results have been obtained by turning from traditional production to repetitive JOT-production.[109]

The cell is organizationally a separated production unit, that works independently. The workgroup of the cell consists of multiskill workers, who carry out and complete the work as a group. There can be one or more work groups per cell, but they do their work in a different time frame. The workgroup's workers are responsible for all their combined goals. The workers can be composed of one or several subcontractors, that are specialized in different kinds of work. The work areas are similar and quite small as a whole project. The work area is completed in one session without work spreading out over several work areas.[110]

Production control emphasizes three categories (Figure 13):[111]

- overlap production
- slowdown when trouble appears
- complete work in one session

[107] Toikkanen, S., 1995, p. 4
[108] Kurikka, A., 1985, p.22
[109] Kurikka, A., 1985, p.22
[110] Toikkanen, S. & Kiiras, J., 1994, p. 10-11
[111] Toikkanen, S. & Kiiras, J., 1994, p. 11

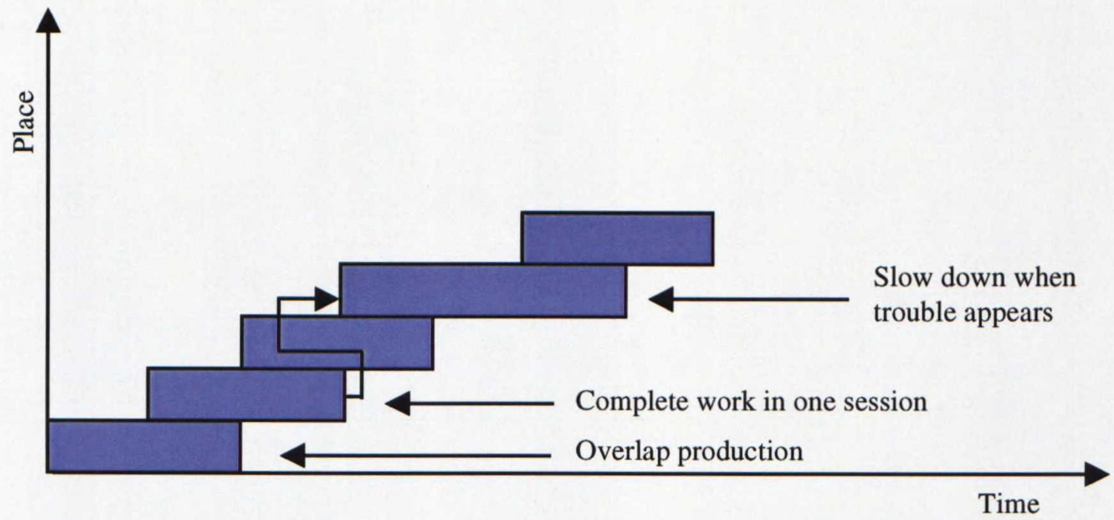

Figure 13 Three of the main work control methods. (Source: Sakari Toikkanen, Licentiate's Thesis, Just On Time Manufacturing at the Repetitive Construction projects, 1995, p. 27)

Bathroom and kitchen repairs are good examples of using the repetitive cell production model in routine construction projects.

Production planning consists of the following five main phases:[112]

1. Repetitive work area selection
2. Preparation of the whole project schedule
3. Preparation of the list of work phases for repetitive work areas
4. Preparation of activity lists for the whole project
5. Preparation of detailed schedules for repetitive work areas

Synchronized production model

The synchronized production model is used to plan work phases from one place to the next in sequence and at the same rate of progress. Synchronized production aims to keep all resources in balance, maintain a constant production rate and a continuity of work for each work group. Interruption in production can be eliminated by using buffers between work phases.[113]

The synchronized production model has been used in heavy renovation projects.[114] Schedule planning is composed of the following four main phases:[115] [116]

[112] Toikkanen, S., 1995, p. 31-38
[113] Toikkanen, A. & Kiiras, J., 1993, p. 35-45
[114] Toikkanen, A. and Kiiras, J., 1993, p. 32
[115] Toikkanen, A. and Kiiras, J., 1993, p. 35-46

1. Project break down
2. Preparation and tasking activity list
3. Preparation of schedule
4. Resource check

Synchronized production and other production models in this thesis can be planned by applying the Line-of-Balance (LOB) technique to them.

One of a Kind -production

The project may be composed of a number of individual small subprojects which are implemented as a single project. Implementation of the subprojects includes different work phases, which are not continuous and non-repetitive. On the contrary they are done only one time in the subproject.[117]

A good example for One of a Kind- production is a single house project. There is one subcontractor, who is responsible for implementation of the whole project.

The best scheduling technique for One of a Kind -production is the critical path method.[118]

2.3.5 Resource Planning

Resource planning is defined as both resources and their quantities which are required to produce the various project activities by using the work breakdown structure and historical information as a basis. The resource planning process is closely co-ordinated with cost estimating.[119]

At the project level, resource planning is composed of the following steps:[120]

1. Defining the resources required to accomplish each activity on the network plan. Resource definition is done by listing the resources systematically and using experience from previous projects as a guide.

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[116] Tuominen, J., 1993, p. 15
[117] Compare: Toikkanen, S., 1995, p. 18
[118] Toikkanen, S., 1995, p. 18
[119] Project Management Institute, 1996, p. 75
[120] Westney, R., 1985, p. 67-68

3. Defining the resources, which can be made available during each time period.
4. Levelling resources by comparing resource requirements with resource availability to identify shortfalls and rescheduling the plan. If resource shortfalls exist, there are two alternative methods (Figure 14):

- Resource-limited scheduling allows the schedule to slip to match availability.
- Time-limited scheduling allows resource availability to match requirements.

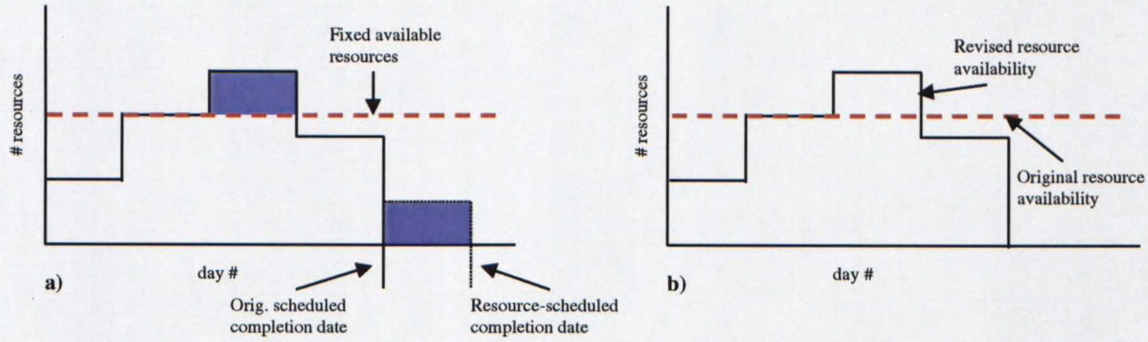


Figure 14 a) Resource- and b) Time-limited scheduling. (Source: Westney, R., Managing the Engineering and Construction of Small Projects, 1985, p. 76.)

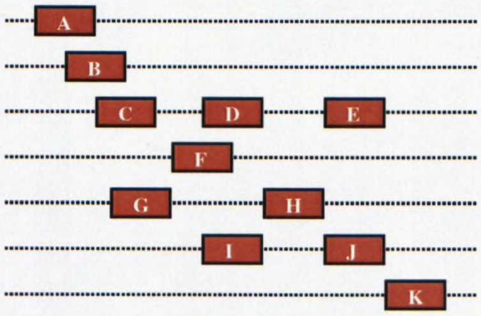
5. Preparing a schedule of requirements for those persons who will be responsible for providing the required resources.

In multiple projects there may be a "pool" of resources, each of which is working on specific projects. The pool of resources is allocated to the various projects by network hierarchies combined with the principles of resource aggregation.[121]

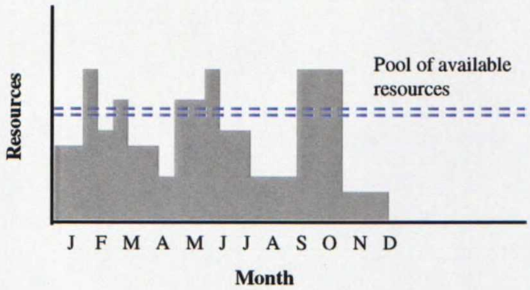
Figure 15 shows allocating a fixed pool of resources to multiple projects. In picture a) the network shows each project represented by one or more activities. A, B, C, ... K represent different projects. Picture b) shows an example of resource analysis. Rescheduling reflects priorities, sequence and resource limitations. Resource aggregation indicates which projects are likely to be delayed because of shortfalls of resources. Resource levelling indicates how the project can be scheduled to match the available resources in the pool.[122]

[121] Westney, R., 1985, p. 78

[122] Westney, R., 1985, p. 78-80



a) **Network**



b) **Resource Analysis Rescheduling**

Figure 15 Allocating a fixed pool of resources to multiple projects. (Compare: Westney. R., Managing Engineering and Construction of Small Projects, 1985, p. 80)

2.3.6 Procurement Planning

Procurement planning is the process of identifying which project needs can be best met by procuring materials or services outside the project organization.[123] Procurement planning includes defining and timing of needed purchase packages, selecting the ways of work (own work or subcontracted) and sharing of responsibilities for persons.[124]
The purchase package may include only materials or subcontractors, which are composed of only work, or work and materials. In addition, the different services (e.g. planning and logistics services) may be included in the purchase packages.[125] [126]

Procurement planning has to be committed into three production planning phases, which are: the tender phase, the start-up phase and the implementation phase. The tender and the start-up phases are made at the project level while the implementation phase includes planning at the task level before a single task start-up.[127]

At the tender phase, procurement planning is based on the main contractor's purchase policy and basic production models. The critical and urgent deliveries and tasks are identified and the principle solutions related to the site logistics are defined.[128]

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123 Project Management Institute, 1996, p. 125
124 Talo 90 -ryhmä, 1994, p. 52
125 Toikkanen, S. and Särkilahti, T., 1997, p. 17
126 Talo 90 -ryhmä, 1994, p. 61
127 Toikkanen, S. and Särkilahti, T., 1997, p. 7
128 Toikkanen, S. and Särkilahti, T., 1997, p. 7

At the start-up phase, procurement planning and production planning must support each other, so that production can advance according to prepared schedules. The project master schedule, a target budget, logistics plans, quality plans and technical specifications from the tender phase are inputs to the general procurement planning. The general procurement plan is composed of a procurement list, which defines persons in charge, a procurement schedule and a logistics plan.[129] The procurement schedule shows the procurement process including preparation of a supply note, request for quotations (RFQs), agreement and delivery. Through these, the timing for main orders and deliveries are divided into smaller lots.[130]

By single task planning, it is ensured that production progresses according the schedule. The task plans have to be made for all scheduled tasks. Their most essential task is ensuring both production start-up conditions and implementation according to the target. [131] By using the task plans as a basis, needed materials and quantities for different tasks are defined.[132]

A deal with a validated subcontractor can be made regarding the most urgent purchases based on the pre-tenders already at the tender phase. Then the purpose of the task plan is ensuring the fulfillment of the purchases according to the agreement.[133]

2.3.7 Information Distribution

Good communication between project manager and the task owner is essential. Effective reporting helps the project manager and task owners to understand the status of the whole project, the effect of their performance on the project objectives and any risks that lie ahead.[134] The Statement of Work (SOW) defines what reports are needed and the level of information that the project manager decides is necessary to control the work. The following aspects of reporting should be addressed:[135] [136] [137]

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129 Toikkanen, S. and Särkilahti, T., 1997, p. 16
130 Koski, H., 1995, p. 46.
131 Junnonen, J., 1996, p. 7
132 Toikkanen, S. and Särkilahti, T., 1997, p. 9
133 Toikkanen, S. and Särkilahti, T., 1997, p. 9
134 British Standards Institution, 1996, p. 24
135 British Standards Institution, 1996, p. 21
136 Project Management Institute, 1996, p. 107
137 Pilcher, R., 1992, p. 138

- Performance status
- Schedule status
- Cost status
- Status of quality progress
- Risk exposure system
- Procurement status
- Exception thresholds and variance reporting

Meetings (Internal / External) are excellent places to exchange information with the project organization. Other communication methods are hard copy document distribution, shared access to networked electronic databases, fax, mail, voice mail and videoconference.[138]

2.4 Tools and Techniques for Project Control

2.4.1 Schedule Control

Progress monitoring and control is the core activity of project management and has to be done effectively and efficiently. Information about the actual achievements should be collected regularly on the project. This information is processed into reports which compare planned and actual progress.[139] Few projects run exactly according to plan. Prospective changes may require controlling actions and replanning.[140]

Production needs to be controlled at several levels: the company level, the project level, the site level and the task level. Each level has different objectives and methods for controlling production. At the company level, the most essential objectives of control are profitability, acquiring new projects and customer satisfaction. At the project level, the main objectives are keeping production on schedule and effective resource utilization. Production control aims at running the implementation process, faultless work performance, as well as keeping on schedule both at the site level and the task level.[141]

Production operational control occurs at the project level, at the site and at the task level. Operational production control can be modeled as a control system consisting of a

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[138] Project Management Institute, 1996, p. 107
[139] Neale, R. and Neale, D. 1989, p. 90
[140] Project Management Institute, 1996, p. 72

control system and a controlled system (Figure 16).[142] The control system receives data about resource usage and progress of the production process.[143] Via production control, the deviations from plans in production are prevented and then pointed in the right direction in accordance with the plan by steering signals. The objective of production control is to ensure that the controlled process can be completed according to the production plan.[144]

Production control is composed of the following things: [145]

- Baselines are established from the budget and schedules.
- The project's status is measured and monitored regularly.
- Projections are made forecasting future performance.
- Current and forecasted performance variances are identified and qualified.
- The effects of variances on the project's final cost and schedule are analyzed.
- Alternative corrective actions are defined, evaluated and compared.
- The work plan is modified by using the chosen corrective action.

The work associated with the corrective actions is monitored and the results are evaluated.

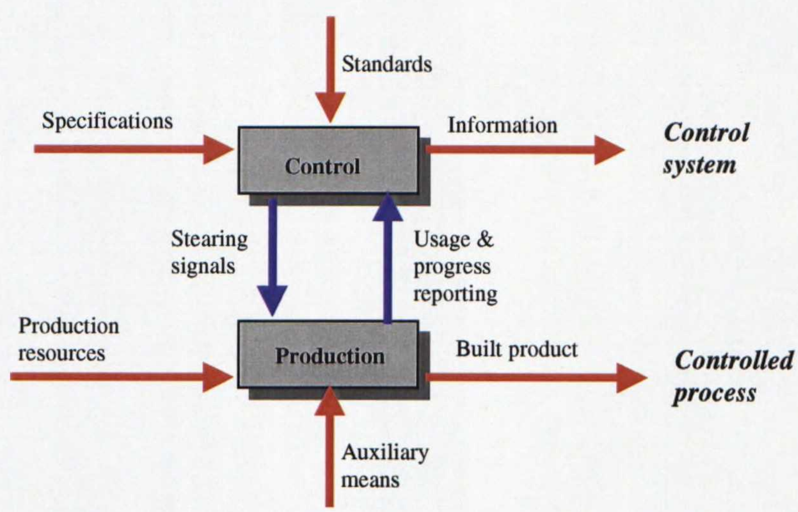

Figure 16 Production operational control (Source: Melles, B., Robers, J. and Wamelink, J., The Management Cycle in Process in the Construction Industry, Building Economics and Construction Management, p. 341)

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141 Nykänen, V.,Kiviniemi, M., Laurikka, P., Kähkönen, K., Koskela, L. and Tyrväinen, H., 1992, p. 14-16
142 Compare: Melles, B., Robers, J. and Wamelink, J., 1990, p. 341
143 Melles, B., Robers, J. and Wamelink, J., 1990, p. 341
144 Compare. Toikkanen, Arto, 1989, p. 53

Production supervision is a continuous operation during the project's roll-out process. The aim of the supervision is to acquire knowledge from fulfilled production, to compare the actual production to the planned production and to report on the observations to the managers.[146]

The subcontractor's production control is based on a precondition of confirming production start-ups and direction internal and external production. Preconditions of production are confirmed by doing model work and teamwork training. Internal and external production control are done with the work bills and thorough subcontractor agreements.[147] Start-up is the really important phase, because production should proceed as soon as possible in as similar a fashion as the model work.

Internal control is done with work bills, that are based on detailed schedule development. The work bills include activities for a work group and their detailed timing in a given period.[148] The work bills are done for a model work area, its start-up and for a repetitive period.[149]

External control is done by defining the key work stages. The key work stages are chosen about 2-4 from repetitive work area schedule. The beginning of the work stage and the end of the work stage belong always to the key work stages. [150]

2.4.2 Resource Control

Small projects are particularly sensitive to cost and schedule's effects of resource shortfalls. Often, lack of critical resources may stop progress altogether. Tracking, forecasting and controlling the usage of resources is of particular importance in these projects.[151]

The resource schedule provided in the budget plan can be used as a basis for tracking the actual resources. At any point of the project, the resource analysis process can be

[145] Kimmons, R.,1990, p. 111
[146] Kankainen, Jouko and Sandvik, Tom, 1993, p.36
[147] Toikkanen, S., 1995, p. 39
[148] Toikkanen, A. & Kiiras, J., 1993, p. 62
[149] Toikkanen, S., 1995, p. 40
[150] Toikkanen, S., 1995, p. 40
[151] Westney, R., 1985, p. 202

updated by optimizing the original time and resource plan to reflect the planned, actual and forecast quantity of resources.[152]

2.4.3 Quality Control

Traditional quality control is carried out by the main contractor. The main contractor takes care of quality control during implementation because the subcontractor does not have a quality system of its own. Still, the main contractor can require in the contract that the subcontractor works out a quality plan. If any errors occur, the main contractor has to make a complaint about them to the subcontractor immediately.[153]

In modern quality thinking, production and material quality control of the subcontractor is made according to their individual quality management system. The main contractor has to ensure that the subcontractor will work according to its own quality management system and will report to the main contractor on the appearance of quality related errors.[154] The subcontractor's quality management system is supported by a quality manual which catalogues descriptions, standards and procedures.[155]

By quality circles the workers undertake their tasks according to quality requirements. The quality circle is based on a belief that the workers are specialists in their own work sector and that they are aware of the main problems related to their work phases.[156] It gives the workforce some measure of ownership of the workplace.[157] Quality circles are composed of two kinds of operations: preventative operations and corrective operations.[158] The quality circle of preventative operations is used before starting a new work phase. At the same time, the workers have a chance to discuss together the right ways in which to carry out their work. In the quality circle of corrective operations, problems, that have occurred and ways to solve them are managed.[159]

By doing a work model and training, the workers are ensured production start-up requirements. The work model has to be scheduled longer than the rest of the tasks,

152 Westney, R., 1985, p. 203
153 Kankainen, J. and Särkilahti, T., 1992, p. 74
154 Kankainen, J. and Särkilahti, T., 1992, p. 74
155 Langford, D. and Rowland, V., 1995, p. 131
156 Lillrank, P., 1990, p. 124-142
157 Langford, D. and Rowland, V., 1995, p. 132
158 Meskanen, V., 1993, p. 77
159 Särkilahti, T. and Kiiras, J., 1996, p. 21

because the work preparation requires more time at this stage. During the work model's implementation, it is important to take in the following points:[160]

- Production start-up requirements and conditions are ensured.
- All workers take part in teamwork training before building the work model.
- The workers are familiarized with all required activities by participating the work model together. At the same time all mistakes and faults that are related to work planning will be corrected before actual production start-up.
- The material delivery schedules and the lots of deliveries are agreed on with suppliers.

By inspections, measuring, testing and controlling, you ensure that the implementation process takes place with the framework of a quality system.[161]

2.4.4 Procurement Control

At the project level, procurement control means mainly procurement list control, which is divided into scheduling control and cost control. The aim of scheduling control is to ensure that purchases are timed and performed according to the procurement list. The subcontractor or material costs are controlled mainly before making an agreement, when received tenders are compared with a target (Figure 17).[162]

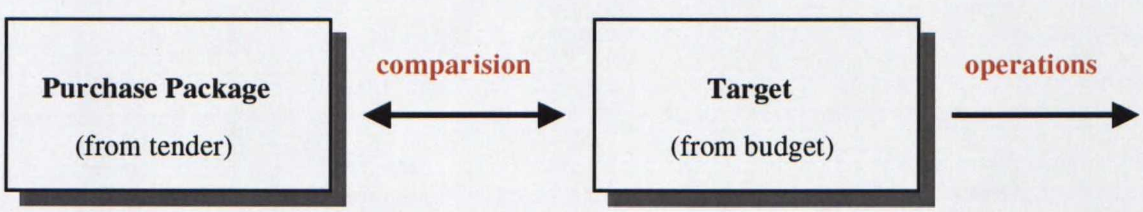

Figure 17 Comparison with purchase package and target. (Source: Toikkanen, S., Kolhonen, R. and Kankainen, J., Hankintojen suunnittelu ja valvonta - nykyisen kirjallisuuden valossa, 1996, p. 16.)

The possibility for the main contractor to act on the subcontractor's and the supplier's work control or work steerability is defined in the contracts between customer, subcontractor and supplier. The problems related to work control are often a

160 Toikkanen, S., 1995, p. 39-40
161 Compare: Langford, D. and Rowland, V., 1995, p. 131
162 Toikkanen, S. and Särkilahti, T., 1997, p. 26

consequence of imperfect conditions for controlling, that have been created in the contracts.[163]

Subcontractor control

Subcontractor control is mainly focused on schedule and quality control. The main contractor can control the subcontractor by using the clauses and the installments included in the contract. Subcontractor control occurs at meetings and in quality circles (2.4.4) between the main contractor and subcontractors. The main contractor has to be aware of the situation of the subcontractor and to control the progress of the subcontractor every week. [164] The main contractor must regularly have control of the following items:[165]

- subcontractor begins on time
- uninterrupted work progress
- production progress as planned
- work progress in correct order from one area to an other
- work areas are ready for next work phase at the right time
- work areas are completed without faults in quality

The contract should state how the subcontractor undertakes to monitor his work, and state progress to the satisfaction of the main contractor. The methods, how the contractor will control his work and the risks associated with them should also be indicated in the contract.[166]

Material control

As mentioned above, material purchase control occurs mainly before making an agreement with the material supplier. The procurement department and site personnel perform the real material control by controlling the following:[167]

- orders and agreements with material supplier are made on time
- delivery is ensured (e.g. factory visit)
- delivery shortcomings are rectified

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[163] Compare. SITRA, 1996, p. 97-105

[164] Toikkanen, S. and Särkilahti, T., 1997, p. 38

[165] Kankainen, J. and Särkilahti, T., 1992, p. 69

[166] Gerrand, John, 1996, p. 24

[167] Toikkanen, S. and Särkilahti, T., 1997, p. 47

- changes in time of delivery and quantities are forecast
- material supplier are informed about changes in time of delivery and quantities

The company has to be aware of the risks related to the subcontractor in all phases of the subcontracted process, both before making an agreement and after it. Perceived risks, and their possible effects have to be identified and forecast by the company.[168] At the same time, the specific threats are eliminated by eliminating the cause. It is difficult to eliminate all risks, but specific risk events can often be eliminated or their harmful effects can be minimized. [169] This risk identification and quantification phase is called a potential risk analysis.

[168] Kankainen, J. and Särkilahti, T., 1992, p. 16
[169] Project Management Institute, 1996, p. 119

3 PROCEDURES FOR PLANNING AND CONTROL

3.1 Problems and Requirements for Project Management

The thesis included an interview study, that was meant to identify the main problems related to planning and control of project implementation. Based on the experienced project personnel's interviews it is possible to say that in the autumn of 1997, NTC does not have all the needed procedures for planning and control of implementation in a turnkey project or they are defective and need focusing and optimization. The problems appear at two levels: at the project level and at the site level. The following problems were identified during the interviews:

- How can the project scope be divided into more manageable elements?
- How can the share of responsibilities between different parties be defined in a turnkey project ?
- What are the main processes both at the site level and at the project level and what are the dependencies between different subprocesses ?
- What are the typical country specific issues that have impact to the site process ?
- How are site, subsystem and project roll-out monitored and controlled ?
- What are the most important milestones at the project level and at the site level ?
- How is it possible to reduce the duration of network planning and site acquisition processes and make them more effective ?
- How is it possible to reach a continuous process in production ?
- What kinds of teams and work groups are needed in the project and what are their optimal sizes ?
- How are the network elements, the complementary systems and other needed material deliveries to the site scheduled ?
- How is communications and reporting arranged inside the project ?

The requirements for Project Management resulted from the problems, and the needed procedures for planning and control of project implementation are based on General Project Management. The focus of this thesis is to study Project Management and its knowledge areas, tools, techniques and procedures from the point of view of planning and control of project implementation and apply them to a cellular network implementation project.

3.2 General Planning and Control

3.2.1 Process Definition

NTC has identified three cross-functional core processes: Customer process, Product process and Management process.[170] Project implementation is part of the Customer process, more precisely, the Delivery process. The customer process is shown in Figure 18.

