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REPORT

SIP - Future Rehabilitation Strategies for Physical Infrastructure:

COORDINATION OF REHABILITATION PLANNING AND MEASURES – CO-INFRASTRUCTURE INTERACTIONS

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TITLE

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ABSTRACT

An increasing level of complexity in our infrastructure requires more efforts in coordination. The current methods used for management, planning and coordination, both at organisation level and at project level, are insufficient and have a potential for improvement. The main conclusions drawn from the work with this report are:

- Before effective communication can take place, good plans must exist. And before good plans can be made, it is necessary to have accurate information about infrastructure.
- Coordination must take place at different levels: management, common systems, and sharing of data. Out of these three, management is probably the most important success factor.
- Coordination of both long term plans and project execution are important. Two important challenges are that infrastructure owners make plans for very different time horizons, and that systems to communicate information about project execution only exist to a limited extent.
- Information about infrastructure and plans for development are for some sectors considered business secrets, and therefore restricted.
- The public, i.e. the municipalities, must take a responsibility for successful coordination of infrastructure projects, because it is in general the public who benefit from it.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Communication technology	Kommunikasjons-teknologi
GROUP 2	Infrastructure	Infrastruktur
SELECTED BY AUTHOR	Coordination	Koordinering

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1 INTRODUCTION

This report is part of the project “Future Strategies for Rehabilitation of Physical Infrastructure”. This is a Strategic Institute Programme (SIP) sponsored by The Research Council of Norway.

1.1 Background – the challenge

A Norwegian initiative in 2008 [5] identified the total length of infrastructure in the Norwegian roads to be more than 200.000 km of pipes and cables for water, wastewater, storm water, high and low voltage electricity, communication cables, television, gas, hot water pipes and other infrastructures. This distance equals 5 times around equator! There may be as many as 8 different infrastructures under the pavement in a road. Figure 1 illustrates the complexity of urban underground infrastructure. It is easy to understand that it is not a simple task to coordinate rehabilitation of underground structures; but the advantages are clear, too.

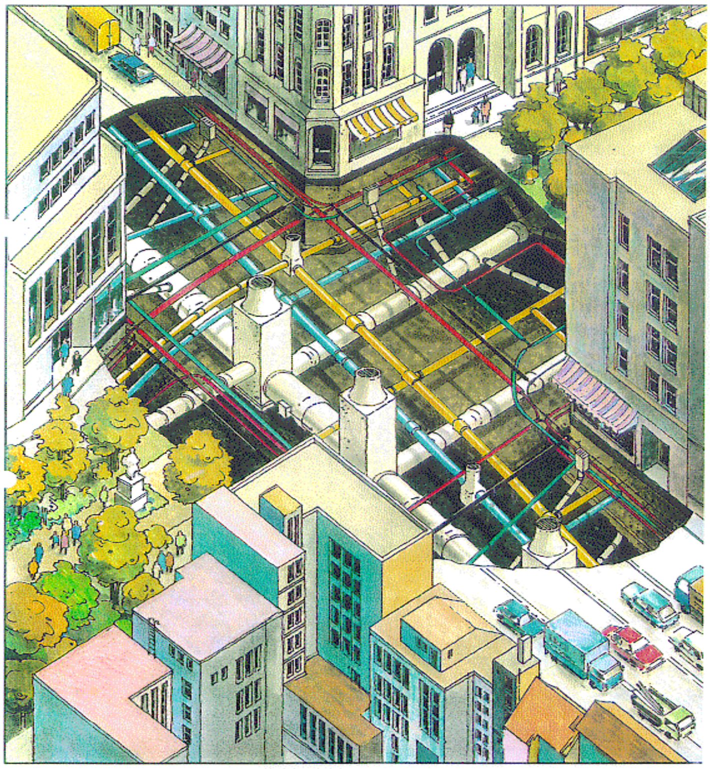

Figure 1: The complexity of urban underground infrastructure

In Oslo (the capitol of Norway) alone, there are approximately 10.000 projects yearly involving excavations in roads. There are several hundreds of accidents where infrastructure is damaged during excavations. Many of these damages could have been avoided with better information about the infrastructure available. This is the reason why many Norwegian municipalities have started initiatives to increase the focus on efficient infrastructure rehabilitation by improving coordination between infrastructure construction works, also called co-infra coordination. The hypothesis is that when we coordinate activities, we gain benefits and the outcome is higher than when we operate un-coordinated.

“Why is the municipality digging in the road for the third time in as many years?” is an example of a newspaper headline that pops up from time to time. Such questions contribute to an impression that the society’s common resources are not managed properly, and it is easy to understand that questions are raised when a pavement is cut frequently. Negative focus on infrastructure undermines the public perception of the important work done my municipalities and water companies worldwide.

It is rare that the different municipal units and other owners of buried infrastructure have an intention to dig many times in a road over a short period of time. Some of the events that lead to the excavation works are random failures that are impossible to plan for. But, although some efforts are made in order to coordinate activities between the various owners of the infrastructure in the road, it is clear that some of the cuts in the pavement could have been avoided by improved planning and coordination.

This leads to the working hypothesis of this report;

The current methods used for management, planning and coordination, both at organisation level and at project level, are insufficient and have a potential for improvement.

This hypothesis is further explored in this report.

1.2 The term *tool* used in this report

In the context of this report, the term *tool*, is used to describe not only a piece of software, but it can also constitute a working methodology, or any organisational model that contributes to an improved systematic way of organising activities (e.g. a legislative or a methodological tool). So the term *tool* is used in a broad sense.

A *tool* can help (or force) the user to coordinate activities with others in an integrated manner. In general, we are coordinating our activities much more frequently than most people are aware of. For example a meeting is a frequently used *tool* to coordinate activities. The reason for using the term *tool* is to emphasise this fact.

1.3 The terms *horizontal* and *vertical integration*

Halfawy [1] introduces the terms *horizontal and vertical integration*, illustrated in Figure 2.

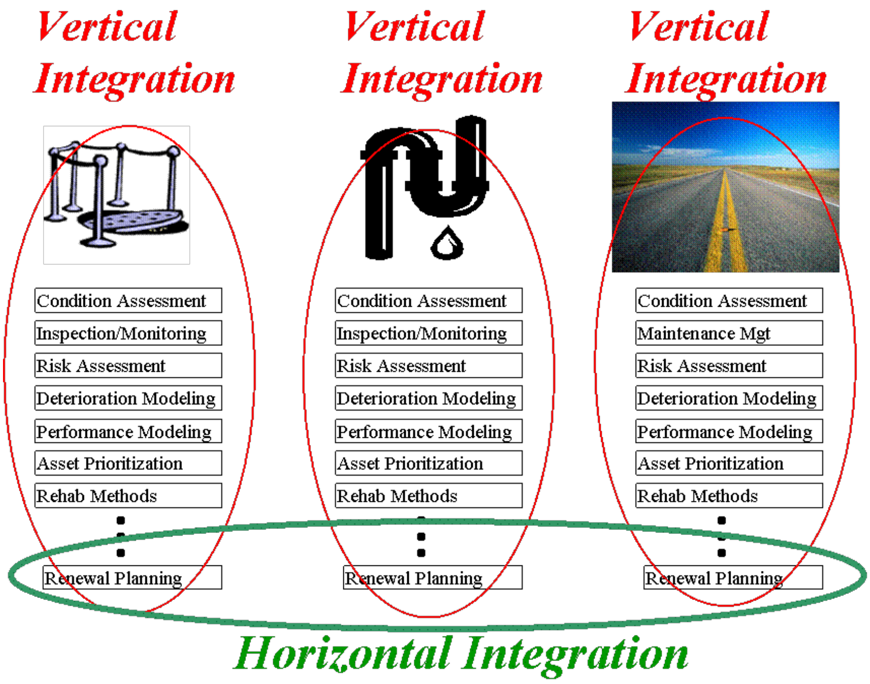

Figure 2: Vertical and horizontal integration of renewal plans for road, sewer and water mains

Vertical integration is when the different aspects listed are considered when planning rehabilitation for one particular type of infrastructure (for example water). Those aspects are part of renewal planning, and include aspects such as:

- Condition assessment
- Inspection/monitoring
- Risk assessment
- Deterioration modelling
- Performance modelling
- Asset prioritisation
- Rehab methods
- … and possibly others

Some tools have been developed to support such planning, and include both research based tools (prototypes) and commercial software. Some examples are listed in Section 3.1.

Horizontal integration is when renewal plans for different types of infrastructures are combined or coordinated, to create integrated plans taking the planned actions (or the planned non-actions) from other stakeholders into account. Some challenges for horizontal integration may be that:

- Decision makers have different budgeting systems.
- Planning methodologies and horizons are different, as well.
- Budgets may be allocated for specific areas.
- It can be difficult to secure mutual benefit for different interests.

These challenges will be discussed in the report.

1.4 About this report

This report consists of the following main parts:

- Some general perspectives of infrastructure planning and coordination of plans and renewal actions (section 2)
- An overview of existing planning tools for infrastructure (section 3)
- Some ideas for improved coordination (section 4)

2 SOME PERSPECTIVES OF INFRASTRUCTURE PLANNING AND COORDINATION

2.1 Reference to some literature and initiatives

Halfawy discusses facilitation of the development of MIMEs, Municipal Infrastructure Management Environments in [101]. There are three main requirements:

1. Efficient coordination and information flow between inter-dependent processes.
2. Efficient integration and management of infrastructure lifecycle data within and across municipal departments in a way that maximises the reuse and sharing of data.
3. Integration of various software applications with open and modular software architecture.