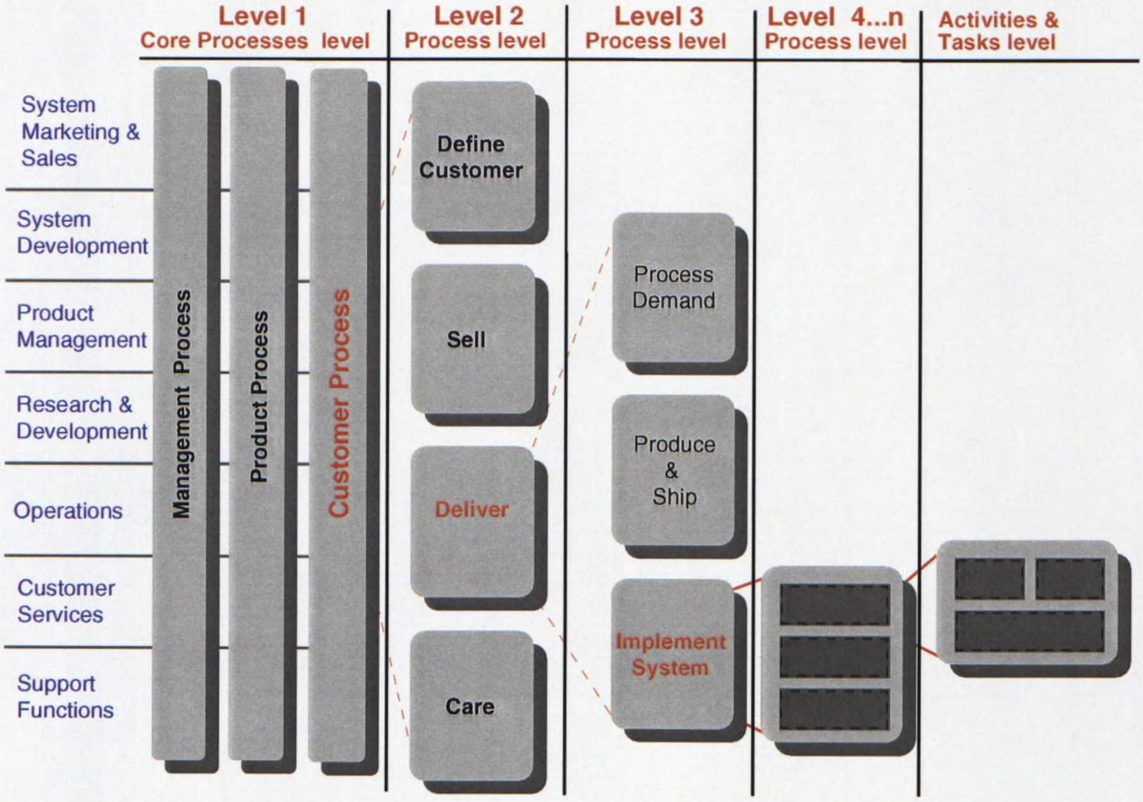

Figure 18 The hierarchy of customer process. (Compare: Nokia Telecommunications, NTC Customer Process, Communication Set, 1997, p. 4)

[170] Nokia Telecommunications, 1997, p. 4

In a cellular network implementation project, every site in a network needs network planning, acquisition, construction work and network element installation, as well as commissioning, integration and acceptance.

The purpose of defining the site level process is to describe the whole site process from network planning to site acceptance on the same flow chart. The dependencies between the main parties of the site process are defined and linked together. The share of responsibilities and monitored milestones are presented on the flow chart. The main parties to the site process are the following:

1. NTC
2. Customer (Operator)
3. Authorities
4. Site owners
5. Contractors and consultants
6. NTC's internal customers: product line and other telecommunication equipment and products suppliers

A generic site process flow chart is presented in Appendix A. In every new project the local circumstances, legislation, culture have to be taken into consideration in planning the site process because they may have enormous effects on the project's implementation. Typical country specific issues that have impacts on the site processes are:

- build permit policy
- local construction culture
- typical structures
- power supply availability
- local authorities
- needed permits
- geographical situation
- earthing requirements and regulations
- health and safety regulations
- alternatives for transmission
- customs
- transportation

3.2.2 Work Breakdown Structure and Purchase Packages

The project decomposition method is based on the Work Breakdown Structure (WBS) and the Location Breakdown Structure (LBS). The project has been split into five types of main delivery items. Geographically the project is divided into regions, areas and individual sites. The main delivery items are divided into the lowest level of the WBS, which are more manageable elements as work packages. The project's main WBS is presented in Figure 19.

Project's main delivery items are:

- Project Management
- Network planning
- Site acquisition
- Construction works
- Telecom implementation

Project's geographical areas are:

- Regions
- Areas
- Sites

The share of responsibilities is based on the contents of purchase packages (Appendix B). Network planning and site acquisition are composed of purchase packages, which include only work. Construction works consist of purchase packages, which include usually both materials and labor. Telecom installation is composed of purchase packages, which include only work, when NE's and CoSy materials are delivered by NTC.

In practice, the contents of purchase packages may be combined. In this way NTC may reduce its own tasks by delegating tasks and responsibilities for the subcontractors. However it is important to keep the project management in NTC's hands.

There are many alternatives for sharing responsibilities between NTC and subcontractors in a project. Figure 20 shows three alternatives how the implementation of the site can be shared among any number of subcontractors. Subcontractor's responsibilities can be shared by different areas (sites) or by different work phases.

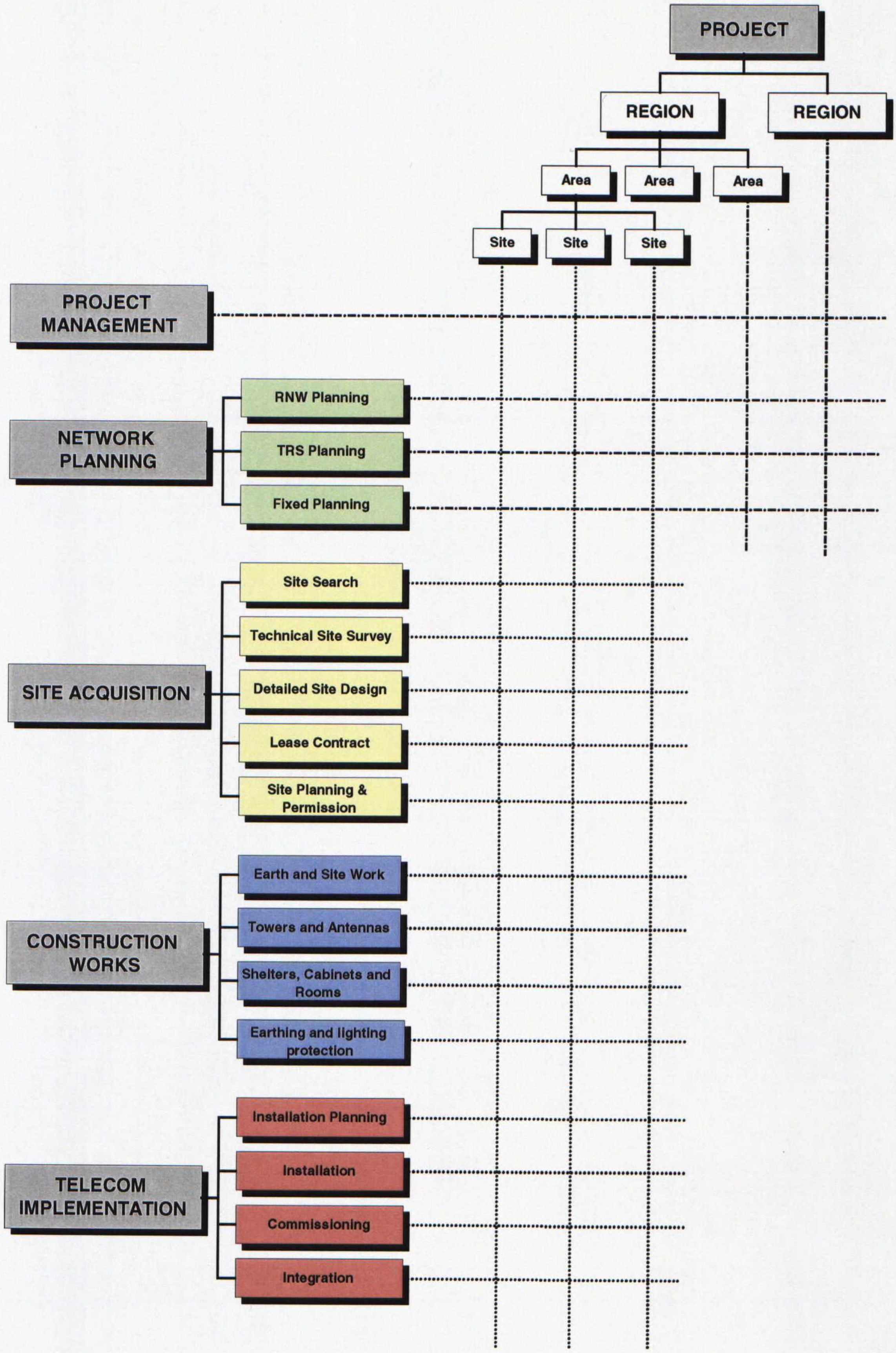

Figure 19 The project's work breakdown structure.

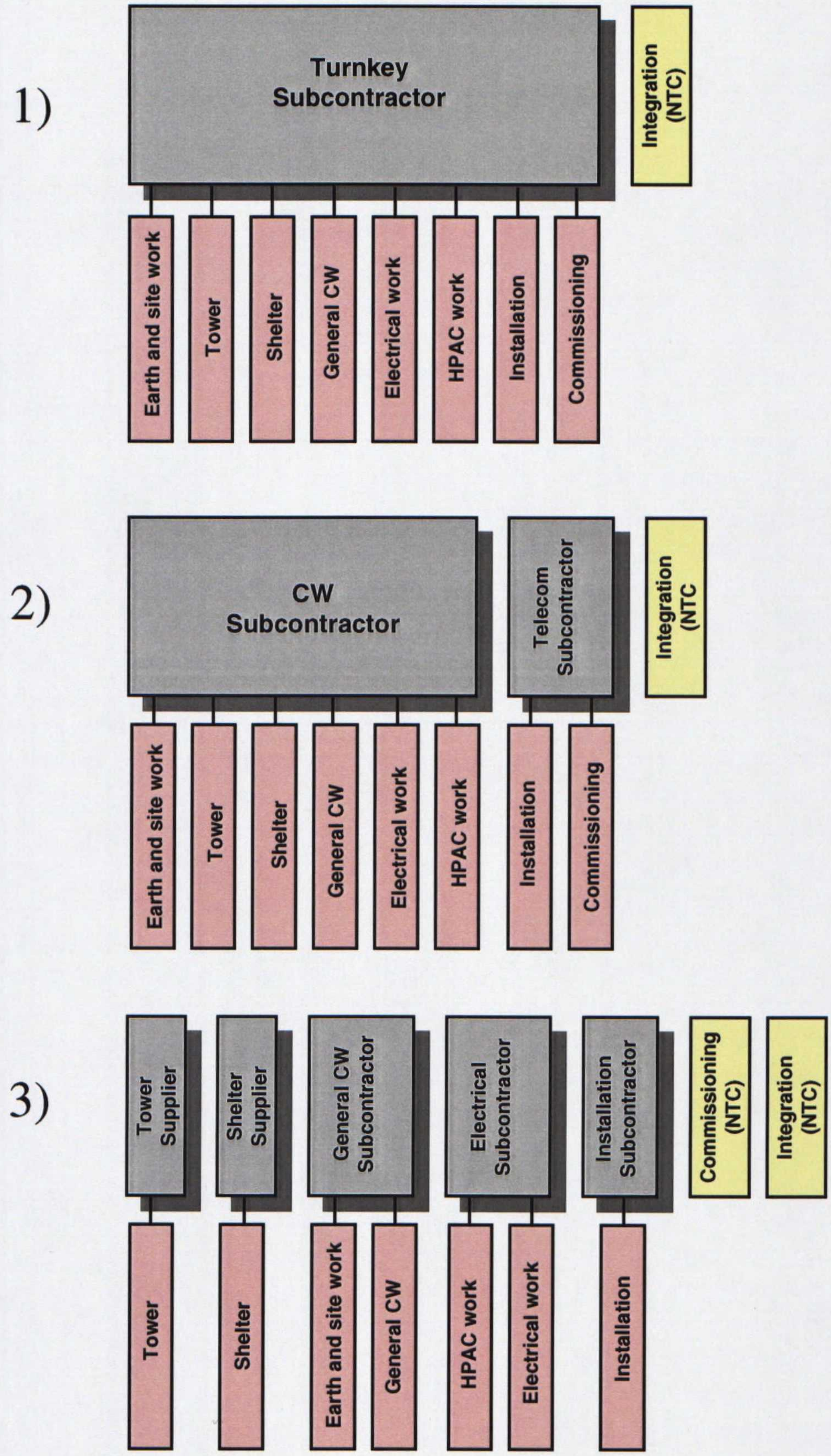

Figure 20 Three alternatives for sharing responsibilities among different subcontractors.

3.2.3 Project Organization

Project organization is consistent with the Work Breakdown Structure. Each WBS-element has to have clearly defined organization or person in charge. A generic turnkey project organization is presented in Figure 21.

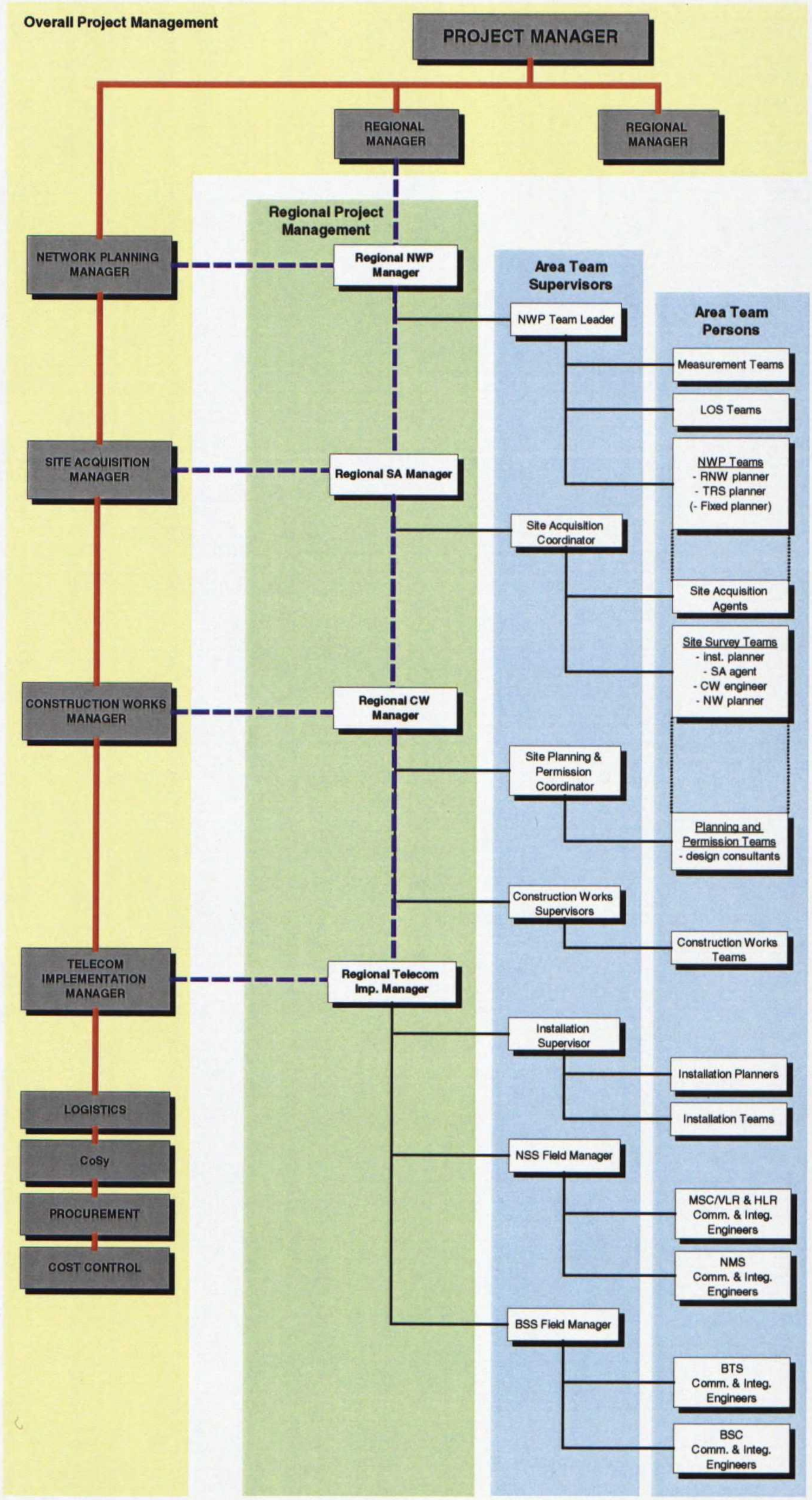

Figure 21 Turnkey project organization.

3.2.4 Schedule Planning and Control

At the project level, schedule planning and control are performed by using two different types of schedules:

- Project master schedule presents a summary of main milestones and processes at the project level (Appendix C). BTSs are presented as volume Network Elements (NEs) whereas BSCs and MSCs are presented individually. The project master schedule is the basis for other project plans, such as detailed roll-out schedules and material plan. Actual progress is updated into the project master schedule every week.

- Roll-out schedules present the progress of volume NEs by using main milestones both at the project level and validated sub milestones at the site level (Appendix D). Roll-out schedules are updated continuously on a weekly basis. They then form a basis for resource calculation and subcontractor schedules. Project roll-out progress is stored into a separate database.

Project scheduling can be performed at different hierarchical levels, which are linked together. The Work Breakdown Structure provides an ideal medium for schedule planning. Geographically the project is divided into regions, areas and individual sites. By using this decomposition structure the project schedule can be modified into more and more detailed subschedules up to the site level (Figure 22).

At the site level schedule planning and control are based on standard implementation time frames which are defined for different BTS sites. The average lead-times between the milestones are presented in Appendix E. The lead times are country specific and they depend on local circumstances, resource availability, location, site types and working methods in the country in question. The time frames have to always be modified in accordance with local circumstances.

Detailed generic schedules for model sites are used in:

- planning production
- agreeing on the rate of progress with subcontractors
- agreeing on the site specific delivery periods with subcontractors
- ordering network elements to the site

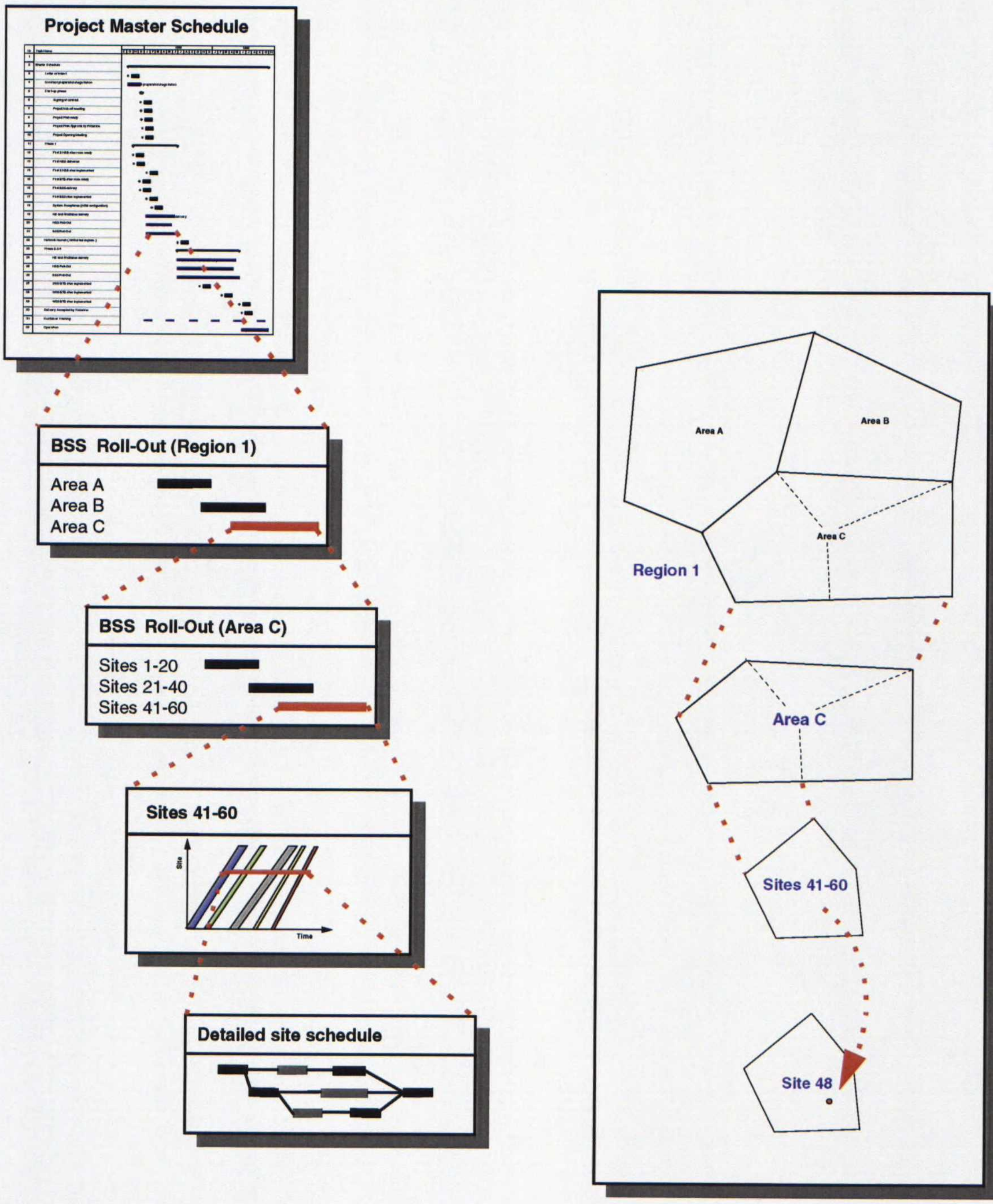

Figure 22 Principles for scheduling at different hierarchical levels.

3.2.5 Progress Monitoring and Control

The Project Manager and the project team monitor and control the project's planned, estimated and actual roll-out regularly. The Project Manager analyses deviations from the project plan, the resource plans and milestones. Analysis is made at the project, region and area level. In case of major deviations, the Project Manager should start immediate corrective action. The principles of progress control at different levels are demonstrated in Figure 23.

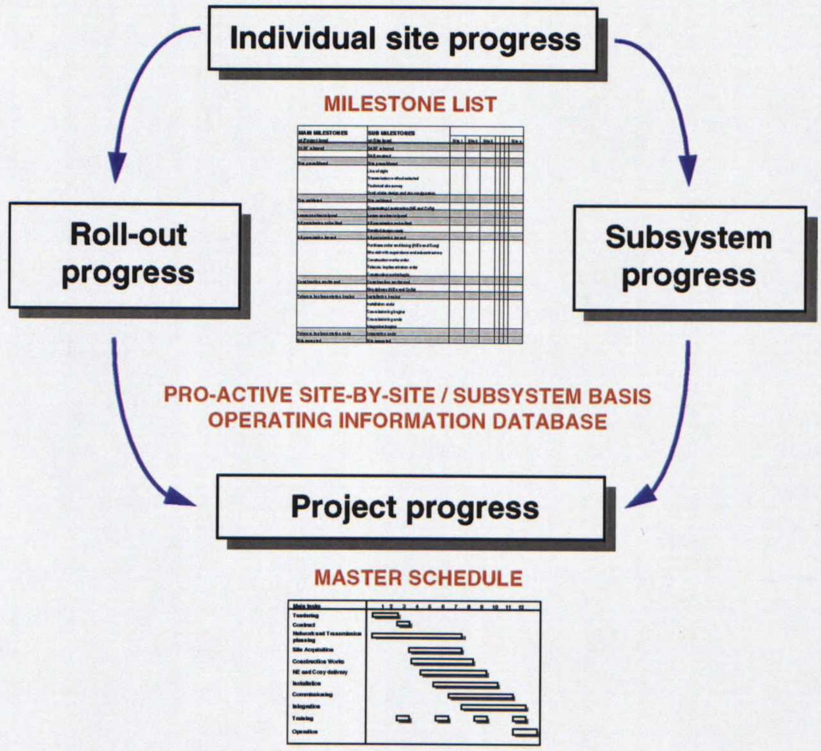

Figure 23 Progress control at different levels. (Compare: Luhtala, I., Turnkey Project Management process for cellular project, 1997, page 49.)

<u>Individual site progress</u>

Individual site progress is monitored by using the milestones. One site has 10 main milestones and 17 sub-milestones, which are listed in Appendix F. Site related milestones are partly project specific and partly generic. All authority and site owner related tasks and contractual milestones for ordering or invoicing are automatically taken as site milestones. Regardless of the share of responsibilities between the Customer and NTC, there should always be monitoring of site milestones for each site's life span, from network planning to site acceptance. 'Construction works begin' and 'Installation begins' milestones are entered into NTC's Modular Logistics System (MLS) for the purpose of logistics planning.

<u>Roll-out progress</u>

Project roll-out monitoring and control are performed at two levels: at the project level and at the site level. All sites' milestones are collected as a roll-out schedule. The roll-out schedule presents planned and actual progress of BTS and BSC sites against main milestones. The Roll-out database is updated continuously but at least weekly by persons responsible for milestone activity. The share of responsibilities for updating the status of different processes are defined as follows:

- Network planner (team leader) updates network planning status.
- Regional SA Manager updates site acquisition status.
- Regional CW Manager updates planning and permission status.
- Project Manager ordering and invoicing status of the site.
- Regional CW Manager updates detailed site design status.
- Regional CW Manager controls achievement of target and update status of construction works.
- Field Managers update status of installation, commissioning and integration.

The roll-out progress is stored in a pro-active site-by-site basis information database. Tools like PM Tool or NETQ can be used. A tool should work on a network basis and be available for every project member with a structured level of authorization. The following data and characteristics should be included in the database:

- milestones and their plan, actual and estimate status (dates)
- radio requirements and search parameters included in SARF
- site descriptions (including site name, address, co-ordinates, contact persons, phone numbers, photos and so on)
- owner and contract information
- information included in SAR
- possible radio technical remarks
- authority requirements
- existing enclosures

<u>Subsystem progress</u>

A network is built from subsystems, which are composed of both BSCs and BTSs. A BTS has to be integrated to a BSC and a BSC connected to a MSC. Usually turnkey contracts have milestones for roll-out and also for subsystem handovers. The acquired, constructed and installed sites have to fit into the subsystem and all key sites and transmission solutions have to be ready before a subsystem can be taken into use. The subsystem progress control for each subsystem (BTS cluster) is concentrated into BTS sites (pcs).