The 3 points listed above relate to software requirements. Information should ideally be shared in an open manner, using open systems and software that can work together and integrate easily. This is opposite to many existing commercial products, which may use proprietary data bases or formats which makes interactions and use of the same data source much more difficult.

The three main challenges to reach the requirements listed above are [101]:

1. Process systemisation and coordination.
2. Data integration.
3. Software integration.

A successful implementation of a MIME, including coordination planning, is not just a question of developing a well functioning computerised software system. It is equally important that this system is adapted to relevant processes in the municipality. There are many examples of software systems that do not work as intended because they do not support the processes they were meant to. On the other hand, there are also examples that a process is not adapted to a software syste. The MIME must therefore be adapted to the way data is organised in this specific municipality. However, the municipal processes and data systems may be required to change and improve in order to implement a particular MIME.

A Norwegian initiative in 2008 [5] identified the following main solutions for improved infrastructure management:

- A coordination authority on a national level.
- A coordination authority on a local level.
- Necessary changes in legislation to enhance and ensure solutions to maximise the economic and social benefits for society.
- An evaluation of existing initiatives for coordination.
- Measures to stimulate use of advanced ICT solutions.

2.2 The role of management and organisation

Coordination can take place at different levels. At utility level, coordination is largely a question of proper management. A Swedish study [12] estimates that 75 % of the key factors in order to realise coordination benefits in a utility belong at organisation or management level, while 25 % are at a technical level.

Coordination at project level also depends on both organisation and technical issues, and one cannot function without the other. The Swedish study mentioned above [12] defines coordination as synonymous to organisation.

2.3 Planning phases

Different phases of rehabilitation require different planning tools. Planning can be split in 2 distinctly different tasks or phases, as illustrated in
Figure 4:

1. Long term planning (with a horizon of 3 years or more).
2. Short term project execution, where the objective is to execute plans and install components as quickly as possible.

2.3.1 Long term planning

In order to be able to coordinate plans, the plans have to be made for a sufficiently long time horizon. The horizon should ideally be 3-5 years to allow for effective coordination to take place. The planning in this phase should take into consideration the condition of assets, economic aspects, life cycle considerations, and coordination between infrastructures, among other things. This level of detail in the plan must not necessarily be available at asset level, but should at least be available at area level. As an example, information that a certain area is targeted for water pipe renewal is very useful for planning of actions to the sewer pipes and to the roads.

Examples of the contents of a ‘plan’ in this context can then be:

- A defined geographic area (polygon) in which actions are planned and described to a certain extent.
- A list of targeted individual asset within a certain time frame and description of corresponding planned actions.

The information has to be available through an effective portal, for example a web interface or a software application (it’s unlikely that a manual system is sufficient). The system should possibly be supported or operated by a coordination authority, a topic that has been discussed in Norway lately. This coordination authority could be a government or municipal office, or a private company.

A good example of a system where plans are accessible is the area plans available by web, for example for the municipality of Trondheim shown in Figure 3:

Figure 3: City planning in Trondheim, Norway – made available via web http://webhotel2.gisline.no/GISLINEWebInnsyn_Trondheim/
(In *Velg karttype*, chose *Regulerings- og bebyggelsesplan*).

The map in Figure 3 displays different plans for development of the municipality. Currently, only plans that are public by law as part of the public procedure for acceptance of the plan are presented in the web portal. But it could fairly easily be used to present other plans, such as infrastructure rehabilitation plans.

Figure 4 shows the long term planning efforts of two infrastructures, one blue and one green, above the timeline. Below the timeline are rehabilitation or operation and maintenance actions, i.e. where the plans are executed. The hatched areas below the timeline are where works take place for both infrastructures at the same time.