The subsystem progress monitoring can be carried out as well by using a map, in which the subsystem's progress is illustrated with different colored labels. The map is fixed on the wall and different colored labels define the status of a site within the project (Figure 24).

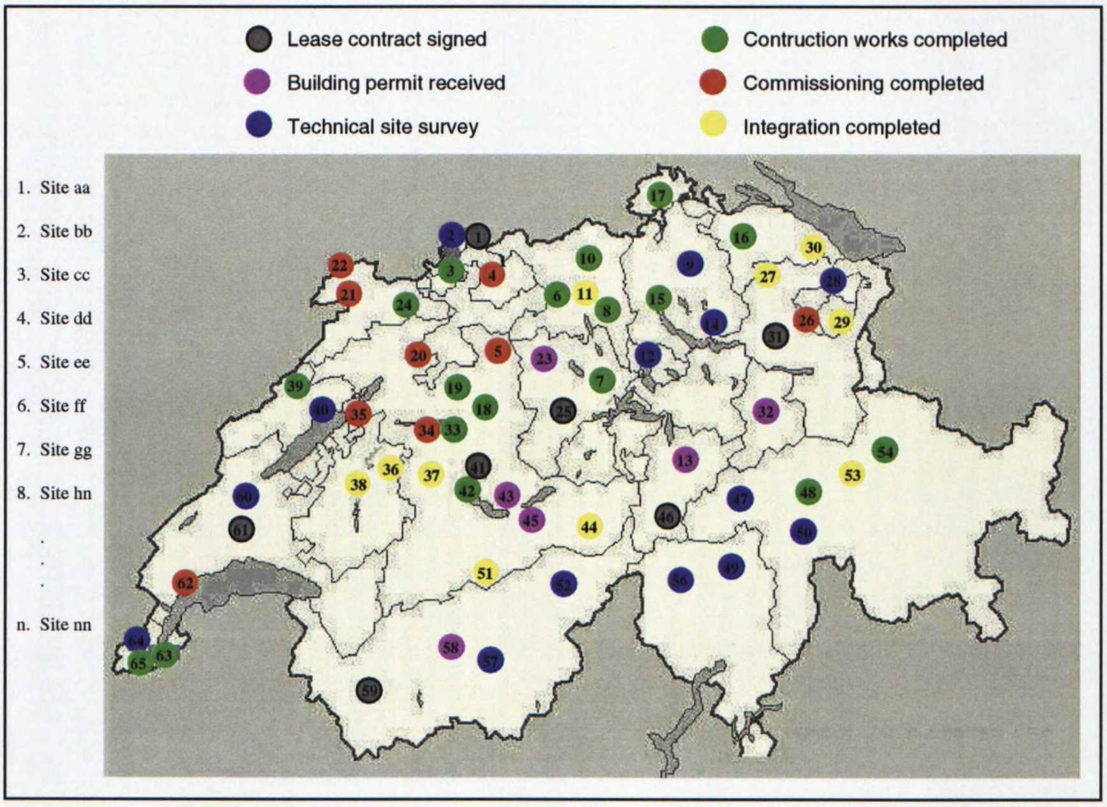

Figure 24 The subsystem's progress monitoring in the diAx project.

<u>Project progress</u>

The master schedule presents the summary of milestones and processes. BTSs are presented as volume Network Elements (NEs) whereas BSCs and MSC are presented individually. The project schedule should be updated with actual information each week.

3.2.6 Resource Planning and Control

One problem in telecommunication projects is the simultaneous management of several sites. Project managers and engineers must handle hundreds of 'small' projects simultaneously. It is difficult to decide how to allocate resources among multiple sites. Resource planning occurs at two levels:[171] [172]

- <u>Long-term resource planning:</u> To ensure a sufficient amount of resources with the proper skills available for the planned roll-out. The Project Manager is responsible

[171] Compare: Luhtala, M., 1995, p. 73-74
[172] Compare: Luhtala, I., 1997, p. 53-55

for resource planning and the IS Manager for resource availability. Long term resource needs and the current situation are reviewed and reported monthly in internal meetings. The report is delivered to responsible Managers.

- Short-term resource planning: To allocate resources for daily roll-out on a weekly basis. Field Managers are responsible for weekly planning and reporting to the Project Manager. Short term resource needs and allocation are reviewed weekly in internal project meetings.

A special "task force" can be used as a moving resource pool in case of a large national turnkey project with several regions. The task force is not allocated to a specific region. It works and moves in all regions and levels out resource peaks. The Task force's schedule should be fixed for a period, say, three months and it is reviewed monthly in internal meetings.[173]

Contents and capacities for different teams are presented in Appendix G. Calculating the needed amount of resources can be performed for example by Excel program. The resource plan for 100 sites per month is presented in Appendix H.

Project Teams and their tasks

Project Management team

A Project Management team consists of Project Manager, Regional Managers, Network Planning Manager, Site Acquisition Manager, Construction Manager, Telecom Implementation Manager, Logistic Manager and Project Cost Engineer. The team is supported and controlled by NTC's Customer Services senior management, which has extensive experience in the project management field. The Project Management team is responsible for implementation planning of overall work flow, general process definition, progress tracking, monitoring and reporting, resource management, general subcontractor management and information management. Maintaining overall schedule, standardized processes and information exchange is the main responsibility of the team.

[173] Luhtala, I., 1997, p. 55

Network planning team

A network planning team consists of two radio network planners, two transmission planners and a fixed network planner (if needed). The senior radio network planner is a team leader. Network planning is performed in close co-operation with site acquisition. Interworking between site acquisition and network planning is crucial. The network planning team takes care of coverage-, capacity-, frequency- and parameter planning by using Nokia's NPS/X planning system. The network planning team is also responsible for transmission planning for access and backbone networks. Work includes BTS - BSC connection planning and optical fiber link calculations. The network planning team produces a list of preferred sites including coordinates, antenna height and search ring, also known as Site Acquisition Request Form (SARF).

Site Acquisition team

The site acquisition teams are composed of local site acquisition agents. The team identifies three suitable sites according to the radio frequency and transmission parameters issued in a SARF document by network planners. Possible candidates are presented to network planners in a Site Acquisition Report (SAR). The site acquisition has to be performed in close co-operation with network planning. Site owner's willingness to rent out the site has to be clarified within the course of the first site visit. The team prepares a preliminary lease contract with the site owner and takes part in technical site surveys.

Line of site survey team

A line of site survey team is composed of two engineers each performing a line of sight field survey, checking of microwave radios and measurements for external interference.

Technical site survey team

A technical site survey team is composed of installation planner, construction engineer from the planning and permission team, radio network planner and site acquisition agent. Site survey teams are responsible for technical site surveys and required technical site survey reports. The team members qualify and compare the site functions with the requirements and its suitability for the network.

Installation planning team

An installation planning team is composed of installation planners. The team takes part in the technical site survey and prepares its own technical site survey report. The installation planner makes the required arrangements for purchase orders (NE and CoSy) and detailed design for telecom installation.

Planning and permission team

A planning and permission team is composed of local planning and design consultants and is led by the local Construction Works Manager. The team prepares required documents and drawings for all permits. A Planning and permission team also takes part in technical site surveys.

Detailed design team

A detailed design team is composed of local planning and design consultants and is led by the regional construction works manager. The team prepares required detailed design for each site by using the drawings for permits as a basis. The detailed design is composed of architectural design, structural design, electrical planning, HPAC planning and detailed installation planning. The planning and permission team and detailed design team can consist of the same persons.

Construction works team

A construction works teams consist of local construction works subcontractors and are led by the local construction works supervisor. The team could be composed of two or three workers. Construction works teams are responsible for constructing needed sites for telecom installation on schedule and to a required level of quality.

Telecom implementation teams

The telecom implementation teams can be divided into installation, commissioning and integration teams.

- Installation teams are responsible for installing antennas, microwave radios, power systems and BTSs, BSCs and MSCs equipment to be ready for commissioning. The installation teams are composed of two or three electricians. One team installs telecom outdoor equipment and the other team installs remaining telecom indoor equipment.

- Commissioning teams are responsible for ensuring that network elements are functioning properly after transportation and installation and they set network elements ready for integration. The commissioning team includes a commissioning engineer. The telecom installation and commissioning can be combined in one team.

- Integration teams integrate the network element or subsystem ready for commercial use. The commissioning team ensures that the network elements have been configured and tested as stand alone entities. During the integration phase, the interconnections between the elements are configured and the network element parameters are customized. The integration team includes two integration engineers.

Logistics team

A logistics team consists of logistics co-ordinators and is led by the logistics manager. The logistics team is responsible for purchase orders, forwarding, delivery control, HW repair support and invoicing support.

Measurement team

A measurement team consists of two measurement engineers. The team is responsible for measurements and network quality surveys required for network planning.

3.2.7 Information Distribution

The meetings and reports keep the customer, Account Manager (AM), Project Manager (PM), CS line organization and other participants aware of the progress of the project.

Project Meetings

All internal and customer project meetings are planned in the Project Plan. A meeting plan should include the scope of every meeting, intervals, participants and standard agendas. Customer meetings and reporting procedures are confirmed with the Customer. The main goals of meeting and reporting practices are:

- to keep the Customer involved and fully aware of progress
- to keep the Account Team and other CS organization informed about the progress of the project
- to provide the Project Manager with all information necessary for managing the project in order to achieve the set objectives
- to record the project life cycle and decisions made

Appendix I outlines a standard project meeting and reporting practices in a turnkey project at the project level.

Weekly progress review meeting with the customer

The purpose of this is to keep customer's operative project team fully informed on the progress of the project. In the meeting, the daily issues are handled and the practical problems that are related to the project with the customer are solved. The meeting has the following topics and participants:

Main Topics in agenda:

- Time schedule
- Network status analysis
- Technical issues raised during the week
- Activities during next week
- Material deliveries
- Action points
- Customer acceptances

Participants:

- Project Manager
- Customer Project Manager
- Other customer representatives
- Regional Managers
- Network Planning Manager
- Site Acquisition Manager
- Construction Manager
- Telecom Implementation Manager
- Logistics Manager

Executive meeting

NTC's and the customer's project management teams take part in quarterly meetings, that have the following topics and participants:

Main Topics in agenda:

- Time schedule and status analysis of the project progress
- Material deliveries for next month
- Delivery planning for the coming months
- Action points
- Customer acceptance status
- Potential risks
- Technical problems

Participants:

- Project Manager
- Customer Project Manager
- Other customer representatives
- Other NTC's representatives
- Network Planning Manager
- Site Acquisition Manager
- Construction Manager
- Telecom Implementation Manager
- Logistics Manager

Weekly internal project meeting

The purpose of the weekly internal project meeting is similar to the weekly progress review meeting with the customer, i.e. to keep the NTC project team fully informed about the progress of the project. It is wise to hold the internal project meeting a day or two before the similar progress review meeting with the customer to check the situation internally and to take action with possible problems prior to the meeting with the customer. The meeting has the following topics and participants:

Main Topics in agenda:

- Time schedule
- Network status analysis
- Technical issues raised during the week
- Activities during next week
- Material deliveries
- Resource plan for the next two weeks
- Action points
- Customer acceptances
- Customer satisfaction
- Potential risks

Participants:

- Project Manager
- Project Management Team
- Subcontractors (if necessary)

Account Team meeting

The purpose of the Account Team meetings is to set general guidelines for the Account and make strategic choices concerning the Account. The meeting has the following topics and participants:

Main topics in agenda:

- Account status analysis
- Strategic policy
- Customer relations
- Critical issues in the project

Participants:

- Account Manager
- Project Manager
- Product lines' representatives (Product Managers)
- Other Area representatives

Meetings with subcontractors

All meetings with subcontractors are planned in the Project Plan. A meeting plan should include the scope of any meeting, intervals, participants and standard agendas.

Weekly network planning and site acquisition meetings

The purpose of this is to keep the network planning teams and the site acquisition teams fully informed about the situation of site acquisition and network planning. The weekly issues are handled and the practical problems are solved. The meeting has the following topics and participants:

Main topics in agenda:

- Time schedule
- Network planning status
- Site acquisition status
- Activities during next week
- Action points
- Potential risks
- Change information

Participants:

- Regional NWP Managers
- Regional SA Managers
- NWP team leaders
- Site acquisition team leaders
- Subcontractors

Weekly construction works meetings

The purpose of this is to keep the construction works teams fully informed about the situation of construction works. The daily issues are handled and the practical problems are solved. The meeting has the following topics and participants:

Main topics in agenda:

- Time schedule
- Detailed design status
- Construction works status
- Activities during next week
- Material deliveries
- Action points
- Change information

Participants:

- Regional CW Manager
- Design consultants
- Construction works supervisors
- Subcontractors

Weekly telecom implementation meetings

The purpose of the meeting is to keep the telecom implementation teams fully informed about the situation of telecom implementation. The weekly issues are handled and the practical problems are solved. The meeting has the following topics and participants:

Main topics in agenda:

- Time schedule
- Installation status
- Commissioning status
- Integration status
- Activities during next week
- Material deliveries
- Action points
- Change information

Participants:

- Regional Telecom Implementation Manager
- NSS Field Manager
- BSS Field Manager
- Installation supervisors
- Installation planning team leaders
- Subcontractors

Reporting

The project reporting schedule, formats and responsibilities have to be agreed on the Project plan. Tools used for project control are also used for reporting. At the moment an integrated turnkey project reporting tool for reporting of planned, actual and estimates for financial status, costs and invoicing, schedule and progress, quality, resources and risks does not exist.

Project reporting is divided into customer reporting and internal reporting. Contents of customer and internal reports are presented in Appendix J.

Change control

Change control procedure is the most critical issue in the control of design and planning. Each subprocess has to have persons in charge who are responsible for ensuring that all planners, construction contractors, telecom implementation teams and other essential persons are always aware of the latest planning situation, occurred changes and site rejections. Persons in charge and their sphere of responsibilities are as follows:

Person in charge:	Sphere of responsibilities:
Network Planner (team leader)	• radio network planning • transmission network planning
Site Acquisition Co-ordinator	• site search • lease contracts
Installation Supervisor	• technical site survey • installation planning • telecom installation
Site Planning and Permission Co-ordinator	• site planning • permits • detailed site design
CW Supervisor	• construction works
Field Managers	• commissioning • integration

The general site status has to be reviewed weekly at internal project team meetings. The more detailed site status reviews and informing of occurred changes and site rejections are performed weekly or if necessary more often at the meetings with subcontractors. However information about urgent and critical changes and site rejections between responsible persons have to be executed by phone, fax or e-mail.

Rejected sites are documented in a rejected site form. Urgent and critical changes have to be documented too. The most likely points of site rejections are illustrated with red 'No-boxes' in the site process (appendix 1).

3.2.8 Procurement Planning and Control

The procurement plan is a part of the project plan and it includes the following topics:

- purchase packages
- time schedule for procurement
- responsibilities
- time schedule for needed information; for example plans and specifications
- supplier information for project level procurements
- frame agreements

The procurement plan is reviewed bi-weekly in internal project meetings. Site level procurement and purchase orders are controlled with site milestones.

Procurement is divided into numerous purchase packages based on practical, commercial and industrial relations considerations and NTC's previous experience in similar projects. A list of prospective tenderers is prepared for purchase packages. Prequalification information may be requested from subcontractors and suppliers to ensure that only capable companies are providing quotations. After receipt of the customer's purchase order, NTC makes a final selection of subcontractors and suppliers.

To achieve the most economical outcome it is advisable to release the sites in batches of 10 to 20 sites at a time for one subcontractor. The tenders for each purchase package are compared with a target budget. If tender exceed budget limits, alternatives are studied.

The delivery process is one part of procurement planning and control. The main operative activities during the delivery and implementation process are logistics, network planning, site acquisition, construction works and telecom implementation (Figure 25).

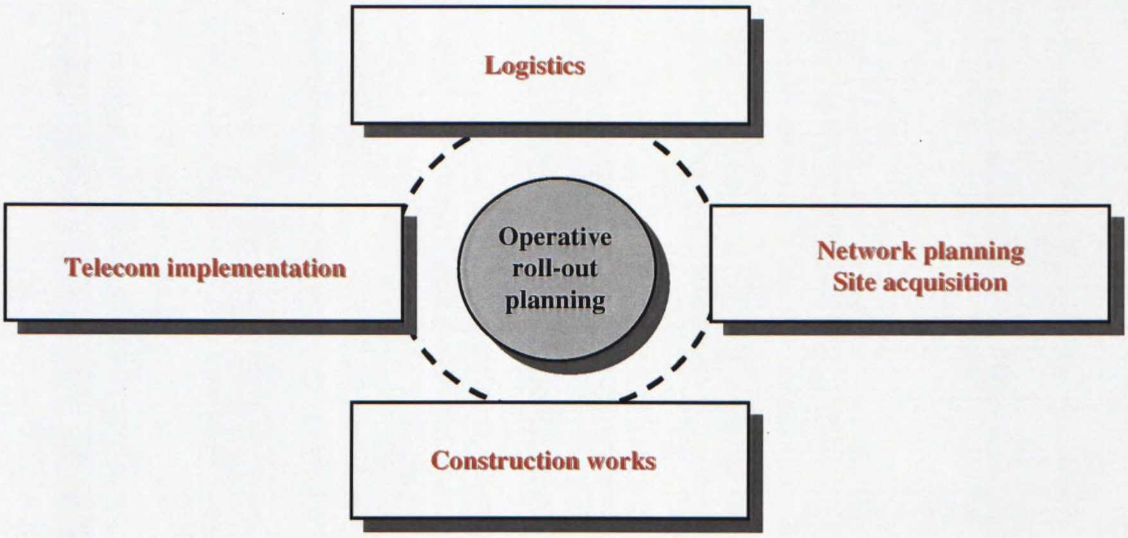

Figure 25 Main operative activities during delivery and implementation process.

In a turnkey project preliminary forecasting for NE and CoSy materials have to be made already at the tendering phase so that their availability can be ensured. Preliminary reservations for NE and CoSy materials are made in the contract negotiations phase by the Account Manager. Reservations are based on the Project Manager's forecast, customer RFQ and project plan.

Installation planning is responsible for selecting network elements (NEs) and required CoSy materials for sites according to the requirements of RF planning. The project monitoring database keeps track of all requirements, regardless of the status of the sites. The point of actual ordering for NE and CoSy materials for individual site is 'All permission issued'. Nevertheless, focused reservations for NE and CoSy materials have to be made after 'Site validated'.

The delivery process from reservation to delivery to site and inputs to reservation, order and delivery to given site are presented in Appendix K.

3.3 Planning control

In this thesis, planning control means a process that includes the network planning process, the site acquisition process, the technical review process and the permission process. A share of planning control as a part of the site process is illustrated by red in Figure 26.

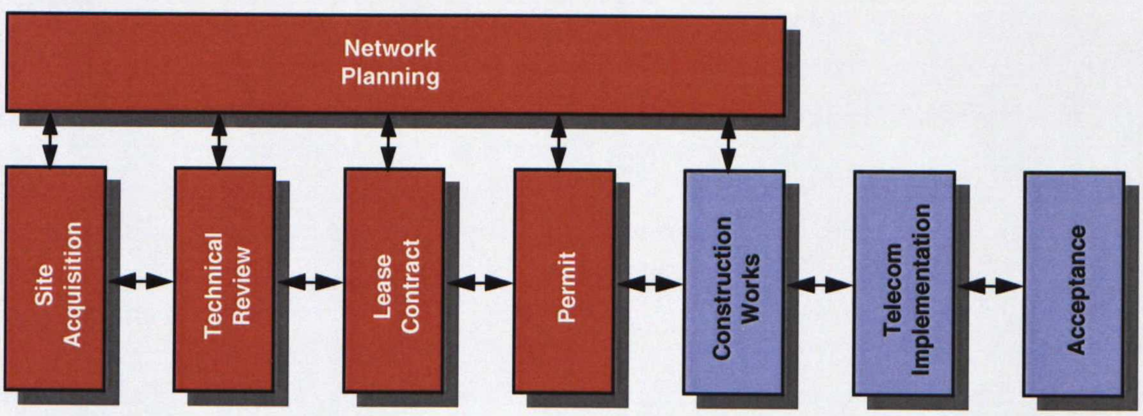

Figure 26 A share of planning control as a part of the site process.

3.3.1 Planning Processes

Network Planning Process

The network planning process is a continual process, which has to be started already at the tendering phase together with the site acquisition process. Network planning and site acquisition interworking have to be fully specified before beginning and they have to work very closely with each other until the site is qualified.

In the site process, network planning starts from nominal cell planning. Network planners produce a radio frequency plan which indicates the area to be covered. The document to be used in this context is the Site Acquisition Request Form (SARF). Radio and transmission planners analyze the site candidates according to the Site Acquisition Report (SAR) and rank them in order of importance. The radio network planner takes part in the technical site survey and prepares his/her own technical site survey report and radio frequency submission form for the authorities.

Final transmission planning is performed before the installation process. Radio network planning and parameters planning have to perform before the commissioning process.

Site Acquisition process

The target of the site acquisition process is to find suitable sites for the network elements. It is a part of the tendering and start-up phase before signing of contract. In this way a sufficient amount of sites are secured for roll-out start-up without causing delays to site construction and roll-out of the network. An effective site acquisition process saves time in implementation.

Site acquisition agents search physical site candidates according to the SARF requirements. The sites are presented to network planners in the SAR including the following data: street address and co-ordinates, roof height, ground altitude, description of site type, conditions and structures and supporting photographs of the building and surroundings, an indication of the owner's willingness to enter lease negotiations, electricity and telephone sources and capacities, access to the site and basic documentation necessary for transmission network planning.

Technical review process

The technical review process is composed of Line of Sight (LOS) checks and a technical site survey. The LOS for all three site candidates and neighboring sites are checked by the LOS team. By checking LOS before the technical site survey it is possible to reduce unnecessary site visits. The technical site survey is performed by the technical site survey team which ensures technical requirements and suitability for a potential site. The technical site survey team is composed of installation planner, construction engineer, radio network planner and site acquisition agent. The architect, who is responsible for preparing the site planning and the build permit drawings, should also take part in the technical site surveys. Each engineer prepares a report for site qualification and site planning and design purposes.

The following topics have to be checked during the technical site survey:

- antenna sectors
- vertical cable route
- outdoor equipment
- existing antennas to be moved
- cable entry port
- existing ducts
- coax cable tray
- platform
- antenna support structure
- equipment support structure
- access ladder system
- electrical power supply
- grounding point
- existing grounding point
- Mbt cable route
- grounding conductor route
- downriser external
- downriser internal
- roof access
- equipment layout

The next steps after the technical site survey report for the architect to prepare the site plans (draft of site design). Site configuration is performed after site qualification. Both site configuration and draft of site design are inputs for site validation.

Lease contract process

The lease contract process may be a time-consuming process and therefore it has to be cleared up already during the tendering and start-up phases before signing of the contract. After the site is prevalidated, the site acquisition agent will start lease negotiations with the site owner. The standard lease contracts in appropriate national language(s) and lease price guidelines should be used as a basis for the lease negotiations. Before the lease contract is signed by the site owner, site approval by the customer has to be ensured.

Permit process

The permit process may be a time-consuming and complicated process in many countries and therefore it has to be cleared up already when contract negotiations start. All authorities have to be contacted before the tendering phase so that the requirements of municipal and governmental authorities are known precisely. It is vital to clarify procedures for an application process, how long it normally takes to get the permits and what kind of plans and drawings are needed in the country or area in question. The following permits and authority requirements have to be clarified beforehand:

- build permit
- power supply
- radio frequency
- type approval
- aviation
- military
- environmental board
- highway department
- conservation and museum board

Normally the application of the permits from governmental authorities takes much more time than from municipal authorities. These two process application phases are linked together and are sequential, which has to be taken into consideration when scheduling the activities. The permit processes are very country specific. It is usually more convenient to acquire a permit for several sites simultaneously instead of individual sites. In this way the meetings with authorities are reduced.

The planning requirements (e.g. general standards for loads, materials, quality, and possible soil tests) have to be clarified because required planning depends on technical site survey reports and a site requirement programme. Model site planning has been done already during the pretendering phase so that model sites are suitable for using in the country in question.

3.3.2 Network Planning and Site Acquisition Strategies

Network Planning Strategy

To be able to properly plan the network it is very important to clearly define the network planning and deployment strategy. The following issues have to be taken into account with planning the network planning strategy:[174] [175]

- customer requirements for coverage, capacity, quality
- different NE, CoSy materials and site configurations to be used in the project
- definition of planning environment (what is the strategy for site acquisition, possible restrictions by the authorities)

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[174] Compare: Luhtala, I., 1998, p. 10

[175] Compare: Lamberg, M., 1997, p. 3-4

- targets are clear from the beginning (prioritized sites, definition of regional organization etc.)
- nominal cell plan and definition of input information to site acquisition
- the same office with site acquisition personnel

The network planning manager plans the strategy in close co-operation with other services like site acquisition, design and permitting, construction services and complementary systems and product competence centre.

Site Acquisition Strategy

A clear site acquisition policy has to be determined before starting actual site hunting. The Project Manager is responsible for the policy and it contains the following issues:[176] [177]

- possible friendly sites
- target site owners
- target average rent
- standard lease contracts with site owners
- typical approach with site owners
- 'marketing folder' prepared for site owners
- identification of the most critical sites and prioritization of sites
- definition of network planning and site acquisition organization and regional division of the area and interfaces
- a good and clearly defined documentation system and communication channels between planning and site acquisition
- change control process in planning and site acquisition
- sufficient SA agents are available
- SA agent training
- bonus fees for SA agents
- public holidays

[176] Compare: Luhtala, I., 1998, p. 10

[177] Compare: Lamberg, M., 1997, p. 6-7

3.4 Production Planning and Control

In this thesis, production planning means a process that includes the construction works process, the telecom implementation process and the acceptance process. A share of production planning as a part of the site process is illustrated by red in Figure 27.