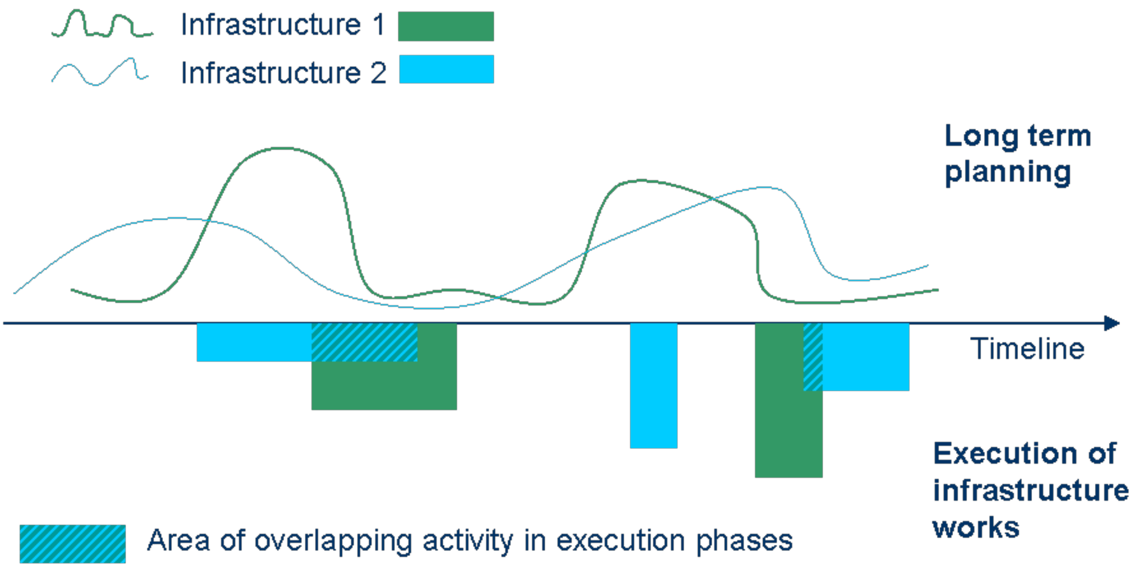

Figure 4: Efforts in long term planning and execution of infrastructure construction projects

As an example, if the green colour in
Figure 4 represents road and blue is water, then the lines above the time line are resources spent for long term planning (e.g. master plans and rehabilitation plans) for water and road. The blue squares below the time line are different rehabilitation and operation and maintenance tasks for water, while the green squares are e.g. road re-pavement. The hatched areas are simultaneous work on both water and road, for example corridor rehabilitation of a street.

Water pipe has a typical life expectancy of 100 years, while road typically has 20 years. The objective is not necessarily to simultaneously work on all infrastructures for every project, but rather to coordinate sufficiently to identify the projects where it is the optimal solution to do so. The objective of coordination is to find the optimal hatched area in
Figure 4, where well coordinated plans are executed with the best possible total result for the invested resources.

The optimal situation would be when all infrastructures plan their activities sufficiently long time in advance, so that others are aware of the plans and can act accordingly. The long term planning horizon therefore needs to be long enough so that actions can be coordinated.

2.3.2 Short term planning and project execution

When a project is planned in detail, the objective becomes to execute the plans and install components as quickly as possible according to the project plan. Direct coordination and the availability of accurate and detailed information are vital for short term planning. Therefore, the project meeting is an effective “tool” in this phase. But there exist also other tools for coordination in this phase, such as technical construction management (BIM). It is commonly used in construction but for different reasons not (yet) for infrastructure.

2.4 Different levels of asset management and planning

In order to succeed in co-infra coordination, asset management planning tools should cover the following levels:

1. Asset information: Data collection and digitalisation, building up data bases, GIS
2. Quality control of data
3. Application of long term planning tools at asset level
4. Coordination of plans at asset level for different infrastructures (set integration of actions based on optimisation)

Level 1 is the most basic, while 4 is the most advanced. Some municipalities and some infrastructures have come quite far in this procedure and are ready to start coordination actions (level 4). But in most cases, utilities will find themselves somewhere in steps 1-3. The following sub sections will address the 4 points listed above.