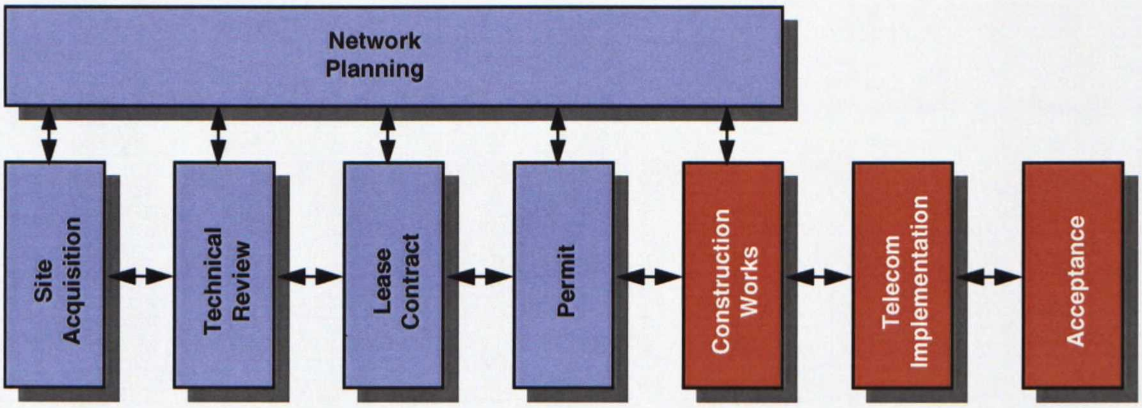

Figure 27 A share of production planning as a part of the site process.

Schedule planning is realized together with the chosen production planning model. Local culture has to be taken into account in choosing the correct production models for project implementation.

3.4.1 Repetitive Cell Production Model

Construction and telecom implementation processes can be divided into several repetitive cells, which are organizationally separated production units. A workgroup of a cell consists of multiskilled workers who are responsible for doing their work as a group. Still, the work groups do not do their work simultaneously at the same work area.

Figure 28 demonstrates the principles of the sites' place commitment in construction and telecom implementation processes.

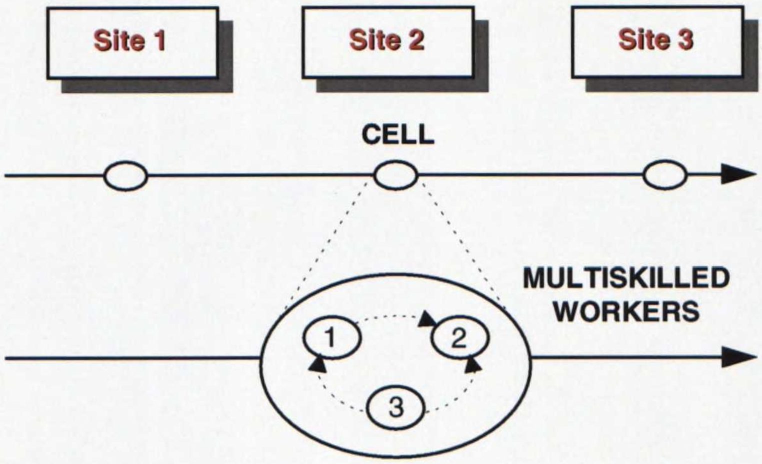

Figure 28 The sites' place commitment in construction and telecom implementation processes.

Cell production planning consists of the following five main phases:

1. Defining the implementation sequence of sites in a chosen area (NTC)
2. Defining the main schedule for chosen area (NTC/Subcontractor)
3. Preparing a list of items for different sites (NTC)
4. Preparing activity lists for different cells (Subcontractor)
5. Preparing detailed schedules for different cells (Subcontractor)

<u>1. Defining the implementation sequence of sites in chosen area</u>

A chosen area is divided into repetitive work areas by handling a single site as a repetitive work area. The repetitive work area has to be sufficiently small so that its lead-time will be suitably short. The implementation sequence of sites is defined by taking into account commissioning needs (Figure 29). A work group progresses from site to site at the same rate of production and hands over the site for the next work group as finished. The implementation sequence of sites is defined by NTC.

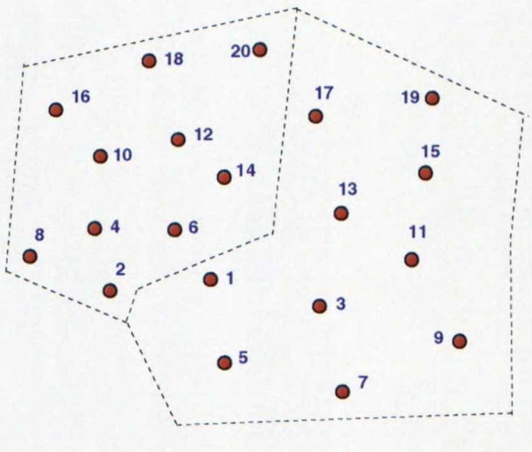

Figure 29 Defining the implementation sequence of sites in a chosen area.

2. Defining the main schedule for chosen area

In repetitive production the main schedule for the chosen area is prepared by using a number of sites, standard time frames for different work phases, buffers and overlapping as a basis. The site is completed in one session without work spreading out over several sites. After the site is accepted by the supervisor, the multiskilled work group moves to the next site. Problems occur, the work groups have to slowdown their work. In the schedule, only the beginning and end of work and overlapped production are presented (Figure 30). NTC is responsible for defining the schedule for the chosen area.

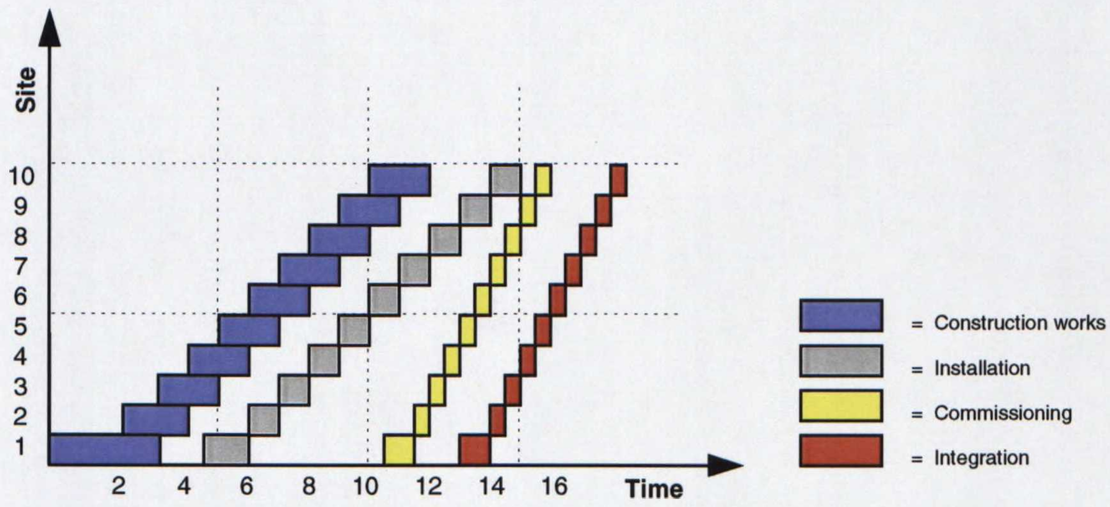

Figure 30 Defining the main schedule for all sites.

3. Preparing a list of items for different sites

Items related to different sites are listed according to their implementation order. An average site is created by using average quantities and average contents of materials. Although the quantities and the contents of materials vary site by site, the work areas' lead-times are kept similar. NTC is responsible for listing the items.

Appendix L shows the list of items for an indoor BTS (3trx) rooftop site. The list of items is based on NTC's global model site structure.

4. Preparing activity lists for different cells

An activity list is composed of activities, which must be performed to produce the work area's deliverables. By using multiskilled work groups it is possible to increase the contents of work and to decrease the time of waiting between different cells. Subcontractor is responsible for preparing the activity list.

Appendix M and Appendix N show two different kinds of activity lists and activities' durations of different teams for an indoor BTS (3trx) rooftop site.

5. Preparing detailed schedules for different cells

Detailed schedules for different kinds of cells are planned according to the activity list, that consists of all needed activities. Technical dependencies between the activities are identified and they are listed in order according to their dependencies and point of time. Detailed scheduling is realized by the CPM, that is based on specified, network sequential logic and a single duration estimate. Durations of activities are estimated and checked by using available material and experience as help. The schedules are similar for similar sites. By detailed schedule it is ensured that it is possible to complete the site within the planned time. Figure 31 shows the relationship between the different work groups on the upper level.

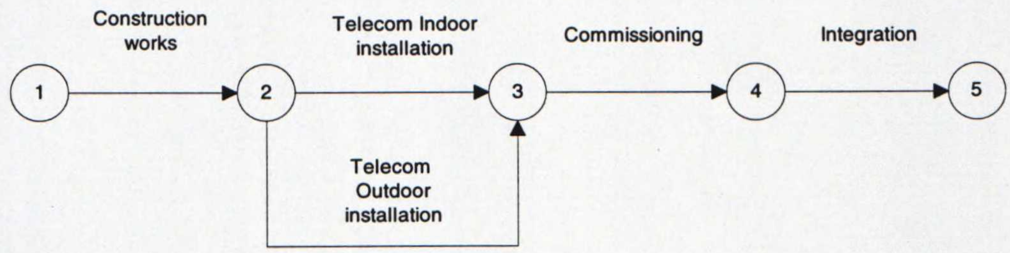

Figure 31 The relationship between different work phases.

After the technical dependencies are inspected, the detailed schedule for production planning and control purposes is adapted to a site-time chart form. Example schedules for ten Indoor BTS (3trx) rooftop sites are presented in Appendix O and Appendix P.

The first site is scheduled longer than the rest of sites, because work preparation requires more time at first. During implementing the first model site it is important to look over the following items:

- Production start-up requirements are ensured.
- All workers take part in teamwork training before the model site start-up.
- Workers are familiarized with all required activities together by doing the model site. At the same time all mistakes and faults related to production planning are corrected before real production start-up.
- Material deliveries are confirmed with the material suppliers.

The subcontractor is responsible for detailed scheduling, planning its resource usage, training the workers and confirming material deliveries to the sites with the suppliers according to NTC's requirements. NTC is responsible for its own resource planning.

3.4.2 Synchronized Production Model

Construction and telecom implementation processes can be synchronized by maintaining a constant rate of production and a continuity of work for each work group from one site to the next in sequence and at the same rate of progress. Synchronized production aims to keep all resources in balance and adjusts the rate of production for each work phase, so that this approximates to a common rate of production for all work phases.

Synchronized production planning is composed of the following four main phases:

1. Chosen Areas decomposition (NTC)
2. Preparing and dimensioning a list of work phases for different kinds of sites (NTC/Subcontractor)
3. Preparing the schedule (NTC/Subcontractor)
4. Checking resources (NTC/Subcontractor)

<u>1. Chosen Areas decomposition</u>

The chosen area is divided into repetitive work areas by handling a single site as a repetitive work area such as in a repetitive cell production model. The implementation order for sites is defined by taking into account commissioning needs. The implementation sequence of sites is defined by NTC.

<u>2. Preparing and dimensioning a list of work phases for different kinds of sites</u>

A list of work phases is prepared keeping different kinds of sites separate. The list includes the economically and temporarily most important work phases, which are linked together and directed to given work groups. In practice, scheduled work phases are as follows:

- Earth and site works (tower site)
- Tower delivery and erection (tower site)
- General construction works (all sites)

- Shelter delivery and installation (shelter needing sites)
- Electrical and HPAC works (all sites)
- Telecom installation (all sites)
- Commissioning (all sites)
- Integration (all sites)

The work phases are dimensioned by using quantities of materials and capacity of work as basis. Hours for subcontractors' work are defined together with subcontractors and using available materials and experience as help. The work phases are synchronized by changing the size or number of a work group or contents of work. Rate of production is planned continuously from site to site.

The activity list and the activities' durations for different work groups in an indoor BTS (3 trx) rooftop site is presented in Appendix Q.

3. Preparing the schedule

A Line-of-Balance is used for scheduling the work phases at a common rate of production. The implementation order for sites has to be planned carefully. Changes at the implementation phase always lose time. Synchronized work phases are drawn on the same chart (Figure 32). The schedule is prepared by NTC with the subcontractors.

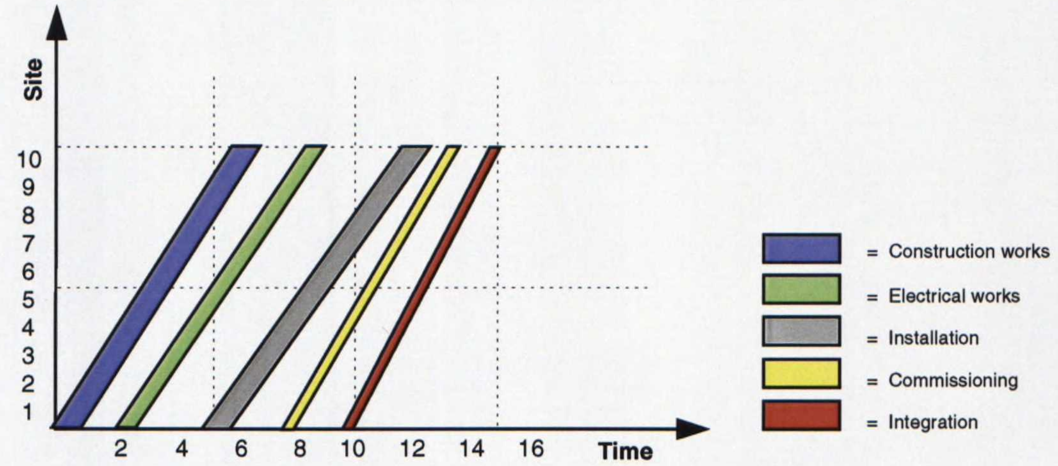

Figure 32 An example of synchronized work phases for a rooftop site.

Time buffers between work phases at the same site and stage buffers between work phases at different sites are used to maintain a constant production rate for the work group on the work phase.

The schedule for ten Indoor BTS (3 trx) rooftop sites is presented in Appendix R.

4. Checking resources

By checking resources it is insured that it is possible to complete the sites in the planned time and the resources are used steadily through the schedule. The subcontractor is responsible for checking its own resource usage and NTC is responsible for its own.

3.4.3 One of a Kind Production Model

The chosen area may be composed of a number of individual sites, which are implemented as a single project. The site implementation includes different work phases which are not continuous and not repetitive. There is one contractor that is responsible for implementation of the whole site.

The best scheduling technique for One of a Kind production is the critical path method. A bar chart may also be used for scheduling (Figure 33).

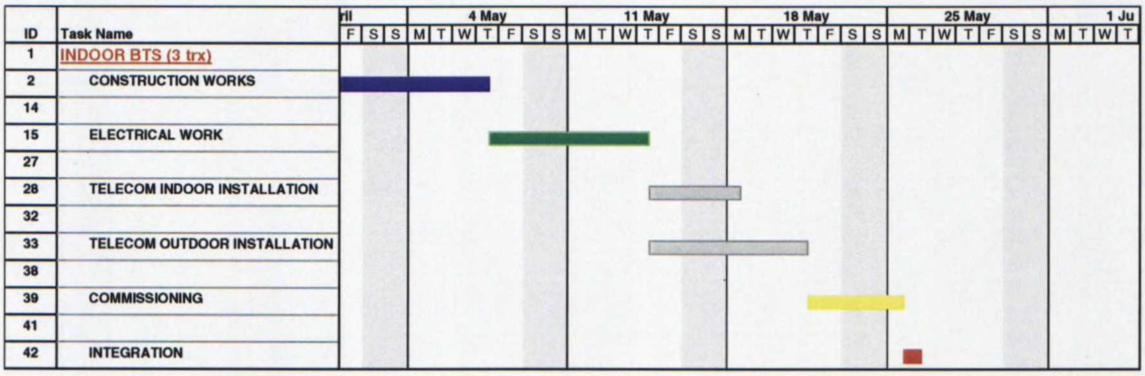

Figure 33 An example of a bar chart for an indoor BTS.

3.4.4 Quality Control

NTC should aim for the situation, in which the production and material quality control is performed by the subcontractors according to their individual quality management systems. NTC should only ensure that the subcontractor works according to its own quality management system and reports to NTC when quality errors occur. If the subcontractor does not have its own quality management system, quality control is carried out by NTC.

The following operations are used for quality control during the production phase:

- Teamwork training is arranged for the subcontractors before production start-up.
- Model site is done before the real production start-up by the subcontractor. The site is inspected by NTC and mistakes are checked with the subcontractor. The model site has to be scheduled for a longer period than the rest of the sites because work preparation requires more time in the beginning. By doing a model site and training workers, production start-up requirements are ensured.
- A quality circle of preventative operations is held with the subcontractor before starting construction works, implementation, commissioning and integration on the site. At that time, the workers have a chance to discuss the right ways to carry out their work and to ask for clarification on any confusing issues.
- The quality circle of corrective operations is held with the subcontractor immediately when the problems occur. The problems should be solved as fast as possible, so that the production continues without lengthy delays.
- Inspections, measurements and tests are performed by supervisors and authorities. The purpose of these is to ensure that the implementation process takes place within the framework of a quality system and according to regulations.

4 TEST CASE TESTING PROCEDURES

4.1 Presentation of Test Case

A turnkey dualband GSM 900/1800 network project includes network planning, site acquisition, construction works, telecom implementation and technical support services. Network operation services will be provided to diAx until the end of 1999. NTC will be the sole supplier to the diAx GSM network and the contract will run for the next four years.

The project is composed of three main phases. The first phase will be taken from May to October 1998, when 380 BTS sites are to be integrated. In addition, sites up to a total of 850 are planned for phases 2 and 3, due at the end of 1999. Switzerland is divided into three main zones which in all, comprises 26 cantons. The amount of sites in different zones and phases are illustrated in Table 2.

Table 2 The amount of sites in different zones and phases.

Zone	Phase 1	Phase 2 & 3	Total	Remote office
1	165	240	405	Zürich
2	115	135	250	Luzern
3	100	95	195	Lausanne
Total	380	470	850	

4.2 Test Case Testing Procedures

4.2.1 Work Breakdown Structure and Purchase Packages

The Work Breakdown Structure organized and defined the total scope of the project. The purchase packages were defined by using the project decomposition as a basis. The diAx project has been split into five types of main delivery items. Geographically the project is divided into zones (regions), cantons (areas) and individual sites.

The project's main delivery items are:

- Project Management
- Network planning
- Site acquisition
- Construction works
- Telecom implementation

Project's geographical areas are:

- 3 zones
- 26 cantons
- 380 sites in 1st phase
- 470 sites in 2^{nd} and 3^{rd} phase

The share of responsibilities is based on the contents of purchase packages. In the diAx project, NTC has subcontracted or purchased the following services:

- Site acquisition management (partly)
- Site acquisition (including site search, permits and lease contracts)
- Detailed site design
- Construction works management and supervision (partly)
- Construction works
- Installation and commissioning
- Logistics

The following services are kept within NTC:

- Project management
- Site Acquisition Manager (belonging to NTC's responsibilities since mid-May)
- Network planning management
- Network planning (including RNW, TRS and Fixed)
- Construction Manager
- Telecom implementation management
- Installation planning and supervision
- Integration
- Logistics management
- Procurement

The scope of construction works has been geographically divided between six contractors using two different types of models. In the first model the contractors are responsible for all construction works in their own area. In the second model construction works are divided between three contractors, one of them being the main contractor. The main contractor is responsible for general construction works for the installation of antennas on rooftops, BTS on the roof or in rooms as required earthwork and concrete work for tower foundations, including all related works and supplies. It is also responsible for the task co-ordination with the other two subcontractors, who have signed agreements directly with the main contractor. One subcontractor is responsible for steelworks for antenna poles and towers and the other subcontractor is responsible for electro-mechanical installation for power supply, lightning protection and room ventilation and AC; including lighting, cable trays and related works and accessories.

The scope of telecom implementation has been geographically divided between four or five contractors. However, the same contractor is responsible for all telecom installation and commissioning in its own area. Responsibility for network integration belongs to NTC.

Different kinds of scope of work models used in the diAx project are presented in Figure 34

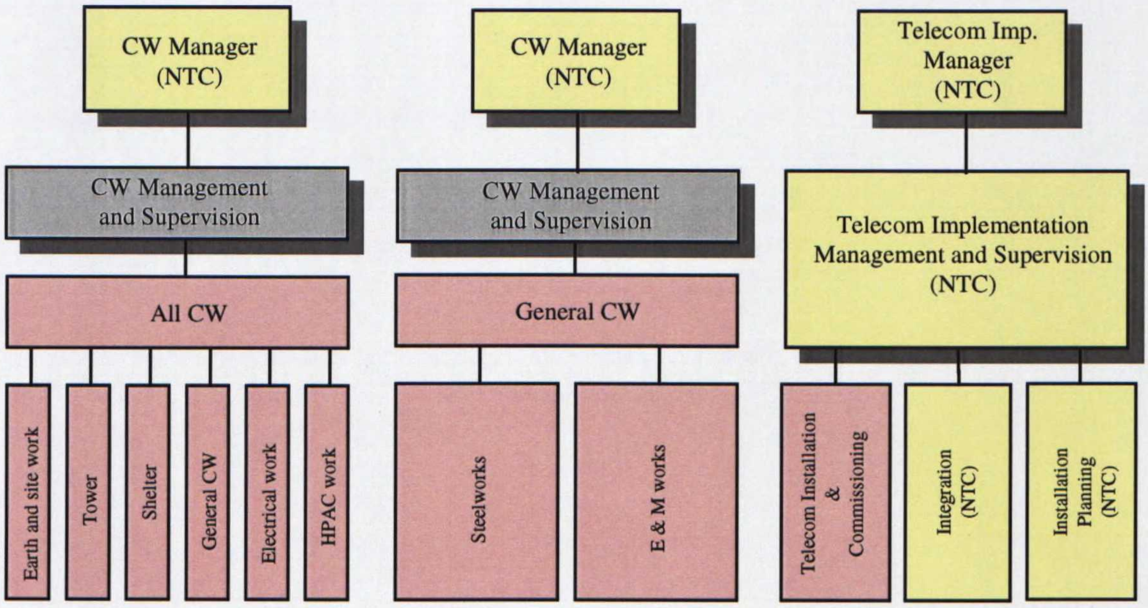

Figure 34 Different kinds of scope of work models used in the diAx project.

Conclusions:

A comparison between the different purchase packages' costs, schedules and quality was not made. Still, the basic WBS and the purchase package models can be used as templates for defining the cost control system and sharing the responsibilities between NTC and the contractors and the other service suppliers. If the service suppliers are used for some management and supervision purposes, the Project Top Management should be kept in NTC Managers' hands. In this way, the competence can be kept in NTC's possession and NTC can take full responsibility for the management and implementation of the whole project.

4.2.2 Site Process

The most fundamental differences between the general site process and the site process used in the first phase of the diAx project were related to lease contracts and technical site surveys. The main differences between the general site process and the used site process in the diAx project are illustrated in Figure 35.

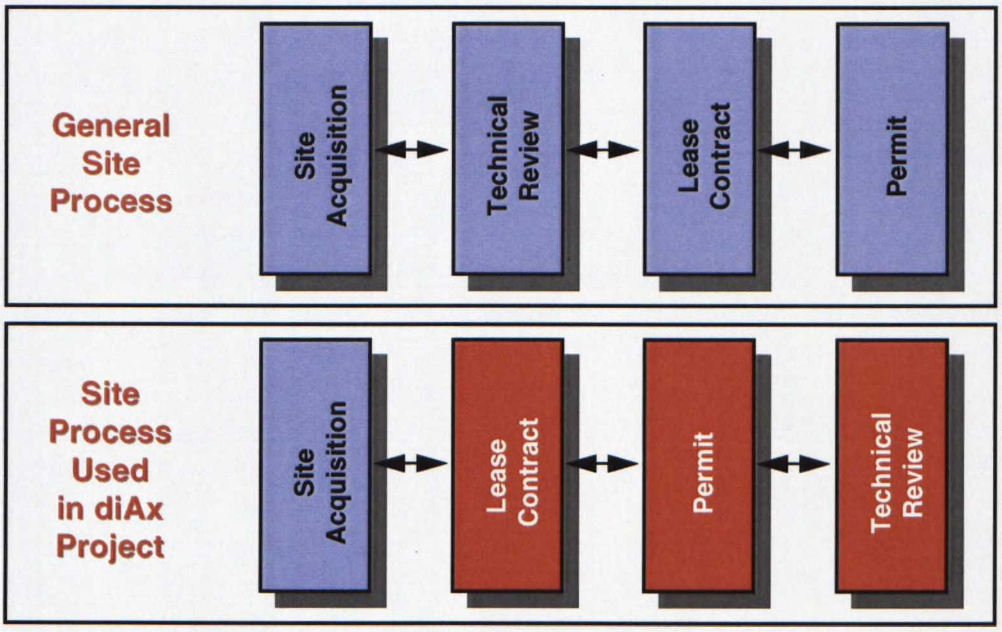

Figure 35 The most essential differences between the general site process and the used site process in the diAx project.

In the diAx project, the lease agreement negotiations were started immediately after the site was identified. Whereas according to the general site process, the lease agreement is not acquired until the technical site survey is performed and the site is validated.

After the lease contract was signed by the site owner, the next step was approving site plans by diAx and submitting permit applications. In practice, the dependencies between different milestones were not systematic because site specific issues had effects on the site process and some sub-processes were overlapped. For example, some sites' permit applications were submitted for approval before the lease contract was signed by the site owner or RF/TRS approval was performed before the whole permit process. The technical site surveys and detailed site design were started according to the following priorities:

1. Lease contract signed, RF/TRS approved and permit application received
2. Lease contract signed and RF/TRS approved
3. Lease contract signed

The most essential reason for these sequence distinctions is the fact that NTC received identified sites from the customer and network planning was based on these sites. At first the sites had to be evaluated and approved by radio network planners and transmission planners. The other reason for these changes was the decision to start a time-consuming lease agreement process as effective as possible and also as soon as possible.

All the test calculations are based on the exported data from the NCC database, and the calculations were performed by Excel-program. A site process network gives a clear graphical picture of the actual dependencies and lead-times for different sub-processes and between different milestones in the diAx project (Figure 36). The actual lead-times are based on average values whose standard deviations are high.