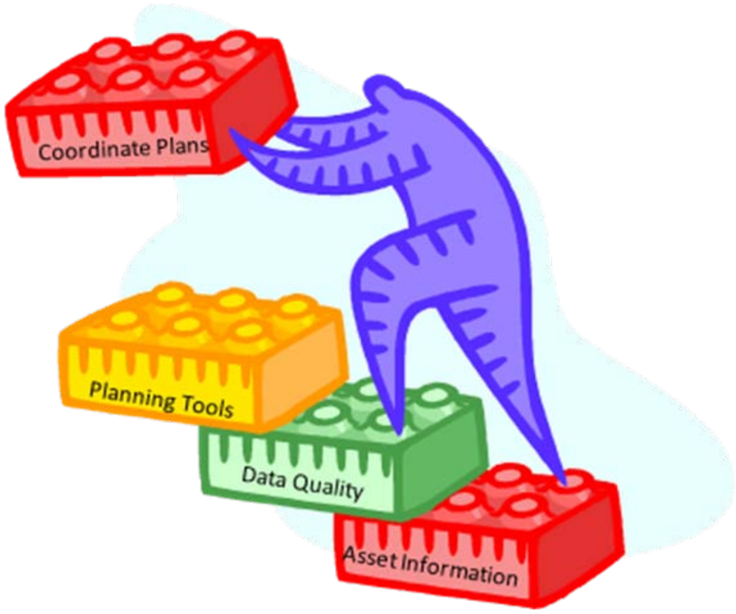

Figure 5: Building capacity to coordinate plans in steps

2.4.1 Asset information

The first step is to organise data in a digital data base, so that it can be processed and analysed (for example, a map as a .pdf or .gif is not sufficient as it is only a picture). All asset items (for example pipes) need to be registered with physical data such as diameter, material and installation year. Operational data should be stored and linked to the same data base. Operational data is necessary to monitor the performance of the network. It is of utmost importance that asset items have unique identifiers and that when information (for example concerning operation of the infrastructure) is stored in the data base, this identifier is used as a reference. There are many examples of asset data bases and operational data bases not being linked (for example a failure data base for water pipes, where the failures are not linked to the pipe ID). It is also important to keep the identifier when data from a data base is exported for use in a secondary data base. An example is when data from a pipe GIS is exported to a hydraulic model. Multiple asset IDs significantly reduces the value of data in terms of advanced asset management.

The power company *Trondheim Energi* has an example of a well functioning asset information system. The utility has historically invested a lot in documentation of their systems, and can benefit from this by reduced efforts for in situ detection. The information is available for others on request. The power company has some interesting principles which are used to keep the GIS updated with high quality data at all times:

- Almost all planning takes place directly in the GIS. This reduces the necessary amount of design and drawings.
- The GIS is updated once a week for system changes.
- A rehabilitated or new part of the system has to be documented in the GIS prior to being set in operation.
- Finding errors in the GIS is awarded.

A lot of infrastructure is fairly well documented with x and y coordinates, but the z coordinate information is generally poor. Also, information about the development of the system is poorly registered. So, at least for some infrastructure, there is also a need for a map based information system where it is possible to find information about infrastructure assets in 2D, 3D, or even 4D considering the time dimension.

2.4.2 Quality control of data

Input data for asset management has always some level of inaccuracy. This will negatively affect the results. Quality control is important to know the accuracy of the analysis, because garbage in, gives garbage out. This is an often overlooked topic in asset management.

2.4.3 Application of tools for long term planning

The use of comprehensive asset management tools is what Halfawy in [1] calls *vertical integration*, see Figure 2. The status for use of advanced tools for long term planning of different infrastructures in Norway are described in the Norwegian report "Status for Norwegian Infrastructure", part of the project "SIP – Future Rehabilitation Strategies for Physical Infrastructure", [105].

The results from the projects CARE-W and CARE-S (Computer aided rehabilitation of water and sewer networks) are examples of tools to plan rehabilitation at pipe level and at system level. At pipe level, rehabilitation candidates are ranked or given a priority based on a large number of criteria defined and weighed by the user. Section 3.1 has an overview of tools used in the water industry.

For road rehabilitation in Norway, there is a large difference between the local (municipal) and governmental (national) road authorities. The authority for the national roads has developed systems for monitoring and planning of different measures. An example is PMS, Pavement Management System, which analyses pavement inspection data from the NVDB (Norwegian Road Data Bank). The estimated year for rehabilitation actions for defined road sections is one of the results from the PMS model. On the other hand, municipalities put little effort in long term road rehabilitation planning for the local roads, so information about re-surfacing or other activities is generally not easily available.

2.4.4 Coordination of plans for different infrastructures

The ultimate step in proposed 4-step rehabilitation planning procedure is coordination of plans with other infrastructures. This is what Halfawy in [1] refers to as *horizontal integration (*see Figure 2).

This coordination topic will be discussed in more detail later in the report. Some important success requirements for data and tools are:

- Standards for sharing information are required, (for example web map service - .wms)
- Infrastructure management systems must communicate
- Common data bases or data bases that communicate seamlessly should be used, for example via web.
- Asset data (location, description, planned actions) must be available, ideally to all stakeholders and free of charge.

As mentioned in section 2.4.1, it is important that a particular asset has a unique identifier. But in order to coordinate rehabilitation plans, it is also necessary to know how a particular asset relates to other assets. There needs to be some sort of asset relation link. Figure 6 shows an example of software for rehabilitation planning developed at National Research Council (NRC), Canada. The sewer asset data sheet also contains information about other related assets, as indicated in the circles in Figure 6. Setting up the direct relation as an attribute to the sewer pipe between water pipe, road, and sewer pipe makes it easier to coordinate activities between the 3 asset types.

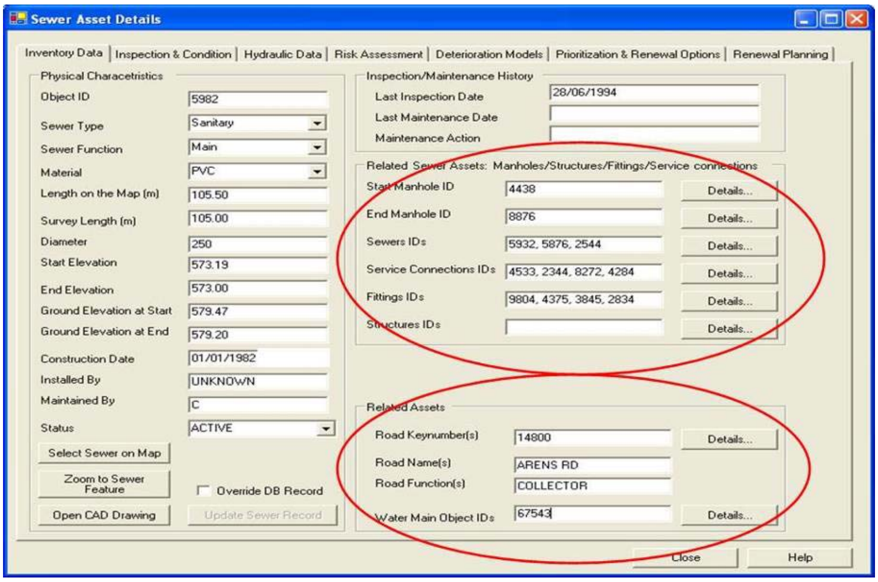

Figure 6: Sewer asset data and other related assets; road and water mains (Halfawy, 2008)

Another method to inter-relate assets is to use geographic reference, typically coordinates. From experience, such geographic reference has large uncertainty, but can on the other hand be applied on large scale with low resource, for example as a GIS overlay ("snap to proximity") routine. Such a routine can also be used to populate database information in the circled areas in Figure 6 to suggest related assets with a certain level of accuracy.

Data should be available in a standard format suitable for sharing. An example from Norway is the standard format *SOSI* for exchange of geodata. This standard format has been used for many years for export and import of data between different tools. Such export and import has some disadvantages. One main disadvantage is that a copy of data is made, and updates to the original data base after the export will not be updated in the copied data set. Another example of a well functioning international standard is WMS, Web Map Service [104], a standard for requesting geo-registered map images from one or more distributed geospatial databases and WFS, Web Feature Service, for specifying requests for retrieving geographic features. These standards enable sharing of georeferenced data.

Finally, data must be available to other stakeholders. Some infrastructure owners are very open with their data and are willing to share maps or digital data bases. For other infrastructures, data is very restricted and only available after approval of a written application or can be purchased for a fee. This has to do with policies, and how the sectors are organised in private businesses and public organisations.

3 TOOLS FOR COORDINATION OF INFRASTRUCTURE WORKS AT THE LONG TERM PLANNING LEVEL

This section will address some requirements for tools for coordination of rehabilitation activities at the long term planning level (and not so much for the shorter term, as explained in section 2.3). The main infrastructures where coordination is likely to be beneficial are:

- Road and road structures
- Water
- Wastewater
- Electricity
- Communication cables (ICT, phone, Internet)
- Gas, centralised heating and vacuum garbage piping, where such systems exist.

3.1 Existing infrastructure rehabilitation planning tools

The purpose of this report is not to give an extensive overview of planning tools for infrastructure. More detailed overviews can be found in [8] (water and wastewater) and [7] (water, wastewater, road, rail and tunnel). It appears that the water and wastewater industry has been forefront in developing different types of asset management and planning tools. Examples of tools include:

- CARE-W, Computer Aided Rehabilitation of Water networks, an integrated suite of tools supporting municipal engineers to establish and maintain a cost-efficient system of maintenance, repair and rehabilitation of their water supply networks (http://www.sintef.no/Projectweb/CARE-W/).
- CARE-S, Computer Aided Rehabilitation of Sewer networks, a decision support system for a cost-efficient system of maintenance, repair and rehabilitation of sewer and storm water networks (http://www.sintef.no/Projectweb/CARE-S/).
- SEAMS, a commercial software developed to support Asset Investment Planning to water, energy and utilities companies to achieve long-term, sustainable business performance (http://www.seamsltd.com/).
- PARMS (CSIRO, Australia), Pipeline Asset and Risk Management System, is a suite of computer-based models exclusively offered by CSIRO Urban Water and designed to assist in the management of water supply network assets (http://www.csiro.au/solutions/PARMSPlanning.html).
- D-Warp (NRC-IRC, Canada), a software program developed to assist water utilities in the planning and management of distribution water mains (http://irc.nrc-cnrc.gc.ca/ui/software/dwarp/index_e.html).
- Hydroplan, supports sustainable water management programmes, including monitoring, maintenance, prioritise renovation and investment.
- TILDE – Tool For Integrated Leakage Detection (www.waterportal.com).
- Casses (Cemagref, France), is a tool for statistical analysis and prediction of water main failures.

There exist in the commercial market or as freeware a large number of models for different hydraulic and hydrologic processes, such as Bentley software, DHI software, EPANET, SWMM, H2ONET, and others.