The average lead-times between the most important milestones are also presented in Appendix S and Appendix T, and the actual lead-time trends between the different milestones are illustrated in more detail in Appendix E.

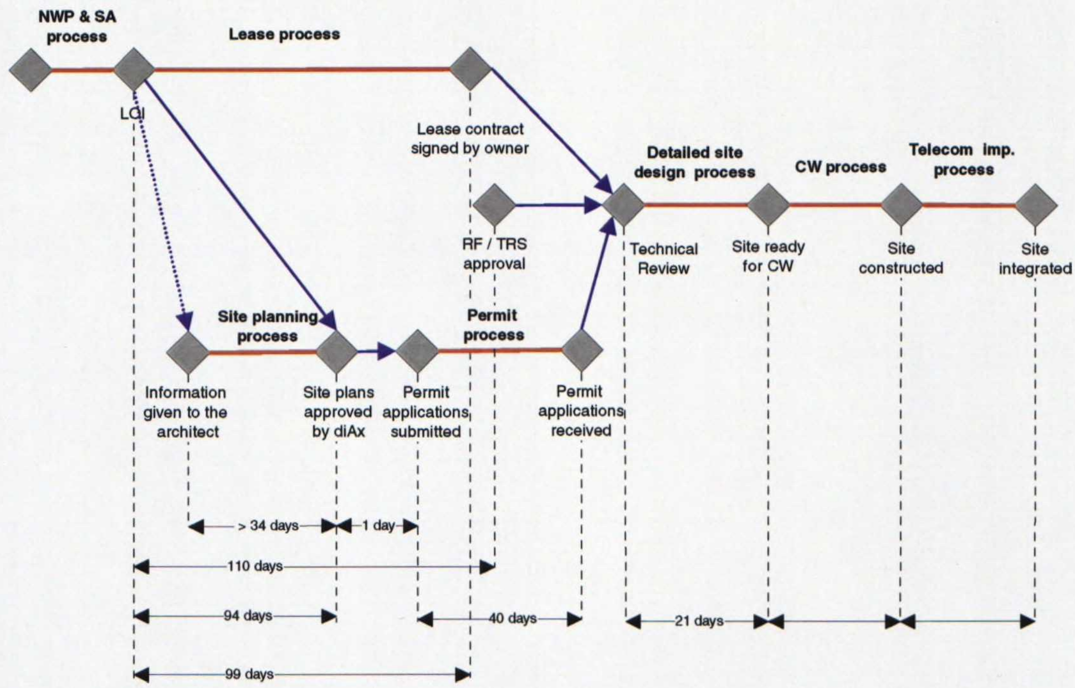

Figure 36 Actual lead-times for different sub-processes and their dependencies between different milestones in the diAx project.

The building permit process is very complicated and time-consuming in Switzerland. It was very difficult to define beforehand how long it takes to get the building permits and what kinds of plans, drawings and network plans are needed in different zones and cantons. In many cases the permit process went in parallel with the lease contract process. The standard deviations related to the lead-times between the most important milestones were high. Any systematic trend between these milestones was not found.

In practice, the sub-processes were overlapped because their lead-times were so long and they were difficult to be estimated beforehand. It meant risk-taking, because the sequence of the subprocesses was not necessarily optimal and the amount of work could have increased. In this way it was possible to reduce the total duration of the site process and to begin construction works and telecom installation earlier.

There were deficiencies in the numbers of permanent TRS planners and RNW planners, which complicated and delayed the site approval process and the detailed site design process. The RNW planners did not always take part in technical site surveys. It caused delays in making the right design decisions. Prospective rejections should be known before all permit applications are submitted.

Conclusions:

The site process worked well in general, but it deviated during the first phase of the project. There are lots of critical issues which have to be taken into consideration before starting to plan a cellular network implementation project. It is very important to recognize these issues because they can cause unexpected problems to the site process and the entire project roll-out. The lease contract process and the building permit process are in general very complicated and time-consuming, so they need detailed clarification. In the future, the standard lead-times can be utilized in roll-out planning and control.

4.2.3 Progress Monitoring and Control

The NCC database used in the diAx Switzerland project was based on standard milestones which were monitored regularly. However, during the testing phase, project roll-out planning, control and reporting were performed by Excel-program because the database was not suitable for these purposes.

The actual cumulative project roll-out did not stay on plan. The deviations between actual and plan roll-out were constantly more than 10% below plan during a two month period when the testing phase was carried out. The most essential reasons for these deviations were the following: diAx had not been able to provide NCC with a full set of site information that could be converted to the NCC database. In some cases the site address or owner information were missing, in other cases milestone information (the actual height of building, changed site ID etc.) was missing, and sometimes both. Also drawings sometimes had wrong site IDs. The persons in charge for updating site information were not clearly defined. It caused delays in making right decisions and it delayed all sub-processes, as well. Some permit applications and lease contracts were delayed because the diAx frame agreements with local power companies were not in order in time. In some areas the authorities did not take the building permit applications into process before the diAx got the license. In some areas the authorities wanted to have a presentation of a GSM network and sites before handling the permit application. These kinds of requirements were not recognized beforehand. The standards for construction works and telecom implementation were partly defined at the tendering phase but the final standards were defined too late. The detailed site design teams were not aware of used standards when the detailed site design process was starting. It caused disorientation and it delayed the detailed site design process start-up. The final selection of construction works and telecom implementation contractors and required negotiations took more time than supposed.

The project roll-out reporting was composed of only two different types of reports. These reports included information about the actual status both at a site level and at a zone level as a list of milestone form. It was not possible to print out graphical diagrams from the NCC database. The diAx project roll-out reporting was performed by Excel-program (Appendix U). In addition to milestones, the NCC database included information and data about SARF's, site descriptions, site owners and contracts, SAR's, radio technical remarks, authorities and existing enclosures.

The chances for tracking and controlling the milestones at the site level were lacking. There was only the chance to follow the project roll-out on an actual date basis. The NCC database was not suitable for planning and controlling a single site roll-out. Construction works roll-out planning, control and reporting were performed by Excel-program. These roll-out reports are presented in Appendix V and Appendix W.

Conclusions:

The database has an important role in the implementation process. The chances for tracking and controlling the most important milestones and reporting should be included in the used database. Delegation of persons in charge for different sub-processes and commitment to updating site information without delay should already be taken into account before the project start-up.

4.2.4 Network Planning and Site Acquisition Strategies

It is very important to clearly define the network planning and site acquisition strategy, in order to be able to properly plan the network The used strategies in the diAx project were found out by interviewing the project personnel.

NTC received identified sites from the customer and network planning had to be based on these sites, though the sites were not approved by RNP and TRS planners. This decision complicated the network planning process. The official network planning strategy was not written on paper. However, the following issues were discussed at a general level: Customer requirements for coverage, capacity and quality were defined in the contract Nokia-diAx. Used NE, CoSy materials and site configurations in the diAx project were taken into account when defining the model sites. The necessary input information from network planning to site acquisition was defined in SARFs. Network planning organization structure was defined both at the project level and at the zone level. Network planners worked in the same office with site acquisition personnel.

Site acquisition strategy was discussed together with the Site Acquisition Manager and the other site acquisition personnel before the actual site hunting. Some parts of the strategy were not written on paper. The SA strategy of the first phase of the project was mainly based on the direct agreement between diAx and Casaplan. As summary can be said the following: Possible friendly sites were mainly owned by power companies, of which there are over 1200 in Switzerland. Target average rent was CHF 2000-3500. Standard lease contracts with site owners were written in different languages (German, French, and Italian). 'Marketing folder' was prepared for site owners. Identification of the most critical sites and prioritization of sites were based on RF/TRS evaluations, lease contracts and needed building permits. Network planning and site acquisition organizations and the zone division of the area and interfaces were defined. A documentation system and communication channel between planning and site acquisition was based on a NCC database and systems were based on four different colored dockets. Possible changes and site rejections were handled at weekly meetings with network planning and site acquisition zone managers and the customer. A bonus fee for SA agents was ill-defined, because it was based only on monthly rent sums and not on time. Public holidays and their effects on the site acquisition process were discussed.

NCC was responsible for the site acquisition management and co-ordination. Casaplan was responsible for the site acquisition work (site search, lease contracts and building permits). Neither of them succeeded in their work according to the plan. Site acquisition management was not performed by local people, which brought out major language problems between the site acquisition agents, authorities and site owners. Site acquisition agents had wrong incentives in their contracts. The bonus depended only on the lease prices and it was not confined to time. The diAx lease frames were very low, and diAx had problems with owners agreeing to those figures. Site acquisition training was not arranged before the project start-up. The site acquisition agents did not have basic information about the requirements for network elements and transmission equipment, which complicated the entire site process. Casaplan was aware of these requirement but somehow the site acquisition agents were not trained and informed beforehand.

Conclusions:

The network planning strategy and the site acquisition strategy have an important role in implementation projects. These strategies should invariably be written on paper and they should fully be discussed together with the project personnel before the project roll-out. Site acquisition training should always be arranged before the real site hunting. The local site acquisition agent's bonus should be dependent on both the lease price and the used time for acquiring a site.

4.2.5 Project Organization and Resources

The diAx project organization was consistent with the Work Breakdown Structure. The project organization was quite similar to a generic turnkey project organization (Figure 21). The most essential difference between these two organizations was the fact that Regional Managers, site acquisition co-ordinators and site planning and permission co-ordinators were not used in the diAx project.

In the diAx project, the implementation of the site process was performed by teams. Each team was composed of specialists for different phases of the site process. Contents of different teams are presented in Table 3.

The capacities for the network planning team, the site acquisition team, the LOS team, the construction works team and the telecom implementation teams are based on estimates in the diAx project and garnered knowledge from previous NTC projects. A comparison between these teams was not made.

The capacities for the site survey team, the planning and permit team and the detailed design team are based on information from the diAx project. Capacities for different teams are presented in more detail in Appendix G.

Table 3 Contents of teams in the diAx project.

Team:	Contents of team: [number * person]
Network planning team	1 * RNW planner 1 * TRS planner
Site Acquisition team	1 * SA agent
LOS team	2 * TRS planner (including NWP team)
Site Survey team	1 * Installation planner 1 * CW engineer 1 * RNW planner 1 * SA agent
Planning and permission team	1 * Architect
Detailed design team	1 * Electrical engineer 1 * Structural engineer
Construction works team	3 * CW worker 2 * Electrician
Installation team	2 - 3 * Electrician
Commissioning team	1 * Commissioning engineer
Integration team	2 * Integration engineer

Conclusions:

It is extremely important to ensure that a sufficient amount of resources with the proper skills are available for the project already during the tendering phase. Particularly, the sufficient amount of network planning and site acquisition resources are needed before the project start-up. Calculating the needed amount of resources can be performed by using the average capacities for different teams as a basis.

4.2.6 Information Distribution

The purpose of the meetings and reporting was to keep the customer, the Project Management team, CS line organization and other participants aware of the progress of the project. The following meetings were held in the diAx project, and their main topics and participants are presented in paragraph 3.2.7.

Project meetings

- Weekly progress meeting with the customer
- Executive meeting
- Account team meeting

Meetings with the subcontractors at the zone level

- Weekly network planning and site acquisition meeting on Monday and Thursday
- Weekly construction works meeting
- Weekly telecom implementation meeting

The following issues were reported in the diAx project:

- Planned, actual and estimated progress
- Project roll-out
- Sub-system roll-out
- Material deliveries
- Invoicing status and estimation
- Resources
- Acceptances
- Quality errors
- Budget costs, actual and estimates (internal reports only)
- Risks (internal reports only)
- Best practice information (internal reports only)

The site document flow and its filing were based on four different colored dockets. The documents from the same phase of the site process were kept in same colored dockets. The contents of the dockets are illustrated in Figure 37.

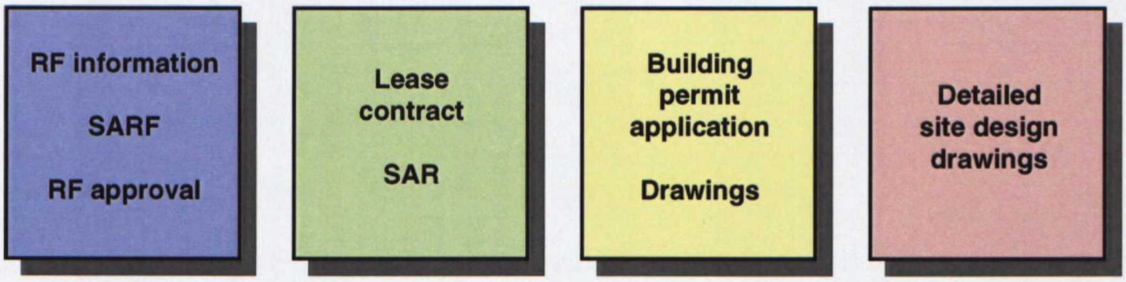

Figure 37 The contents of different colored dockets.

Each site has its own binder in which the pockets were stored. All binders were stored inside the same locker, which was situated near the network planners and site acquisition personnel at the diAx office. In this way all site information was rapidly available for all project personnel. The site document flow and its filing worked well in the diAx project.

Conclusions:

Information distribution is a basis for effective project work. Good communication between the project personnel is essential. Meetings, reporting and real time filing help the task owners understand the status of the site process, the effect of their performance on the project objectives and any risks that lie ahead. The site document flow and its filing should be situated near the network planners, site acquisition personnel and planning and design consultants. In this way all site information is rapidly available for project personnel.

4.2.7 One of a Kind Production

The One of a Kind production model was used in the diAx project by dividing the whole country among four main contractors. The chosen areas were composed of a number of individual sites which were implemented as single projects. The sites were released in batches of 2 to 4 sites at a time for one contractor. The contractor was responsible for constructing all these sites according to agreed model schedules based on two types of model sites: a tower site with shelter and an indoor rooftop site. The contractor acquired, planned and controlled needed resources and materials for the sites by themselves.

Before start of work, the site price was agreed to with the contractor. The construction works supervisor was responsible for quality control and progress control on the site. After the site was constructed, the supervisor accepted the site, received the contractor's invoice and checked and approved it. After approval, the site was ready for telecom implementation.

A comparison between the different sites' costs, schedules and quality was not made. In practice, the duration of work and the capacity for construction works and telecom implementation teams are based on interviews and garnered knowledge from previous

NTC projects. During the testing phase, a comparison between different construction works teams and different telecom implementation teams were not made.

Conclusions:

The One of a Kind production model is a good model if the contractors have sufficient amounts of resources for work on released sites at short notice. In the future, it could be useful also to take into account the repetitive cell production model and synchronized production model in choosing the correct production models for project implementation. By using multiskilled work groups it could be possible to increase the contents of work and to decrease the time in waiting between different work phases. NTC should aim for a situation in which the production and material quality control is performed by the subcontractors according to their individual quality management systems. NTC should only ensure that the subcontractor works according to its own quality management system and reports when quality errors occur. Possible risks related to production should be analyzed before choosing the correct contractors for the project. By doing a work model and training, the workers will be ensured production start-up requirements.

5 CONCLUSIONS AND RECOMMENDATIONS

There are lots of critical issues which have to be taken into consideration before starting to plan a cellular network implementation project. It is very important to recognize these issues because they can cause unexpected problems and delays to the site process and the entire project roll-out. For example, the lease contract process and the building permit process are in general very complicated and time-consuming, so they need detailed clarification. In the future, the standard lead-times can be utilized in roll-out planning and control. The project roll-out planning should be started already during the tendering phase. At this stage the Project Manager defines the project objectives, the work breakdown structure including purchase packages, the processes and the basic procedures for project control.

It is extremely important to ensure that a sufficient amount of resources with the proper skills are available for the project already during the tendering phase. Particularly, the sufficient amount of network planning and local site acquisition resources are needed before the project start-up.

If the service suppliers are used for some management and supervision purposes, the Project Top Management should be kept in NTC Managers' hands. In this way, the competence can be kept in NTC's possession and NTC can take full responsibility for the management and implementation of the whole project.

Information distribution is a basis for effective project work. Good communication between the project personnel is essential. Meetings, reporting and real time filing help the task owners understand the status of the site process, the effect of their performance on the project objectives and any risks that lie ahead. The site document flow and its filing should be situated near the network planners, site acquisition personnel and planning and design consultants. In this way all site information is rapidly available for project personnel.

The database has an important role in the implementation process. The chances for tracking and controlling the most important milestones and reporting should be included in the used database. Delegation of persons in charge for different sub-processes and commitment to updating site information without delay should already be taken into account before the project start-up.

The network planning strategy and the site acquisition strategy should invariably be written on paper and they should be fully discussed together with the project personnel before the project roll-out. Site acquisition training should always be arranged before the real site hunting. The local site acquisition agent's bonus should be depended on both the lease price and the used time for acquiring a site.

In the future, it could be useful also to take into account the repetitive cell production model and synchronized production model in choosing the correct production models for project implementation. By using multiskilled work groups it could be possible to increase the contents of work and to decrease the time in waiting between different work phases. NTC should aim for a situation in which the production and material quality control is performed by the subcontractors according to their individual quality management systems. NTC should only ensure that the subcontractor works according to its own quality management system and reports when quality errors occur. Possible risks related to production should be analyzed before choosing the correct contractors for the project. By doing a work model and training, the workers will be ensured production start-up requirements.

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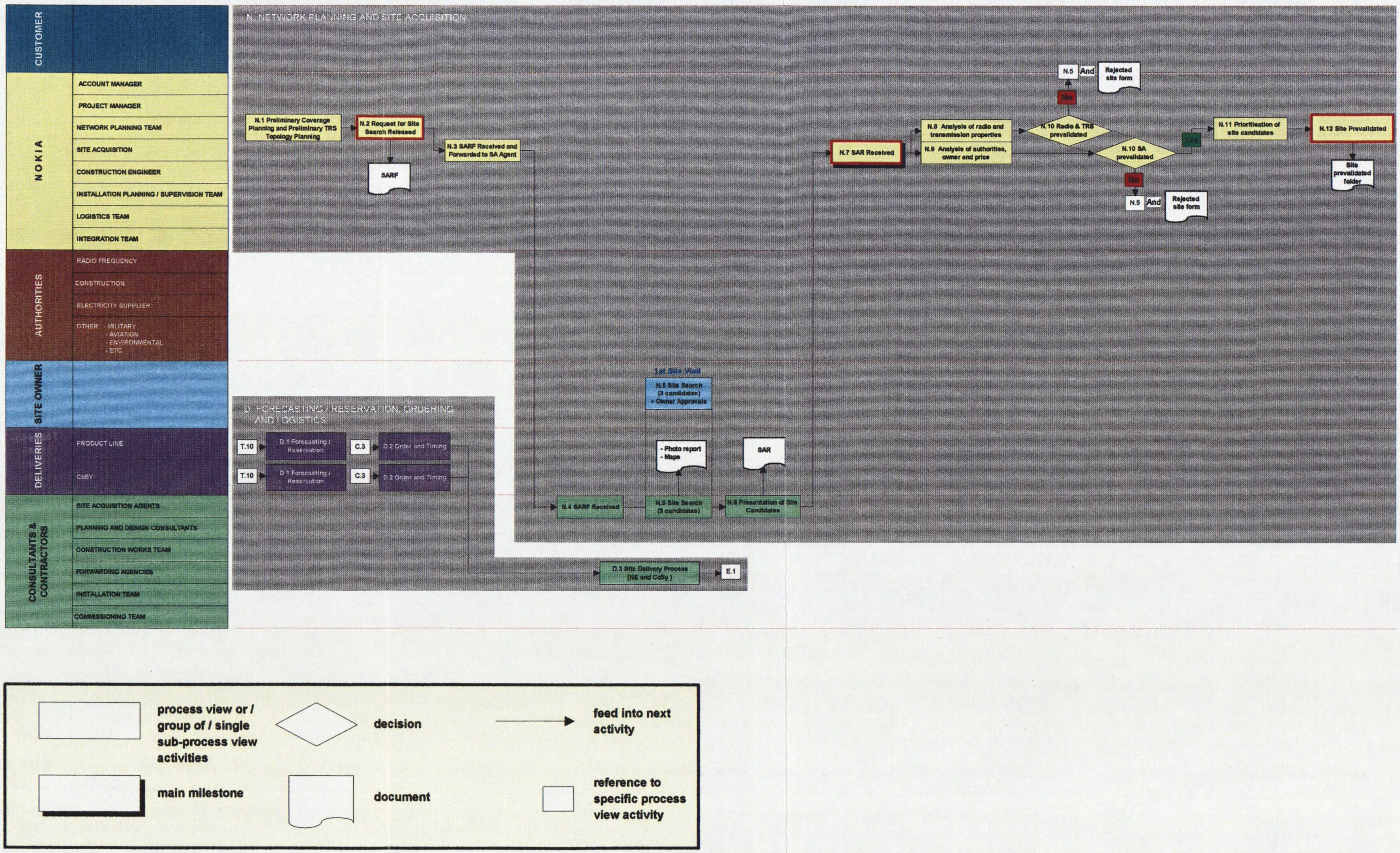
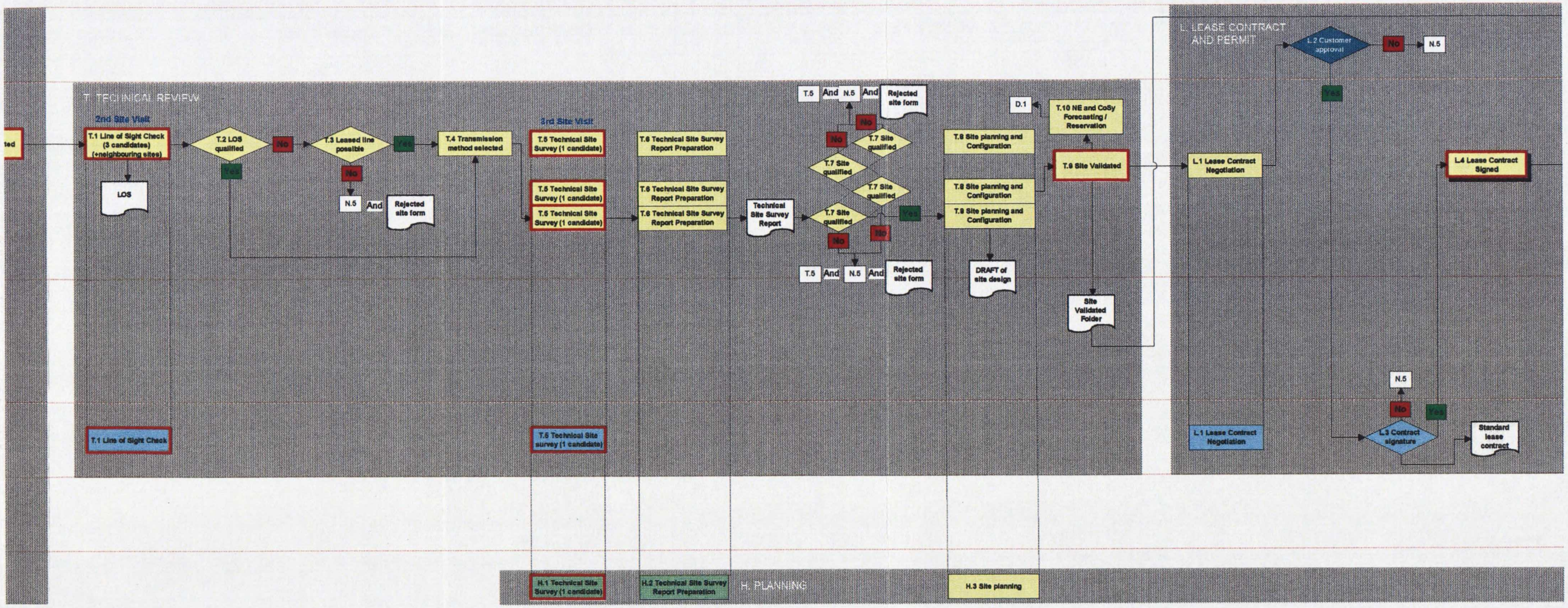
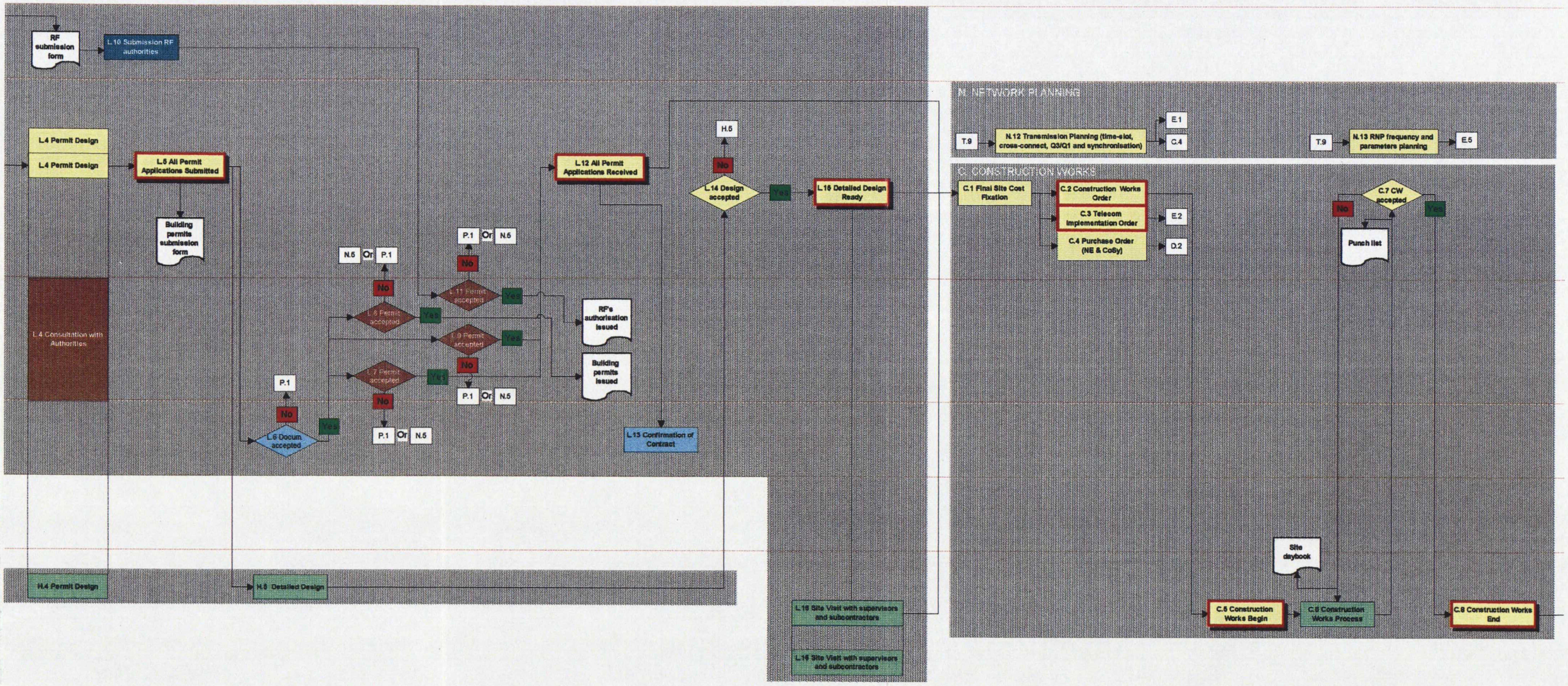
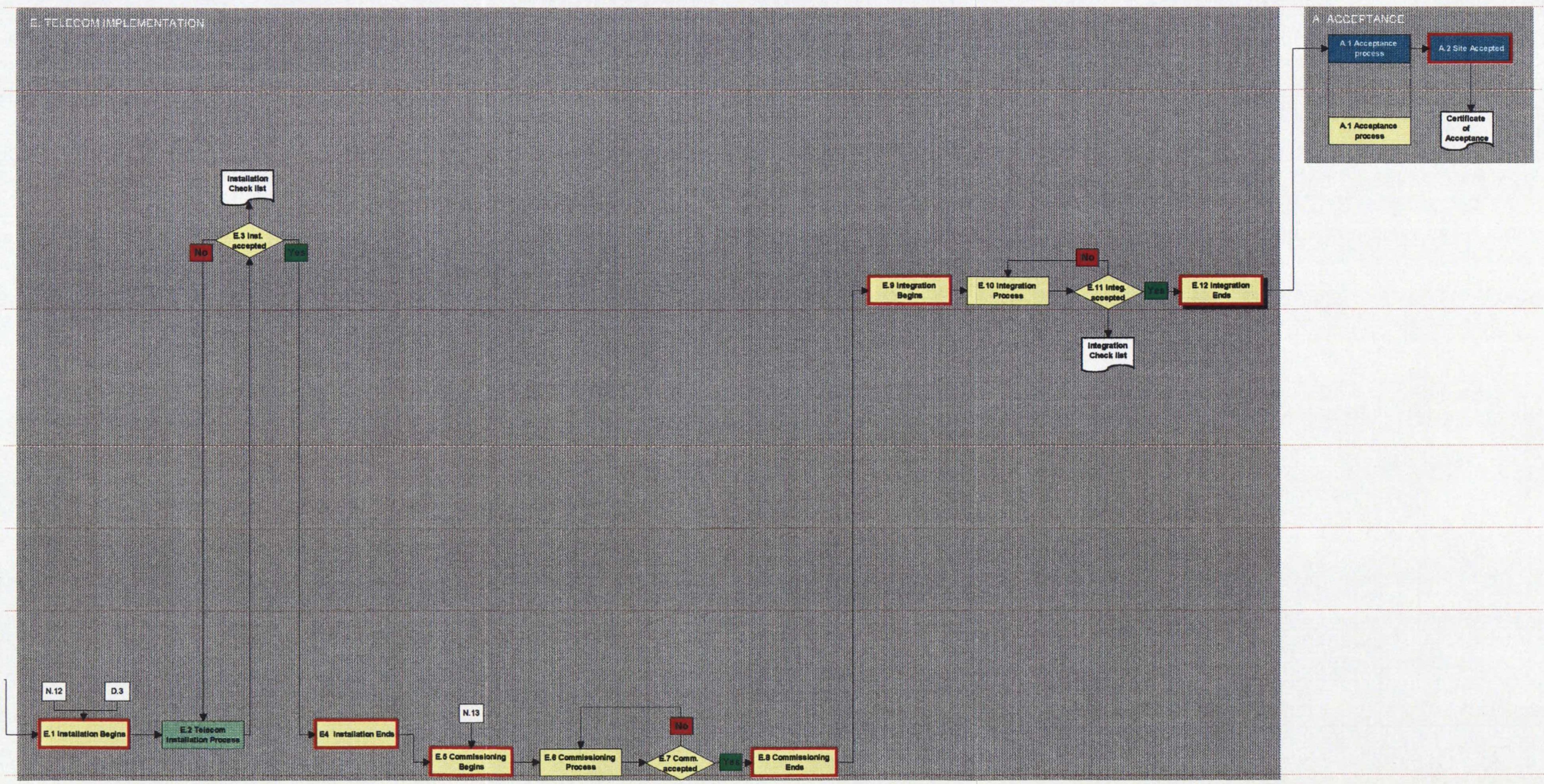
LIST OF APPENDIXES


CUSTOMER
NOKIA
ACCOUNT MANAGER
PROJECT MANAGER
NETWORK PLANNING TEAM
SITE ACQUISITION
CONSTRUCTION ENGINEER
INSTALLATION PLANNING / SUPERVISION TEAM
LOGISTICS TEAM
INTEGRATION TEAM
AUTHORITIES
RADIO FREQUENCY
CONSTRUCTION
ELECTRICITY SUPPLIER
OTHER - MILITARY - AVIATION - ENVIRONMENTAL - ETC.
SITE OWNER
DELIVERIES
PRODUCT LINE
CoSY
CONSULTANTS & CONTRACTORS
SITE ACQUISITION AGENTS
PLANNING AND DESIGN CONSULTANTS
CONSTRUCTION WORKS TEAM
FORWARDING AGENCIES
INSTALLATION TEAM
COMMISSIONING TEAM
N. NETWORK PLANNING AND SITE ACQUISITION
N.1 Preliminary Coverage Planning and Preliminary TRS Topology Planning
N.2 Request for Site Search Released
SARF
N.3 SARF Received and Forwarded to SA Agent
N.4 SARF Received
N.5 Site Search (3 candidates)
1st Site Visit
N.5 Site Search (3 candidates) + Owner Approvals
- Photo report - Maps
N.6 Presentation of Site Candidates
SAR
N.7 SAR Received
N.8 Analysis of radio and transmission properties
N.9 Analysis of authorities, owner and price
N.10 Radio & TRS prevalidated
No
N.5 And Rejected site form
N.10 SA prevalidated
No
N.5 And Rejected site form
Yes
N.11 Prioritisation of site candidates
N.12 Site Prevalidated
Site prevalidated folder
D. FORECASTING / RESERVATION, ORDERING AND LOGISTICS
T.10
D.1 Forecasting / Reservation
C.3
D.2 Order and Timing
T.10
D.1 Forecasting / Reservation
C.3
D.2 Order and Timing
D.3 Site Delivery Process (NE and CoSy)
E.1
process view or / group of / single sub-process view activities
decision
feed into next activity
main milestone
document
reference to specific process view activity

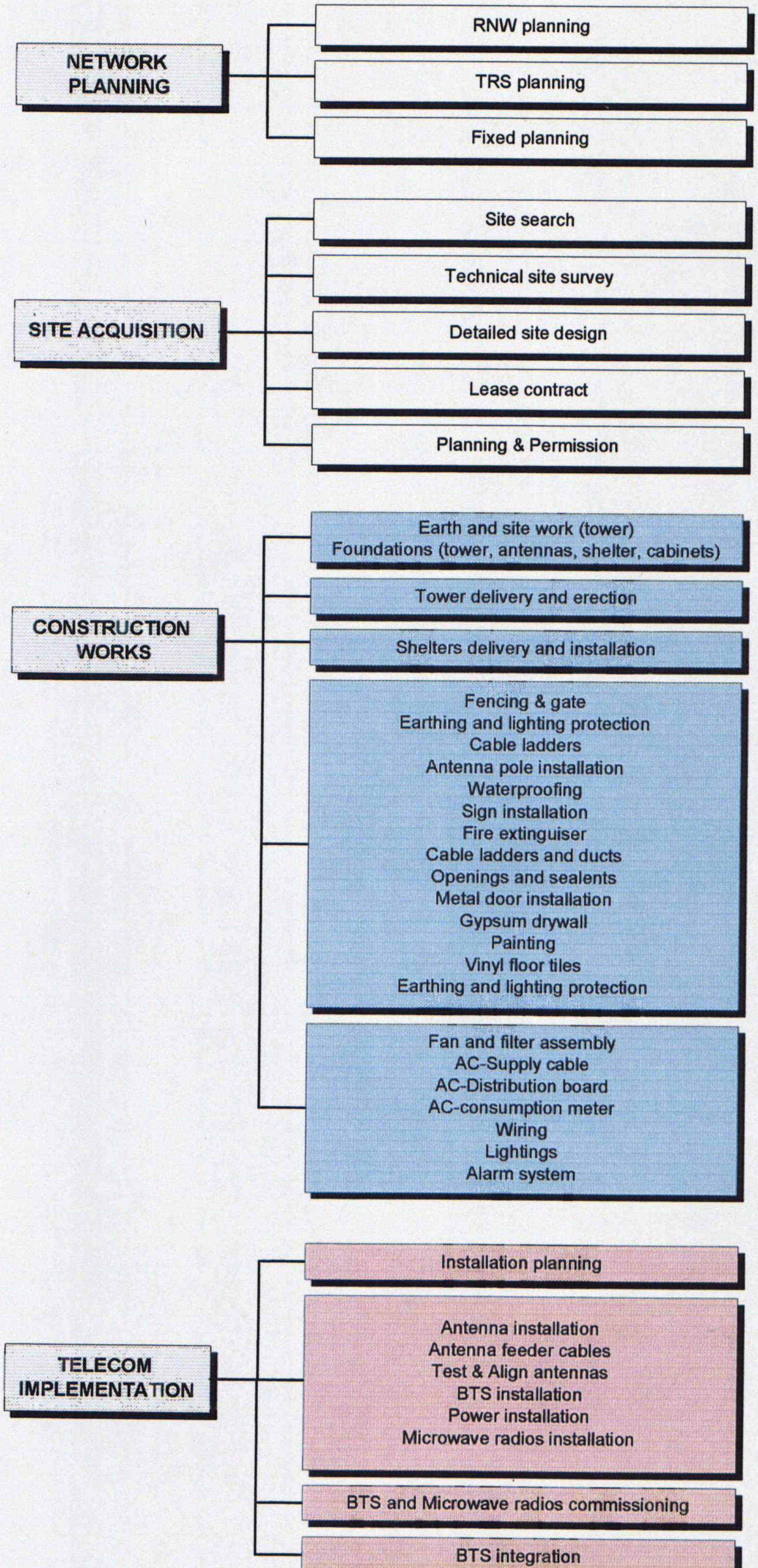

T. TECHNICAL REVIEW
2nd Site Visit
T.1 Line of Sight Check (3 candidates) (+neighbouring sites)
LOS
T.2 LOS qualified
No
Yes
T.3 Leased line possible
Yes
No
N.5
And
Rejected site form
T.4 Transmission method selected
3rd Site Visit
T.5 Technical Site Survey (1 candidate)
T.6 Technical Site Survey Report Preparation
Technical Site Survey Report
T.7 Site qualified
No
Yes
T.5
And
N.5
And
Rejected site form
T.8 Site planning and Configuration
DRAFT of site design
D.1
T.10 NE and CoSy Forecasting / Reservation
T.9 Site Validated
Site Validated Folder
T.1 Line of Sight Check
T.5 Technical Site survey (1 candidate)
L. LEASE CONTRACT AND PERMIT
L.1 Lease Contract Negotiation
L.2 Customer approval
No
N.5
Yes
L.3 Contract signature
L.4 Lease Contract Signed
Standard lease contract
H. PLANNING
H.1 Technical Site Survey (1 candidate)
H.2 Technical Site Survey Report Preparation
H.3 Site planning



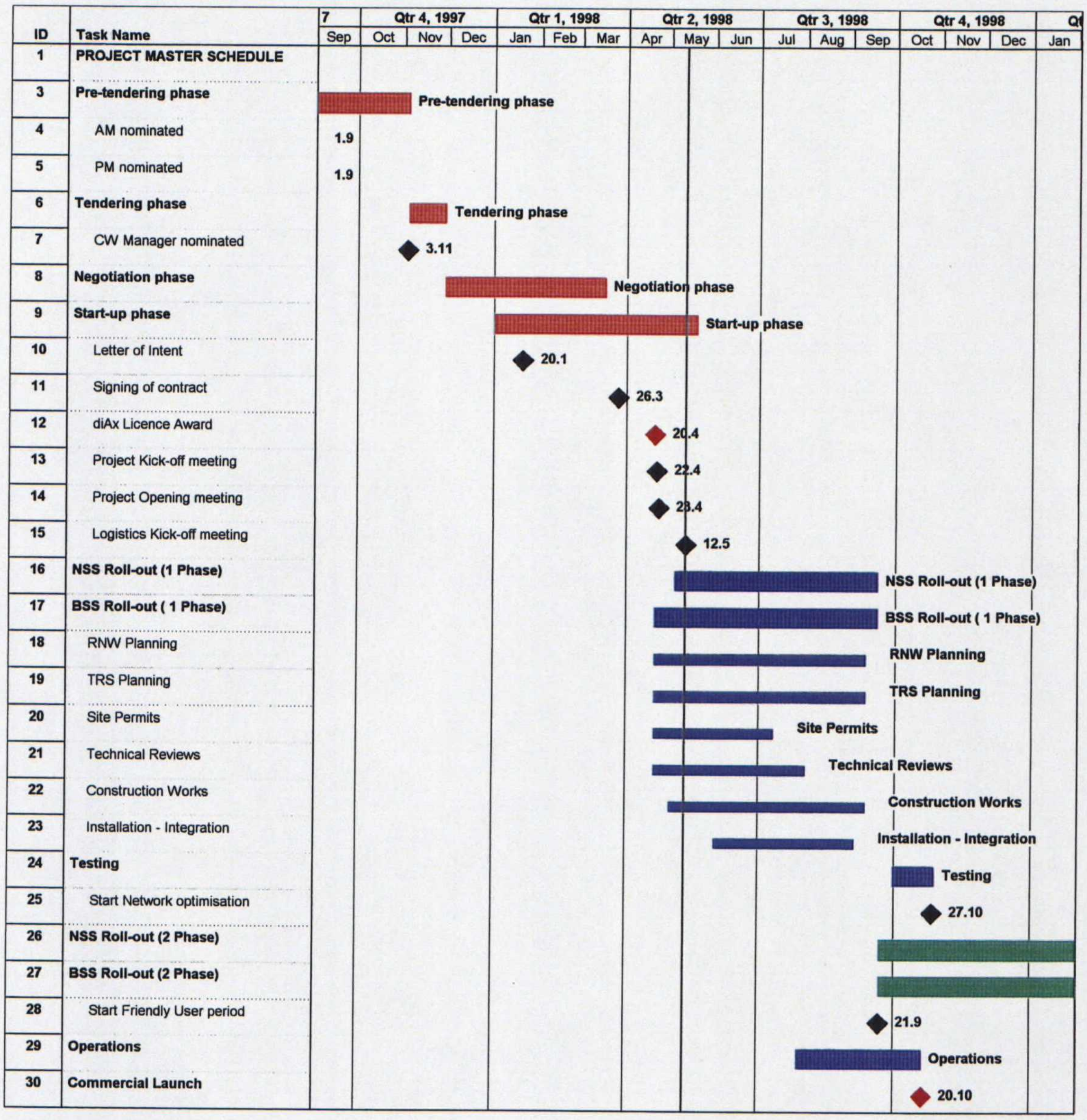
RF submission form
L.10 Submission RF authorities
L.4 Permit Design
L.4 Permit Design
L.5 All Permit Applications Submitted
Building permits submission form
L.4 Consultation with Authorities
L.6 Docum accepted
No
P.1
Yes
L.8 Permit accepted
L.7 Permit accepted
L.11 Permit accepted
L.9 Permit accepted
No
Yes
N.5
Or
P.1
P.1
Or
N.5
RF's authorisation issued
Building permits issued
L.12 All Permit Applications Received
L.13 Confirmation of Contract
L.14 Design accepted
H.5
L.15 Detailed Design Ready
L.16 Site Visit with supervisors and subcontractors
L.16 Site Visit with supervisors and subcontractors
H.4 Permit Design
H.5 Detailed Design
N. NETWORK PLANNING
T.9
N.12 Transmission Planning (time-slot, cross-connect, Q3/Q1 and synchronisation)
E.1
C.4
N.13 RNP frequency and parameters planning
E.5
C. CONSTRUCTION WORKS
C.1 Final Site Cost Fixation
C.2 Construction Works Order
C.3 Telecom Implementation Order
C.4 Purchase Order (NE & CoSy)
E.2
D.2
C.7 CW accepted
Punch list
Site daybook
C.5 Construction Works Begin
C.6 Construction Works Process
C.8 Construction Works End


E. TELECOM IMPLEMENTATION
E.1 Installation Begins
N.12
D.3
E.2 Telecom Installation Process
E.3 Inst. accepted
No
Yes
Installation Check list
E4 Installation Ends
E.5 Commissioning Begins
N.13
E.6 Commissioning Process
E.7 Comm. accepted
No
Yes
E.8 Commissioning Ends
E.9 Integration Begins
E.10 Integration Process
E.11 Integ. accepted
No
Yes
Integration Check list
E.12 Integration Ends
A. ACCEPTANCE
A.1 Acceptance process
A.2 Site Accepted
A.1 Acceptance process
Certificate of Acceptance

Appendix B *Purchase packages*



Appendix C *Project master schedule*



Appendix D *Project roll-out schedule*

PROJECT ROLL-OUT

Legend: Plan · On target · Below target · Critical + 10% below plan

MONTH / WEEK NUMBER	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
MONTH	Feb	March				April				May					June
LOI Received															
Plan Cumulative	98	148	170	200	230	260	290	328	328	328					
Actual Cumulative	314	314	314	314	314	314	314	320	235	325	325	325	325	325	309
Estimate Cumulative															
Δ (Plan - Actual)	216	166	144	114	84	54	24	-6	-93	-3	325	325	325	325	309
Lease Contract Signed by Owner															
Plan Cumulative	3	20	50	80	110	140	170	200	230	260	280	290	300	310	320
Actual Cumulative	0	3	23	48	62	70	90	101	103	125	124	124	133	133	140
Estimate Cumulative															
Δ (Plan - Actual)	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
All Permit Applications Submitted															
Plan Cumulative	3	20	50	80	110	140	170	200	230	260	280	290	300	310	320
Actual Cumulative	5	11	33	52	97	124	172	174	162	172	170	166	172	178	183
Estimate Cumulative															
Δ (Plan - Actual)	2	-9	-17	-28	-13	-16	2	-26	-68	-88	-110	-124	-128	-132	-137
All Permit Applications Received															
Plan Cumulative					5	15	30	45	60	75	95	115	130	160	190
Actual Cumulative					4	4	4	10	7	9	12	16	20	24	33
Estimate Cumulative															
Δ (Plan - Actual)					-1	-11	-26	-35	-53	-66	-83	-99	-110	-136	-157
Technical Site Survey															
Plan Cumulative						1	6	10	20	30	40	50	60	80	100
Actual Cumulative						0	0	2	3	3	23	33	45	57	65
Estimate Cumulative															
Δ (Plan - Actual)						-1	-6	-8	-17	-27	-17	-17	-15	-23	-35
Construction Works Begin															
Plan Cumulative							1	2	2	5	15	30	40	50	60
Actual Cumulative							0	0	0	0	0	0	1	3	6
Estimate Cumulative															
Δ (Plan - Actual)							-1	-2	-2	-5	-15	-30	-39	-47	-54
Construction Works End															
Plan Cumulative									1	1	1	2	2	5	15
Actual Cumulative									0	0	0	0	1	1	1
Estimate Cumulative															
Δ (Plan - Actual)									-1	-1	-1	-2	-1	-4	-14
Telecom Implementation Begins															
Plan Cumulative										1	1	1	2	2	5
Actual Cumulative										0	0	0	0	0	0
Estimate Cumulative															
Δ (Plan - Actual)										-1	-1	-1	-2	-2	-5
Telecom Implementation Ends															
Plan Cumulative											1	1	1	2	2
Actual Cumulative											0	0	0	0	0
Estimate Cumulative															
Δ (Plan - Actual)											-1	-1	-1	-2	-2

MONTH / WEEK NUMBER	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
MONTH	June			July					August				September				October					Nov
All Permit Applications Received – Plan Cumulative	220	240	260	270	320																	
Technical Site Survey – Plan Cumulative	120	150	180	210	240	270	300	320														
Construction Works Begin – Plan Cumulative	80	100	120	150	180	210	240	270	300	320												
Construction Works End – Plan Cumulative	30	40	50	60	80	100	120	150	180	210	240	270	300	320								
Telecom Implementation Begins – Plan Cumulative	15	30	40	50	60	80	100	120	150	180	210	240	270	300	320							
Telecom Implementation Ends – Plan Cumulative	5	15	30	40	50	60	80	100	120	150	180	210	240	270	300	320	Test	Test	Test	Test	Test	

Appendix E *The average leadtimes between the main milestones in the diAx project* (1st phase)

Milestone:	**Average leadtimes between the milestones:** [days]	**0 – solution:** [days]
1. Letter of Intent (LOI)		
	97	35
2. Lease Contract Signed by Owner		
3. Information Given to the Architect		
	34	7
4. Site Plans Approved by diAx		
	1	1
5. Permit Applications Submitted		
	41	49
6. Permit Applications Received		
7. Technical Site Survey		
	21	7
8. Detailed Site Design Ready		
9. Construction Works Started		
		14
10. Construction Works Completed		
11. Installation Started		
		14
12. Integration Completed		
		7
13. Site Accepted		

MILESTONE:	ACTIVITY DESCRIPTIONS:
N.2 SARF released	- SARF issued and released to Site Acquisition Agents
N.7 SAR received	- search completed (3 candidates) - SAR received from Site Acquisition Agents
N.12 Site prevalidated	- radio and transmission properties analysed - suitability of the site in overall network plan checked - the authorities, owner and price analysed - the priority of three physical site candidates ranked and final site evaluation made
T.1 Line of sight check	- line of sight for all three candidates checked - the best site candidate defined - LOS qualified - Leased line possibility checked - transmission method selected by TRS planner

T.5 Technical site survey	- technical site survey arranged by technical site survey team:
	  - Site Acquisition Agent
	  - Network Planner
	  - Construction Engineer
	  - Installation Planner
	- site design and technical site survey reports prepared

T.9 Site validated	- site qualified by technical site survey team
	- site planning (draft of site design) completed and approved
	- site configuration planned:
	  - capacity and network topology plan (TRS)
	  - RNP coverage and capacity planning
	  - link planning (including individual availability calculation)
	  - frequency planning (TRS)
	  - availability calculation of the whole network (TRS)
	  - RNP coverage planning
	- the best site candidate validated

T.10 Forecasting / reservation (NE and CoSy)	- NE and CoSy selected, forecasted and reserved

L.4 Lease contract signed	- lease contract negotiated with site owner - site approved by the customer - lease contract signed by site owner
L.5 All permit applications submitted	- all needed drawings ready for application - all needed documents ready for application - all permit applications submitted to the authorities - all permit applications registered by the local authorities (inspection call)
L.12 All permit applications received	- all permit approvals received - leased line ordered - site confirmed

L.15 Detailed design ready	- site detailed design completed
	  - architectural design
	  - structural design
	  - electric planning
	  - HPAC planning
	  - installation planning

C.2 Construction works order	- site visit arranged with supervisors and subcontractors - site visit completed - final site cost fixed - construction works order submitted to the subcontractor - construction contract signed
C.3 Telecom implementation order	- telecom installation order submitted to the subcontractor - installation contract signed
C.4 Purchase order and timing (NEs and CoSy)	- time-slot, cross-connect and Q3/Q1 planning commenced (TRS) - purchase orders submitted to the product line and CoSy suppliers - logistics is informed about timing site delivery
C.5 Construction works begin	- power supply ordered - construction work material delivered to the site - construction works commenced - synchronisation planning commenced - RNP frequency and parameters planning commenced
C.8 Construction works end	- site accepted by supervisor - construction works completed

D.3 Site delivery (NE and CoSy)	- NE and CoSy delivered to the site
E.1 Telecom implementation begins	- time-slot, cross-connect and Q3/Q1 planning completed - synchronisation planning completed - installation commenced
E.4 Installation ends	- installation accepted by supervisor - installation completed
E.5 Commissioning begins	- RNP frequency and parameters planning completed - commissioning commenced
E.8 Commissioning ends	- commissioning accepted - commissioning completed
E.9 Integration begins	- integration commenced
E.12 Telecom implementation ends	- integration accepted - integration completed
A.2 Site accepted	- site accepted by the customer

Team:	**Contents of team:** [number * person]	**Work performance:** [sites / month]	**0 – solution:** [sites / month]
Network planning team	1 * RNW planner 1 * TRS planner	5 - 10	5
Site Acquisition team	1 * SA agent	2 - 4	2 – 4
LOS team	2 * TRS planner	8 - 10	8 – 10
Site Survey team	1 * Installation planner 1 * CW engineer 1 * RNW planner 1 * SA agent (1 * Architect)	36	25 - 30
Planning and permission team	1 * Architect	8 - 10	14
Detailed design team	1 * Electrical engineer 1 * Structural engineer	21	14
CW team	3 * CW worker 2 * Electrician	2 - 3	2
Installation team	2 - 3 * Electrician	4	4
Commissioning team	1 * Commissioning engineer	8	8
Integration team	2 * Integration engineer	20	20