Similar software exists for different purposes for other types of infrastructure, for example PMS, Pavement Management System, and RoSy, both for road management.

3.2 Existing tools for communication and coordination of plans

In daily life, we use different means of communication to coordinate our activities, such as direct communication via speech, phone, internet, etc. In most cases, the coordinator does not reflect over the fact that a coordination method is used.

It is generally more apparent that a coordination tool is being used in professional life. In a study by Hafskjold and Bertelsen (2008) [103], a number of meeting or phone interviews were conducted with infrastructure owners and other stakeholders. The objectives were to answer some questions about a rehabilitation project in Trondheim, Norway. One of the questions was which tools the interview objects use for coordination of plans between the different stakeholders. The majority replied that they didn't use any tools. However, through the interview it became clear that a number of the coordination tools listed below were, in fact, used.

It is important to understand the tools being used for coordination of plans, and their limitations and advantages. Examples of tools currently used for exchange of information and plans are:

- Meetings
- Other means of direct communication
- Economic tools, such as budgets
- Schedules
- Area plans and maps
- Master plans, rehabilitation plans
- GIS, and data bases
- Internet
- Building Information Management, BIM
- Dedicated personnel dealing with communication
- Communication tools for internal use in an organisation
- Tools for communication to the public, such as advertisements, signs, information boards, dedicated web sites

Planned or ad-hoc meetings seem to be the main method for coordination of plans. It is excellent for direct communication and interactivity, but has some shortcomings. It is very difficult for persons not present to know what happened during the meeting, unless very detailed minutes are taken or the meeting is recorded (sound or camera). Therefore the success of a meeting depends on the right people being present.

The "excavation club" in Bergen, Norway, is an initiative to coordinate excavation activities between municipal interest and the power company. They use frequent coordination meetings to inform each other about planned activities, and information to the public on web sites, in meetings, and in the media. In addition, a map of planned activities in the city centre is posted on the web site of the municipality, and there is an 'excavation calendar' which is updated regularly. An example of the map is shown in Figure 7.

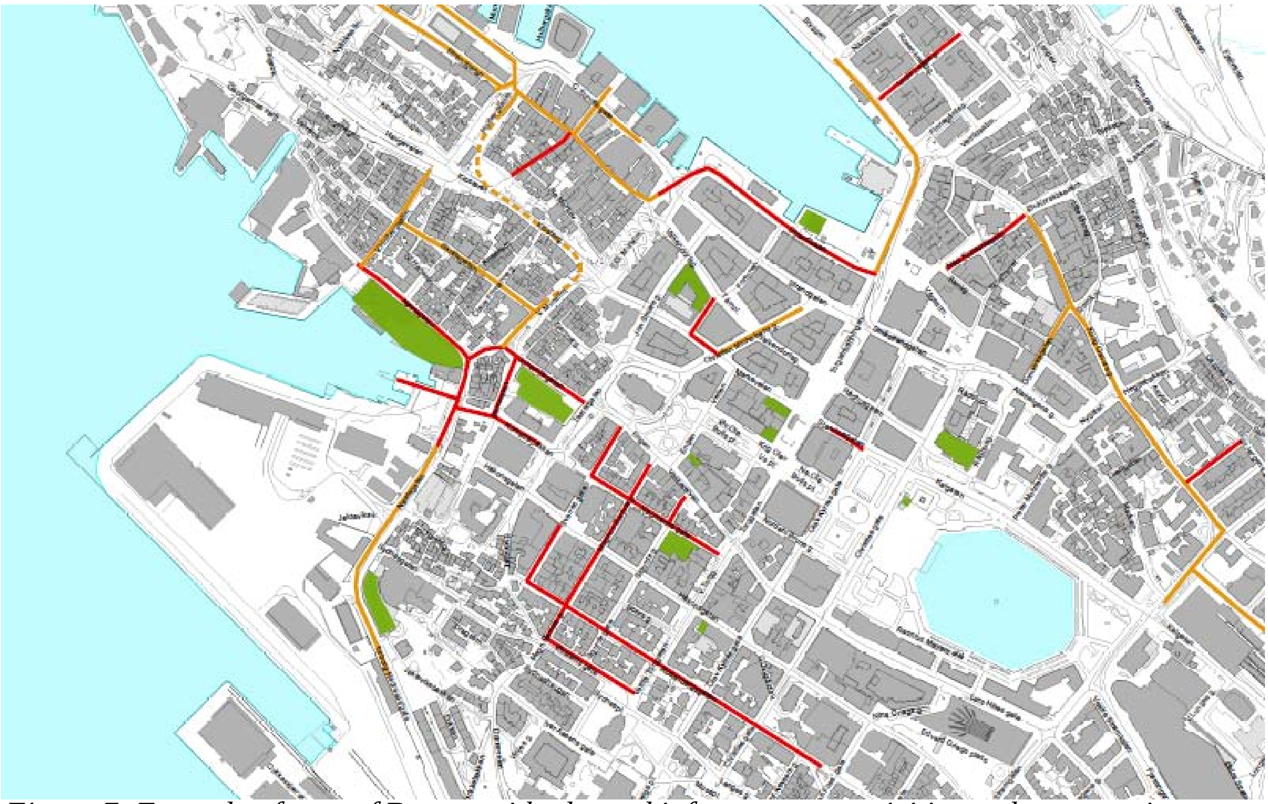

Figure 7: Example of map of Bergen with planned infrastructure activities and construction projects for 2009-2010