RESOURCE PLAN

100 Sites / month

Resources / Teams	SARF - Validation - TRS - RF	SAR and Site acquisition	LOS check	Technical site survey + raport	DRAFT of site design	Permitting	Detailed design	Procurement	Kick-off visit	Construction Works	Installation	Commissioning	Integration	Measurements		Area Team Persons	Project Management	Area Management	Area Team Supervisor
Overall Project Management																			
Project Manager																	1		
Network Planning Manager																	1		
Site Acquisition Manager																	1		
Construction Works Manager																	1		
Telecom Implementation Manager																	1		
Logistics Manager																	1		
Project Cost Engineer																	1		
Subcontracts Manager																	1		
Regional Project Management																			
Regional Manager																		1	
Regional Network Planning Manager																		1	
Regional Site Acquisition Manager																		1	
Regional Construction Works Manager																		1	
Regional Telecom Implementation Manager																		1	
Area Team Supervisors																			
Site Acquisition Coordinator																			5
Planning and Permit Coordinator																			5
Construction Works Supervisor																			5
Installation Supervisor																			5
NSS Field Manager																			5
BSS Field Manager																			5
Logistics Coordinator																			2
Cost Control Engineer																			1
Area Team Persons																			
Radio Network Planner	2			1												14			
Transmission Network Planner	2															10			
Site Acquisition Agent		1		1												37			
LOS Team			2													20			
Planning and Permit Team					1	1	1									36			
Installation Planner				1			1									11			
Construction Works Engineer				1												4			
Construction Works Team									1	3						153			
Installation Team									1		2					53			
Commissioning Engineer												1				13			
Integration Engineer													2			10			
Logistics Team								1								3			
Warehousing Team								1								3			
Procurement Engineer								1								3			
Measurement team														2		2			
Team persons	4	1	2	4	1	1	2	3	2	3	2	1	2	2					
Capasity sites / month / team	**20**	**3**	**10**	**25**	**7**	**7**	**14**	**40**	**40**	**2**	**4**	**8**	**20**	**40**					
Teams needed 100 sites / month	5	33	10	4	14	14	7	3	3	50	25	13	5	1					
Management / person / 100 sites / month																	8	5	33
Team persons	20	33	20	16	14	14	14	8	5	150	50	13	10	2		369			
Persons / Team Supervisor																11			

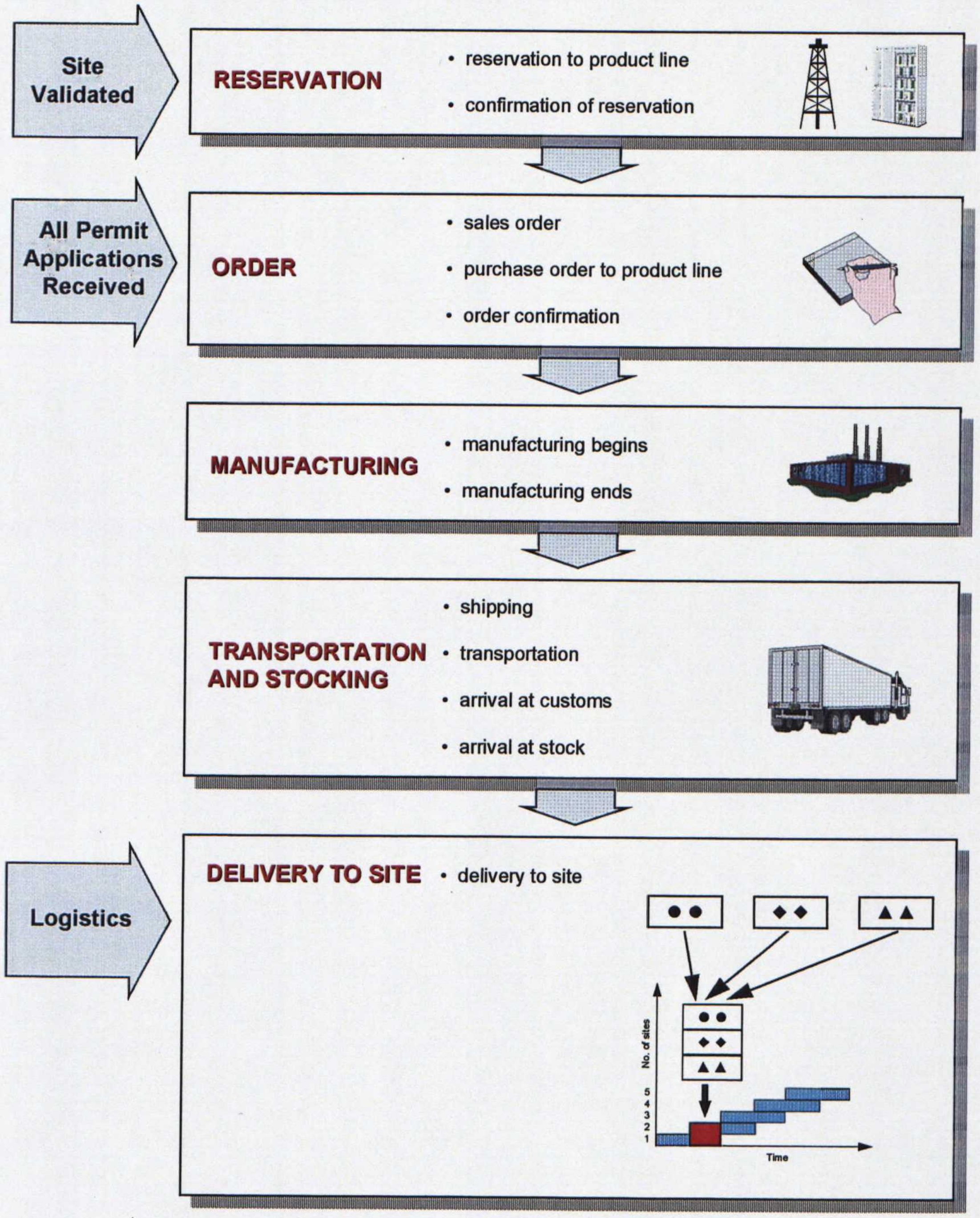
Appendix I *Standard project meeting and reporting practices in a turnkey project*

	CUSTOMER	PROJECT TEAM	CSC AND CS MANAGEMENT
WEEKLY	Progress review meeting & minutes (PM)	Internal project meeting & minutes (PM)	
MONTHLY			CSC Tool report (PM) CS Account Report (PM)
BI-MONTHLY		Account team meeting & minutes (AM)	Account team minutes (AM)
QUARTERLY	Executive report (AM) Executive review meeting (AM)		Executive report (AM) Quality metrics summary
IRREGULAR			Project status meeting in Customer Service Area

Appendix J *Contents of customer and internal reports*

Customer reports contain:	Internal reports contain
Actual progress vs. planned progress Roll-out Sub-systems Material deliveries Invoicing status and estimation Resources Acceptances	Actual progress vs. planned progress Roll-out Sub-systems Material deliveries Invoicing status and estimation Resources Acceptances Budget costs, actual and estimates Potential risk analyzing Best practices information

Appendix K *A generic milestone map for the delivery process and inputs from the site process for reservation, order and delivery to site*



List of items	Unit	Quantity	Usage (hours/unit)	Total hours
D CONSTRUCTION WORKS				
D30 Towers and Antennas				
Cable ladders	m	35	0,4	14
Antenna pole installation	pcs	4	5,0	20
Waterproofing	m2	20	0,2	4
D40 Shelters, Cabinets and Rooms				
Gypsum drywall	m2	12	0,2	2
Metal door installation	lot	1	2,5	3
Painting	m2	32	0,2	6
Vinyl floor tiles	m2	5	1,0	5
Openings, conctrete	pcs	2	1,0	2
Cable openings, wall	pcs	1	4,0	4
Cable ladders	m	6,2	0,4	2
Cable ducts	m	15	0,4	6
Fan and Filter assembly	lot	1	2,0	2
AC -Supply cable	m	15	0,4	6
AC -Distribution board	lot	1	1,5	2
AC -Comsumption meter	lot	1	2,0	2
Lighting	lot	1	1,0	1
Wiring	lot	1	2,0	2
Alarm system	lot	1	3,0	3
Sign installation	lot	1	3,0	3
Fire Extinguiser	lot	1	4,0	4
D90 Installation Earthing				
Earthing cables	m	120	0,2	24
Earth bars	pcs	3	1,0	30
Total hours				**147**
E TELECOM IMPLEMENTATION				
E10 Antennas				
RF antenna installation	lot	1	13,6	14
RF antenna line	m	35	2,1	72
E20 Network Element				
BTS Installation	bts	1	12,8	13
BTS Commissioning	bts	1	19,2	19
BTS Integration	bts	1	5,6	6
E30 Power				
Power installation	lot	1	12,0	12
E40 Transmission				
MW installation	lot	1	16,0	16
MW antenna line	m	30	0,8	24
Total hours				**175**

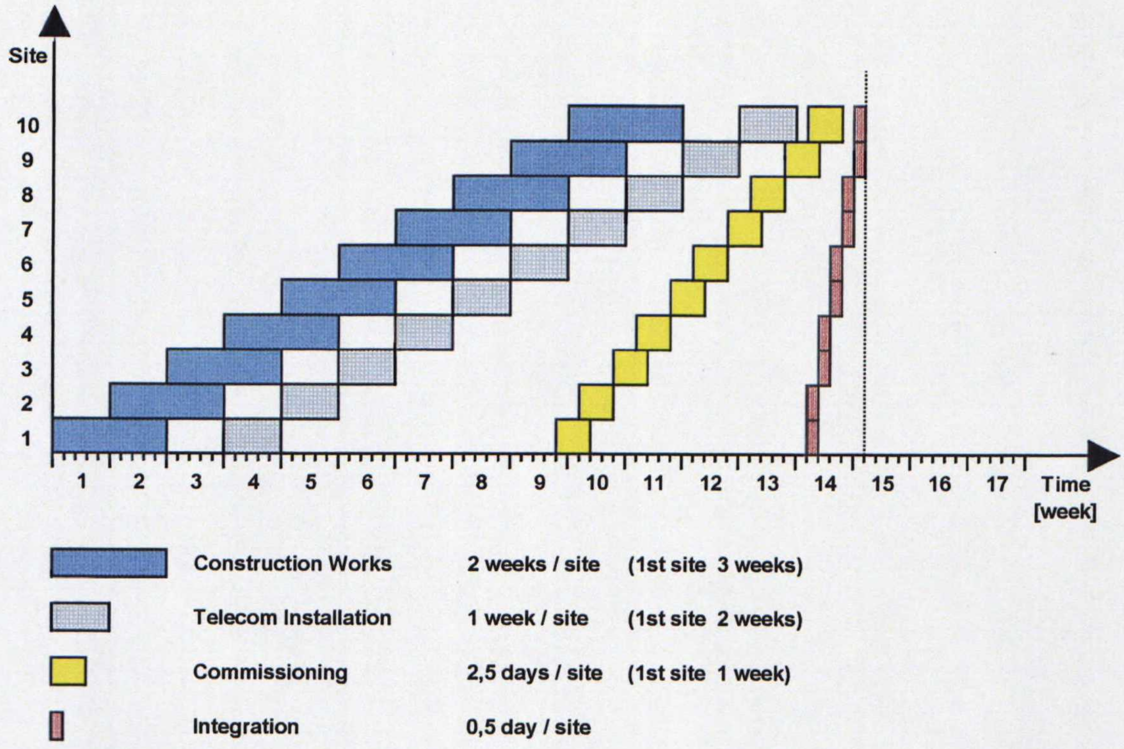
Appendix M *The activity list for an indoor BTS (3 trx) rooftop site (version 1)*

Activity list	Unit	Quantity	Usage (hours/unit)	Total hours	Duration (mwd)	Work group (worker)	Duration (mwd)
CONSTRUCTION WORKS					18,4	2	9,2
Cable ladders	m	35	0,4	14	1,8		
Antenna pole installation	pcs	4	5,0	20	2,5		
Waterproofing	m2	20	0,2	4	0,5		
Partition wall	m2	12	0,2	2	0,3		
Metal door installation	lot	1	2,5	3	0,3		
Painting	m2	32	0,2	6	0,8		
Vinyl floor tiles	m2	5	1,0	5	0,6		
Openings, conctrete	pcs	2	1,0	2	0,3		
Cable openings, wall	pcs	1	4,0	4	0,5		
Cable ladders	m	6,2	0,4	2	0,3		
Cable ducts	m	15	0,4	6	0,8		
Fan and Filter assembly	lot	1	2,0	2	0,3		
AC -Supply cable	m	15	0,4	6	0,8		
AC -Distribution board	lot	1	1,5	2	0,2		
AC -Comsumption meter	lot	1	2,0	2	0,3		
Lighting	lot	1	1,0	1	0,1		
Wiring	lot	1	2,0	2	0,3		
Alarm system	lot	1	3,0	3	0,4		
Sign installation	lot	1	3,0	3	0,4		
Fire Extinguiser	lot	1	4,0	4	0,5		
Earthing cables	m	120	0,2	24	3,0		
Earth bars	pcs	3	1,0	30	3,8		
Total hours				**147**			
TELECOM INDOOR INSTALLATION					4,1	2	2,1
BTS installation	bts	1	12,8	13	1,6		
Power installation	lot	1	12,0	12	1,5		
MW indoor unit installation	lot	1	8,0	8	1,0		
Total hours				**33**			
TELECOM OUTDOOR INSTALLATION					14,1	2 (4)	4,8
RF antenna line	m	35	2,1	72	9,0	4	
RF antenna installation	lot	3	3,0	9	1,1	2	
MW outdoor unit installation incl. antennas	lot	1	8,0	8	1,0	2	
MW antenna line	m	30	0,8	24	3,0	2	
Total hours				**113**			
COMMISSIONING					2,4	1	2,4
BTS Commissioning	bts	1	19,2	19	2,4		
Total hours				**19**			
INTEGRATION					0,7	2	0,5
BTS Integration	bts	1	5,6	6	0,7		
Total hours				**6**			

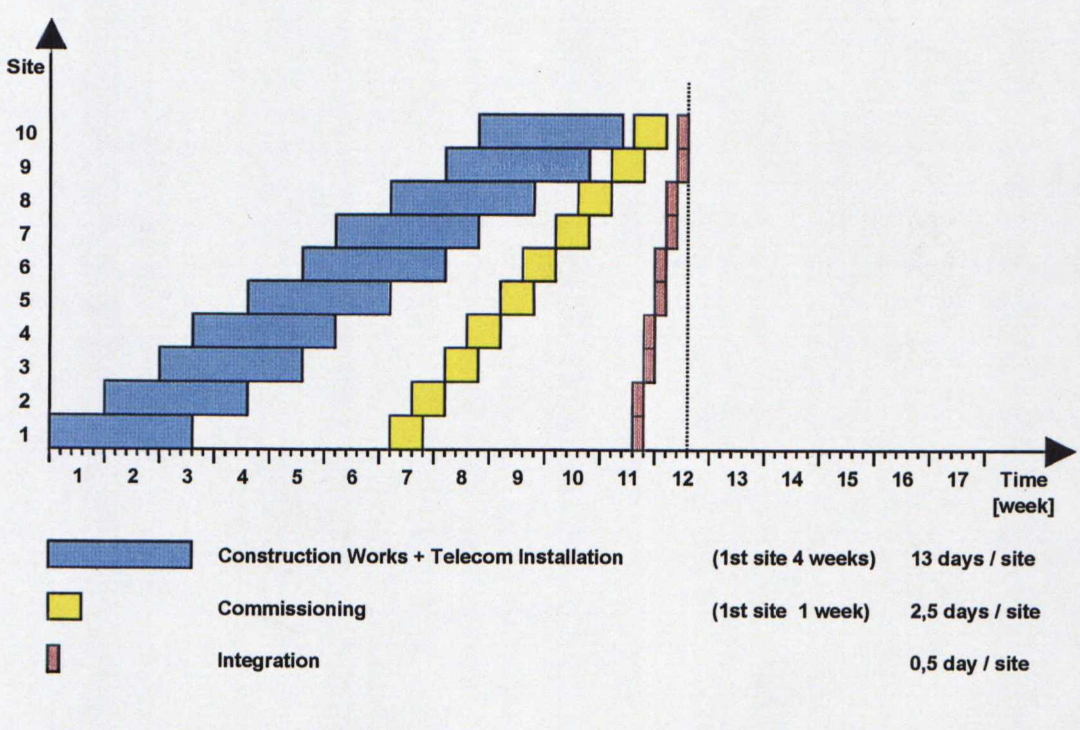
Appendix N   The activity list for an indoor BTS (3 trx) rooftop site (version 2)

Activity list	Unit	Quantity	Usage (hours/unit)	Total hours	Duration (mwd)	Work group (worker)	Duration (mwd)
CONSTRUCTION WORKS + TELECOM INSTALLATION				**293**	**37**	**3**	**12,2**
CONSTRUCTION WORKS					**18,4**	**3**	**6,1**
Cable ladders	m	35	0,4	14	1,8		
Antenna pole installation	pcs	4	5,0	20	2,5		
Waterproofing	m2	20	0,2	4	0,5		
Partition wall	m2	12	0,2	2	0,3		
Metal door installation	lot	1	2,5	3	0,3		
Painting	m2	32	0,2	6	0,8		
Vinyl floor tiles	m2	5	1,0	5	0,6		
Openings, conctrete	pcs	2	1,0	2	0,3		
Cable openings, wall	pcs	1	4,0	4	0,5		
Cable ladders	m	6,2	0,4	2	0,3		
Cable ducts	m	15	0,4	6	0,8		
Fan and Filter assembly	lot	1	2,0	2	0,3		
AC -Supply cable	m	15	0,4	6	0,8		
AC -Distribution board	lot	1	1,5	2	0,2		
AC -Comsumption meter	lot	1	2,0	2	0,3		
Lighting	lot	1	1,0	1	0,1		
Wiring	lot	1	2,0	2	0,3		
Alarm system	lot	1	3,0	3	0,4		
Sign installation	lot	1	3,0	3	0,4		
Fire Extinguiser	lot	1	4,0	4	0,5		
Earthing cables	m	120	0,2	24	3,0		
Earth bars	pcs	3	1,0	30	3,8		
				147	**18**		
TELECOM INDOOR INSTALLATION					**4,1**	**3**	**1,4**
BTS installation	bts	1	12,8	13	1,6		
Power installation	lot	1	12,0	12	1,5		
MW indoor unit installation	lot	1	8,0	8	1,0		
				33	**4**		
TELECOM OUTDOOR INSTALLATION					**14,1**	**3**	**4,7**
RF antenna line	m	35	2,1	72	9,0		
RF antenna installation	lot	3	3,0	9	1,1		
MW outdoor unit installation incl. antennas	lot	1	8,0	8	1,0		
MW antenna line	m	30	0,8	24	3,0		
				113	**14**		
COMMISSIONING					**2,4**	**1**	**2,4**
BTS Commissioning	bts	1	19,2	19	2,4		
Total hours				**19**			
INTEGRATION					**0,7**	**2**	**0,5**
BTS Integration	bts	1	5,6	6	0,7		
Total hours				**6**			

Appendix O *The schedule for ten Indoor BTS (3 trx) rooftop sites (version 1)*



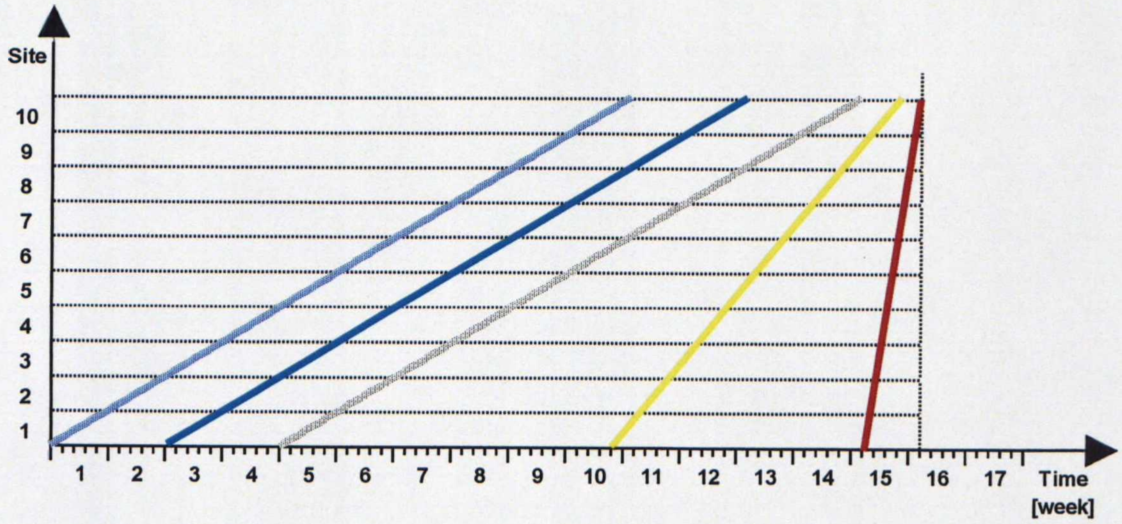
Appendix P *The schedule for ten Indoor BTS (3 trx) rooftop sites (version 2)*



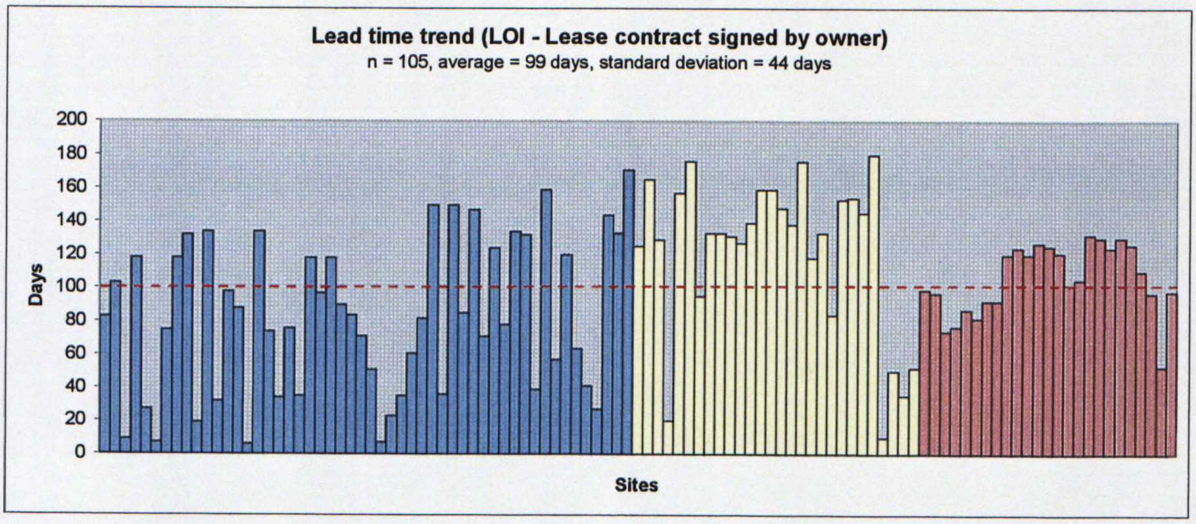
Appendix Q *The activity list and the activities' durations for different work groups for an Indoor BTS (3 trx) rooftop site*

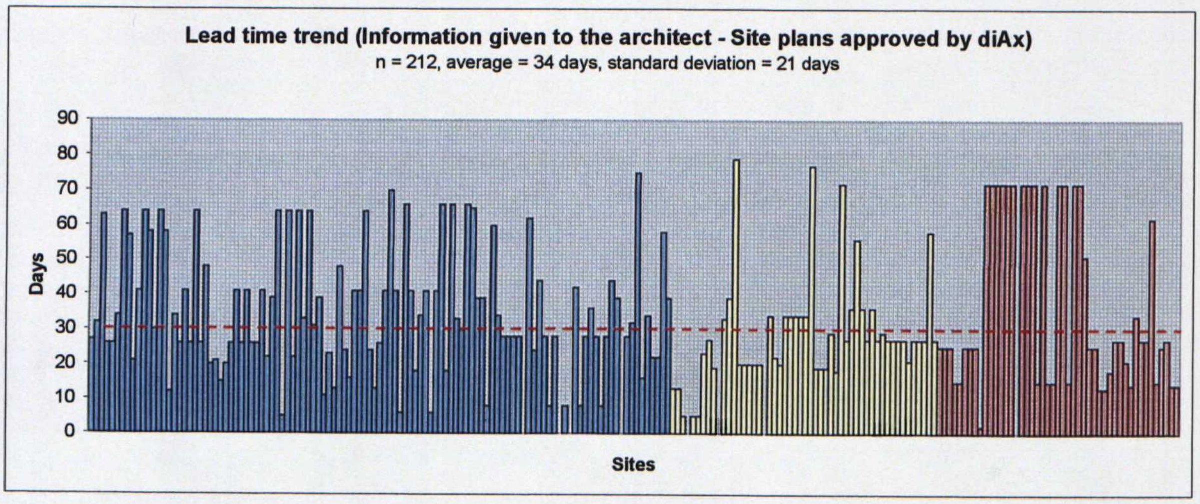
Activity list	Unit	Quantity	Usage (hours/unit)	Total hours	Duration (mwd)	Work group (worker)	Duration (mwd)
CONSTRUCTION WORKS					**8,6**	**2**	**4,3**
Cable ladders	m	35	0,4	14	1,8		
Antenna pole installation	pcs	4	5,0	20	2,5		
Waterproofing	m2	20	0,2	4	0,5		
Partition wall	m2	12	0,2	2	0,3		
Metal door installation	lot	1	2,5	3	0,3		
Painting	m2	32	0,2	6	0,8		
Vinyl floor tiles	m2	5	1,0	5	0,6		
Openings, conctrete	pcs	2	1,0	2	0,3		
Cable openings, wall	pcs	1	4,0	4	0,5		
Cable ladders	m	6,2	0,4	2	0,3		
Cable ducts	m	15	0,4	6	0,8		
Total hours				**69**			
ELECTRICAL WORK					**9,8**	**2**	**4,9**
Fan and Filter assembly	lot	1	2,0	2	0,3		
AC -Supply cable	m	15	0,4	6	0,8		
AC -Distribution board	lot	1	1,5	2	0,2		
AC -Comsumption meter	lot	1	2,0	2	0,3		
Lighting	lot	1	1,0	1	0,1		
Wiring	lot	1	2,0	2	0,3		
Alarm system	lot	1	3,0	3	0,4		
Sign installation	lot	1	3,0	3	0,4		
Fire Extinguiser	lot	1	4,0	4	0,5		
Earthing cables	m	120	0,2	24	3,0		
Earth bars	pcs	3	1,0	30	3,8		
Total hours				**79**			
TELECOM INDOOR INSTALLATION					**4,1**	**2**	**2,1**
BTS installation	bts	1	12,8	13	1,6		
Power installation	lot	1	12,0	12	1,5		
MW indoor unit installation	lot	1	8,0	8	1,0		
Total hours				**33**			
TELECOM OUTDOOR INSTALLATION					**14,1**	**2 (4)**	**4,8**
RF antenna line	m	35	2,1	72	9,0	4	
RF antenna installation	lot	3	3,0	9	1,1	2	
MW outdoor unit installation incl. antennas	lot	1	8,0	8	1,0	2	
MW antenna line	m	30	0,8	24	3,0	2	
Total hours				**113**			
COMMISSIONING					**2,4**	**1**	**2,4**
BTS Commissioning	bts	1	19,2	19	2,4		
Total hours				**19**			
INTEGRATION					**0,7**	**2**	**0,5**
BTS Integration	bts	1	5,6	6	0,7		
Total hours				**6**			

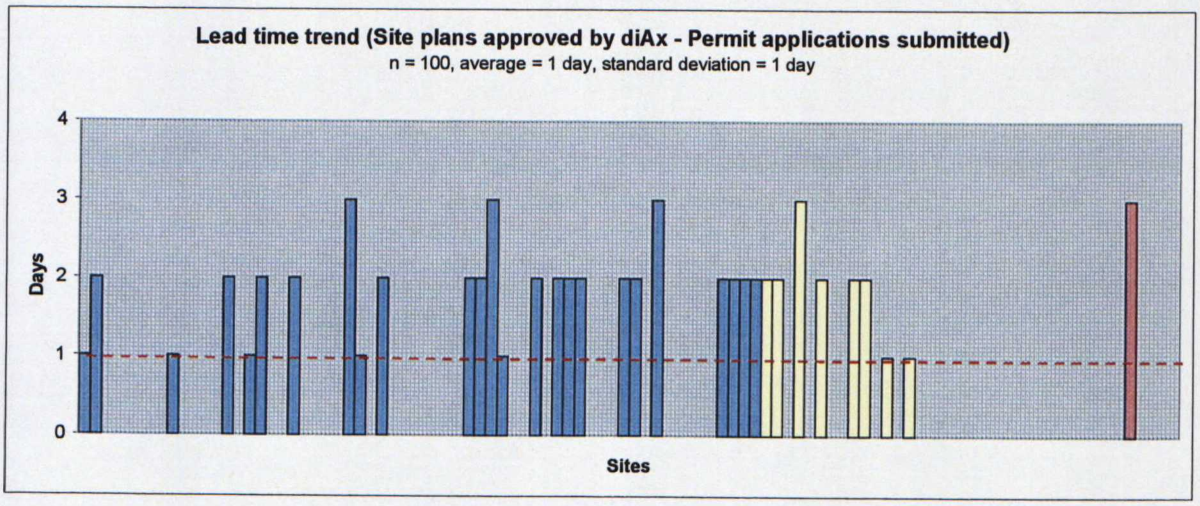
Appendix R *The schedule for ten Indoor BTS (3 trx) rooftop sites*



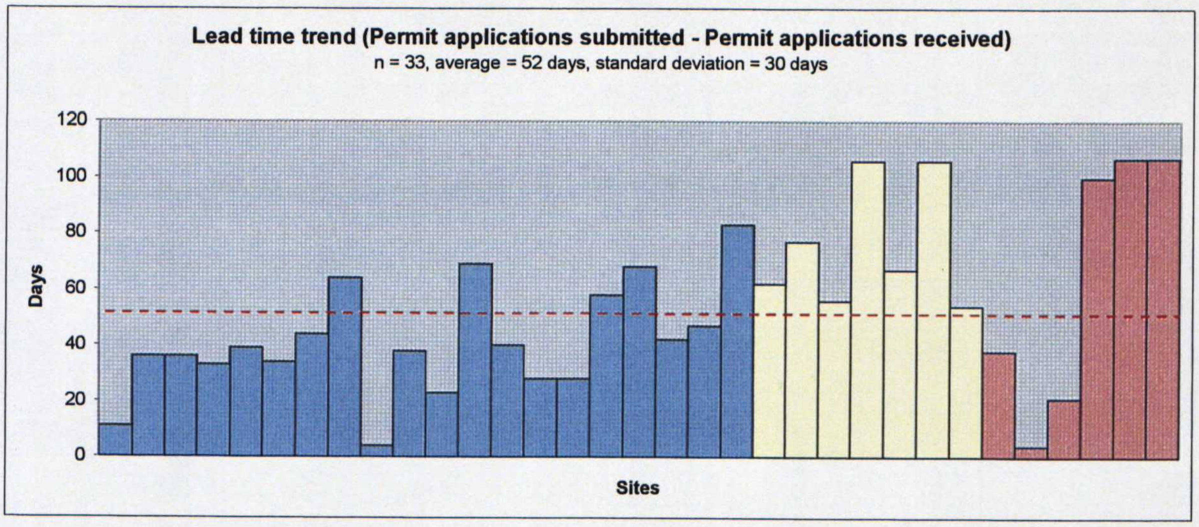
(legend swatch)	Construction Works	1 week / site
(legend swatch)	Electrical Work	1 week / site
(legend swatch)	Telecom Installation	1 week / site
(legend swatch)	Commissioning	2,5 days / site
(legend swatch)	Integration	0,5 day / site

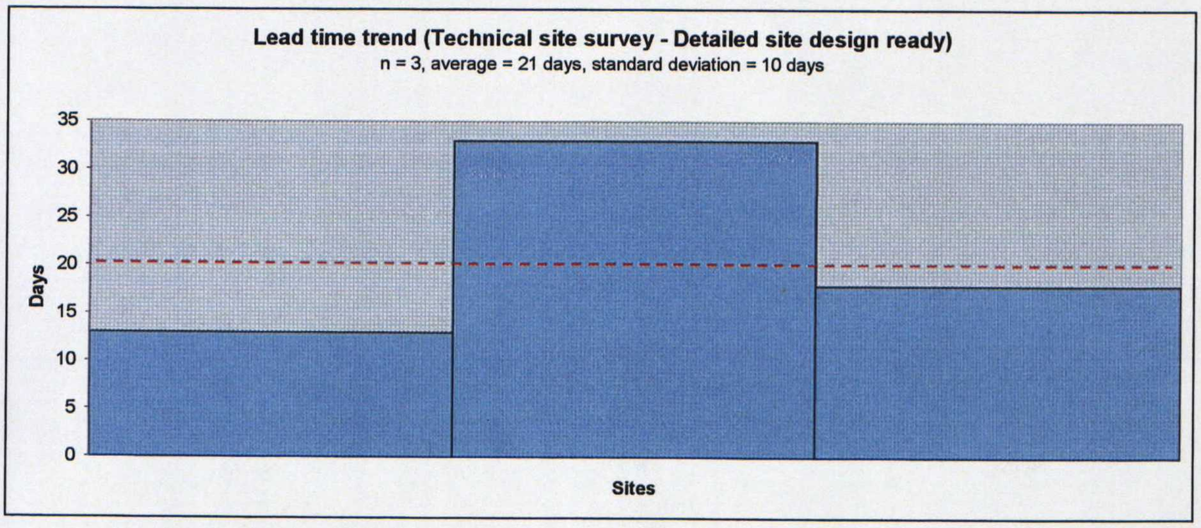

Lead time trend (LOI - Lease contract signed by owner)
n = 105, average = 99 days, standard deviation = 44 days
Days
Sites
0
20
40
60
80
100
120
140
160
180
200

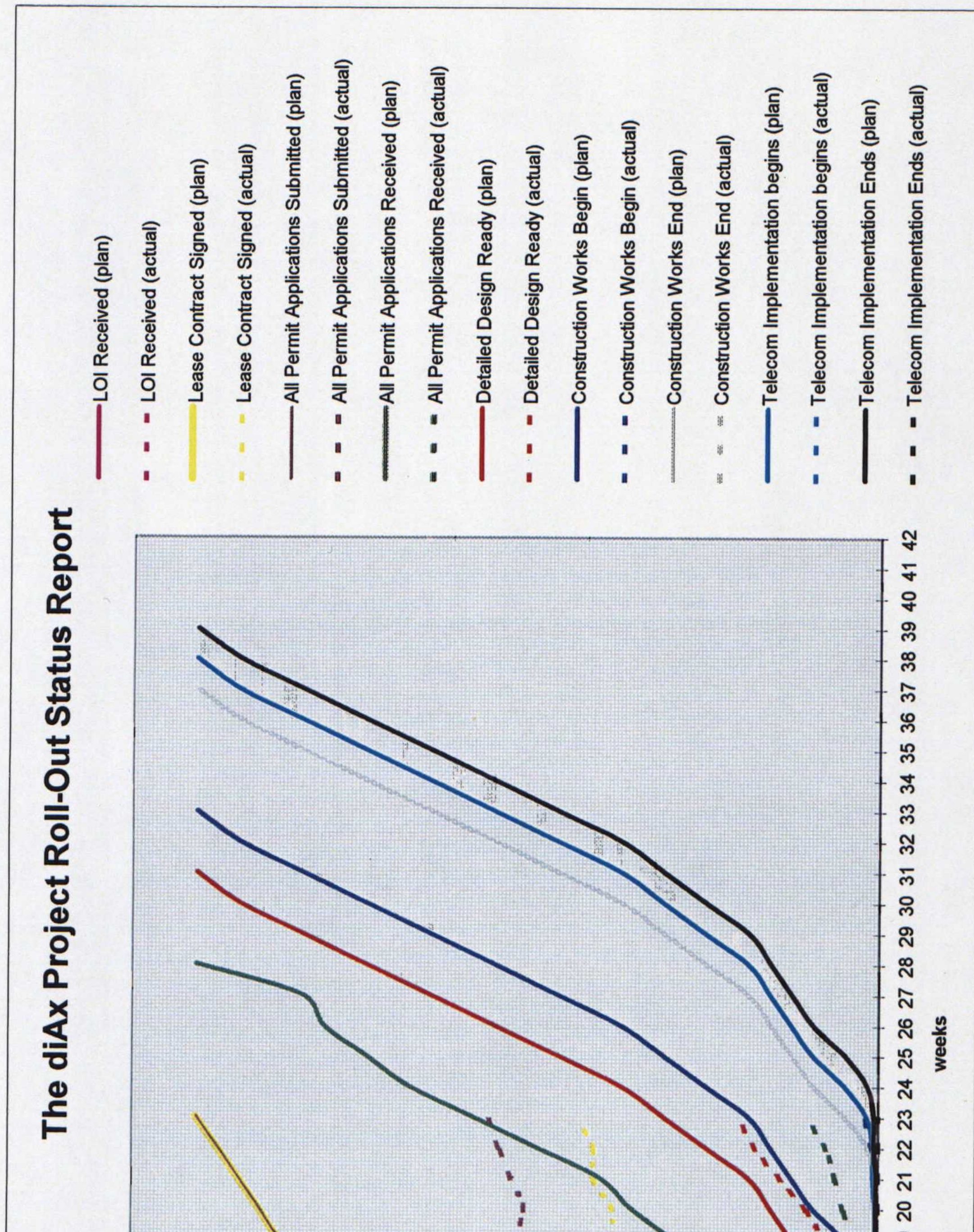

Lead time trend (Information given to the architect - Site plans approved by diAx)
n = 212, average = 34 days, standard deviation = 21 days
Days
Sites
0
10
20
30
40
50
60
70
80
90


Lead time trend (Site plans approved by diAx - Permit applications submitted)
n = 100, average = 1 day, standard deviation = 1 day
Days
Sites
0
1
2
3
4

Appendix T Lead time trends from permit applications submitted to detailed site design ready







The diAx Project Roll-Out Status Report
sites
350
300
250
200
150
100
50
0
weeks
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
LOI Received (plan)
LOI Received (actual)
Lease Contract Signed (plan)
Lease Contract Signed (actual)
All Permit Applications Submitted (plan)
All Permit Applications Submitted (actual)
All Permit Applications Received (plan)
All Permit Applications Received (actual)
Detailed Design Ready (plan)
Detailed Design Ready (actual)
Construction Works Begin (plan)
Construction Works Begin (actual)
Construction Works End (plan)
Construction Works End (actual)
Telecom Implementation begins (plan)
Telecom Implementation begins (actual)
Telecom Implementation Ends (plan)
Telecom Implementation Ends (actual)

Appendix V *Construction works roll-out plan in the diAx project*

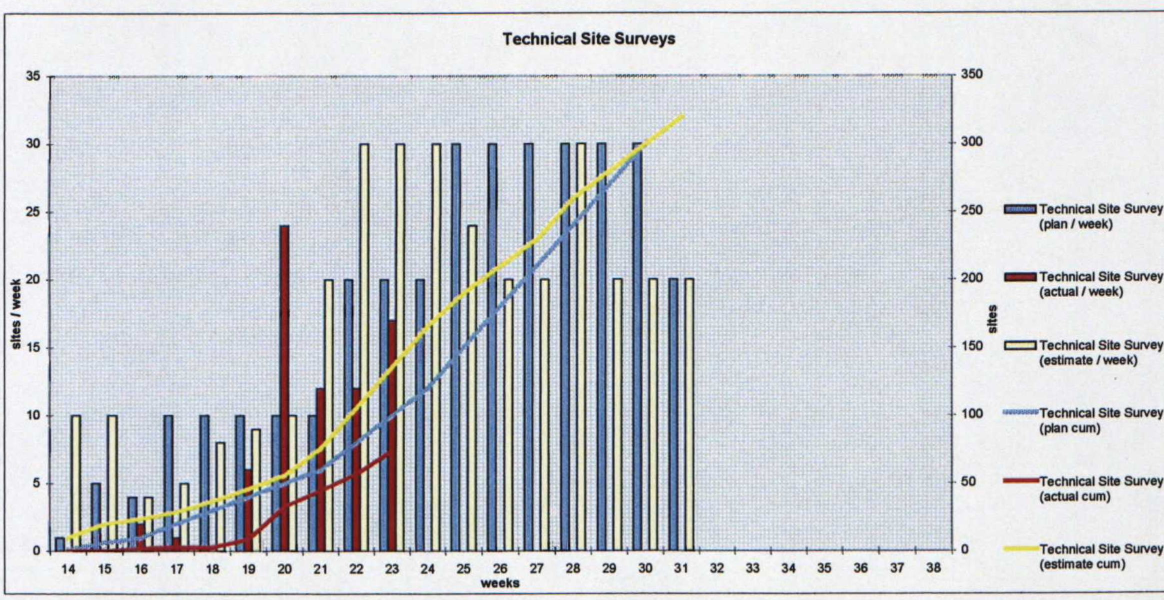
WEEK NUMBER	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Technical Site Survey (plan / week)	1	5	4	10	10	10	10	10	20	20	20	30	30	30	30	30	30	20							
Technical Site Survey (actual / week)	0	0	2	1	0	6	24	12	12	17															
Technical Site Survey (estimate / week)	10	10	4	5	8	9	10	20	30	30	30	24	20	20	30	20	20	20							
Technical Site Survey (plan cum)	1	6	10	20	30	40	50	60	80	100	120	150	180	210	240	270	300	320							
Technical Site Survey (actual cum)	0	0	2	3	3	9	33	45	57	74															
Technical Site Survey (estimate cum)	10	20	24	29	37	46	56	76	106	136	166	190	210	230	260	280	300	320							

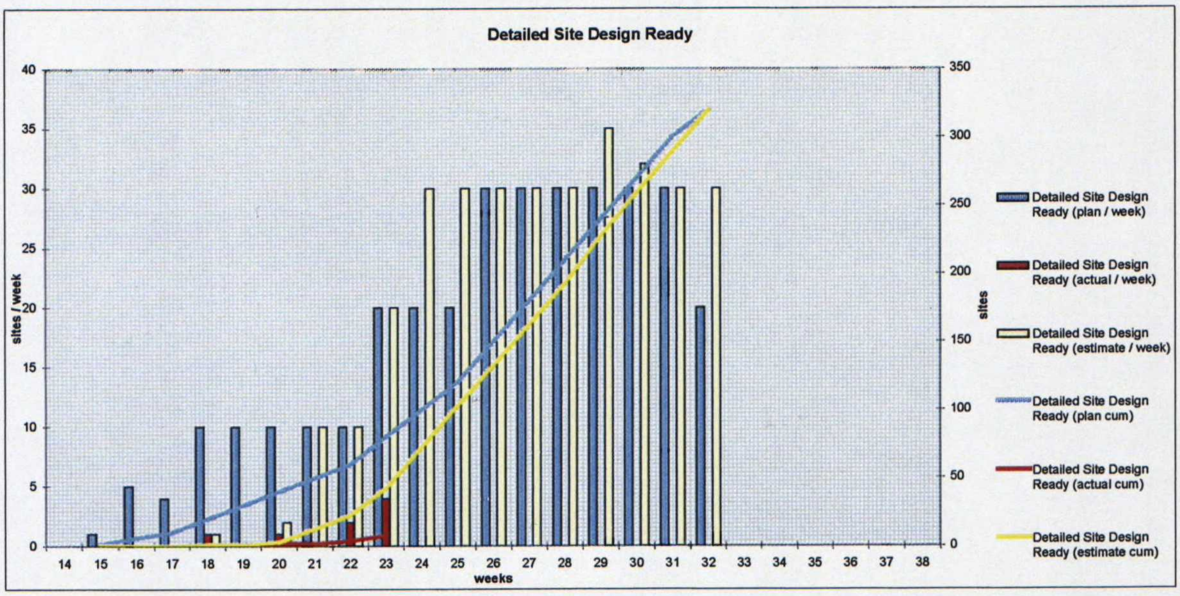
WEEK NUMBER	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Detailed Site Design Ready (plan / week)		1	5	4	10	10	10	10	10	20	20	20	30	30	30	30	30	30	20						
Detailed Site Design Ready (actual / week)		0	0	0	1	0	1	0	2	4															
Detailed Site Design Ready (estimate / week)		0	0	0	1	0	2	10	10	20	30	30	30	30	30	35	32	30	30						
Detailed Site Design Ready (plan cum)		1	6	10	20	30	40	50	60	80	100	120	150	180	210	240	270	300	320						
Detailed Site Design Ready (actual cum)		0	0	0	1	1	2	2	4	8															
Detailed Site Design Ready (estimate cum)		0	0	0	1	1	3	13	23	43	73	103	133	163	193	228	260	290	320						

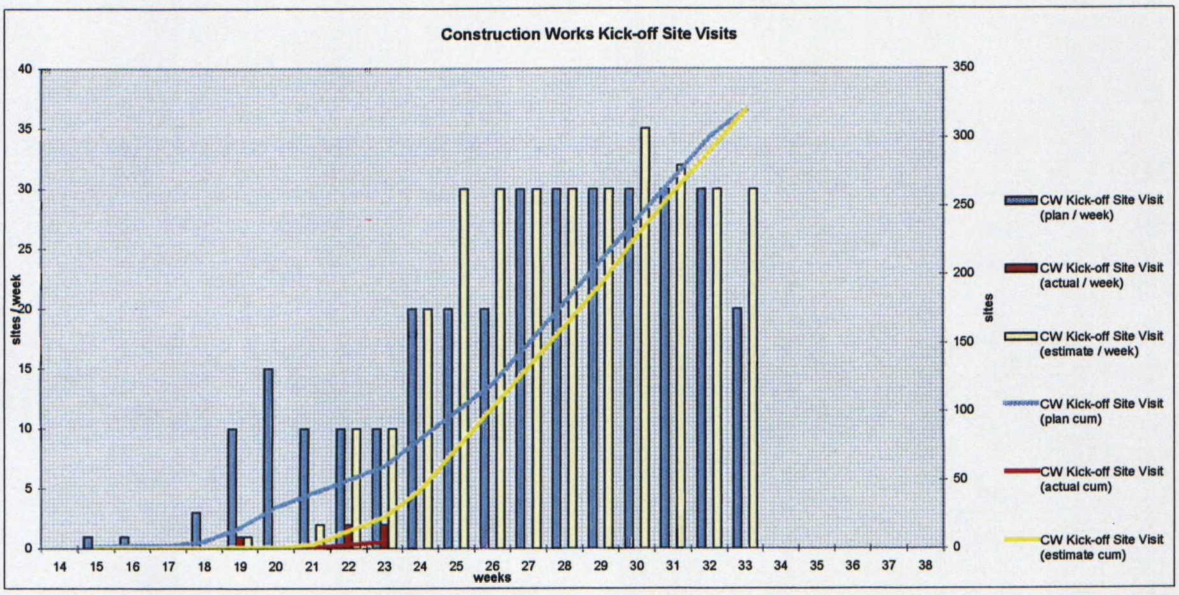
WEEK NUMBER	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
CW Kick-off Site Visit (plan / week)		1	1	0	3	10	15	10	10	10	20	20	20	30	30	30	30	30	30	20					
CW Kick-off Site Visit (actual / week)		0	0	0	0	1	0	0	2	2															
CW Kick-off Site Visit (estimate / week)		0	0	0	0	1	0	2	10	10	20	30	30	30	30	30	35	32	30	30					
CW Kick-off Site Visit (plan cum)		1	2	2	5	15	30	40	50	60	80	100	120	150	180	210	240	270	300	320					
CW Kick-off Site Visit (actual cum)		0	0	0	0	1	1	1	3	5															
CW Kick-off Site Visit (estimate cum)		0	0	0	0	1	1	3	13	23	43	73	103	133	163	193	228	260	290	320					

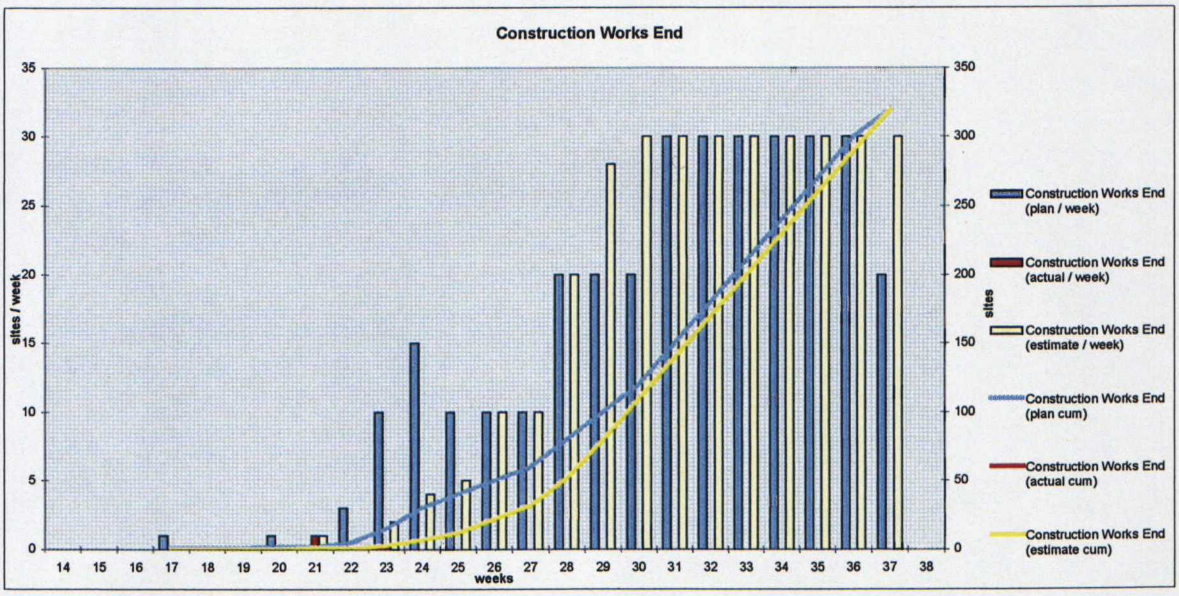
WEEK NUMBER	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Construction Works End (plan / week)				1	0	0	1	0	3	10	15	10	10	10	20	20	20	30	30	30	30	30	30	20	
Construction Works End (actual / week)				0	0	0	0	1	0	0															
Construction Works End (estimate / week)				0	0	0	0	1	0	2	4	5	10	10	20	28	30	30	30	30	30	30	30	30	
Construction Works End (plan cum)				1	1	1	2	2	5	15	30	40	50	60	80	100	120	150	180	210	240	270	300	320	
Construction Works End (actual cum)				0	0	0	0	1	1	1															
Construction Works End (estimate cum)				0	0	0	0	1	1	3	7	12	22	32	52	80	110	140	170	200	230	260	290	320	

Appendix W *Construction works status from technical site survey to construction works end in the diAx project*




Detailed Site Design Ready
sites / week
sites
weeks
Detailed Site Design Ready (plan / week)
Detailed Site Design Ready (actual / week)
Detailed Site Design Ready (estimate / week)
Detailed Site Design Ready (plan cum)
Detailed Site Design Ready (actual cum)
Detailed Site Design Ready (estimate cum)


Construction Works Kick-off Site Visits
sites / week
sites
weeks
CW Kick-off Site Visit (plan / week)
CW Kick-off Site Visit (actual / week)
CW Kick-off Site Visit (estimate / week)
CW Kick-off Site Visit (plan cum)
CW Kick-off Site Visit (actual cum)
CW Kick-off Site Visit (estimate cum)


Construction Works End
sites / week
sites
weeks
Construction Works End (plan / week)
Construction Works End (actual / week)
Construction Works End (estimate / week)
Construction Works End (plan cum)
Construction Works End (actual cum)
Construction Works End (estimate cum)