Other more or less direct communication methods include conversations by phone, by IRC/Internet, and via e-mail. E-mail is easy to misunderstand, but the information is well documented and can be re-read, and sent to other people who request it. Phone conversation is good for clearing up misunderstandings quickly, but poorly documented for future use and those who didn’t participate in the conversation.

Plans printed on paper (drawings, designs, and text), have always been the “engineer’s best friend” and is a very efficient tool for communication of plans. These plans have an array of different applications, from long term planning to the construction phase and as-built documentation.

Software tools have made it possible to consider many new aspects in planning, also coordination of plans. GIS makes it possible to overlay different infrastructure plans together with other information, and analyze in a comprehensive way. A lot of data and metadata is available and can be processed by statistical or deterministic models. Geographic data is more and more available via web, with the use of standards such as WMS, Web Map Service. Recent developments in construction include tools for BIM, Building Information Management, where the object is described as a detailed 3D model, rather than in designs. This opens for new applications, and more effective coordination of the detailed plans. An interesting aspect of the use of BIM in Norway is that the contractors have taken a lead in application of such tools. This is an indication of such tools being effective, since the contractors are traditionally not in front of development of computer tools and models, unless they prove to be effective.

Another example of software that simplifies construction is use of “web hotels”, where files are stored in a library system that handles status version control, updates, user accessibility levels, and other functionality. In brief, the user can access an at all times updated document, a design drawing, minutes from a meeting or other relevant information via a web user interface.

A prototype GIS tool has been developed and used by the Norwegian consultant company Asplan Viak for integration of georeferenced objects with a calendar describing the status of the objects over time. An object may be a *geographic area* (polygon), a *building*, a *road* or any other physical object. The status for the object may be *under construction*, *demolished*, *finalised*, or other properties. This tool has been used in complicated construction projects, where it has been necessary to integrate various processes going on simultaneously and where the processes may depend on each other. By querying a date, the status for the objects is visualised on a map. The tool is used for various project management purposes.

3.3 Best management

The National Research Council of Canada, NRC, have compiled a best practice for coordinating infrastructure works in the report "Coordinating Infrastructure Works" [110], as part of the *Infraguide* initiative [112].

3.3.1 Case study – the City of London

The City of London is situated in Ontario, Canada with a population of over 300000 inhabitants. Their experiences using "Coordinating Infrastructure Works" [4] are summarised in a report [111]. They were generally very positive to the best practice guide and implemented many of the options which were not already implemented in The City's practices. Modifications were also made to the existing practices.

Formal committees existed in the past, and were acknowledged as an effective method contributing to infrastructure coordination. Both internal and external committees are organised:

- The City of London's External Utility Coordinating Committee rotates the chair function each year to better involve utilities.
- The City of London's Internal Utility Coordinating Committee (transportation, construction administration, wastewater, drinking water) makes five-year plans for infrastructure projects.

In addition to formal committees, The City of London uses the following methods for improved coordination and increased effectiveness of infrastructure projects:

- Multi-year plans for infrastructure projects (2 to 5 years).
- Strengthened co-ordination with developers.
- Corridor upgrades (where all infrastructure in a corridor – i.e. a road – is upgraded at the same time) as a standard practice administrated by a selected division.
- Permit requirements.
- Restrictive practices, such as pavement degradation fees (explained in section 4.2).
- Technical considerations, including management systems, GIS and CCTV.
- Broad communication by web, in addition to letters and notices in the newspapers.
- Increased use of Trenchless Technologies.
- Dedicated funding to avoid service area budget cuts.
- Inclusion of social and environmental cost by implementing road lane rental charges is a practice being considered at the time when the report was issued.

In general, the experiences using "Coordinating Infrastructure Works" [4] are largely positive.

3.3.2 Case Study – the Municipality of Trelleborg

The University of Lund, Sweden, has for several years worked on coordination of work and processes in public utilities through the programme "Public Management" (*Teknikprogrammet* in Swedish, [107]). The focus has been on coordination at an organizational or managerial level, and how management can improve horizontal coordination of a public organisation.

During a 15 year period starting around 1990, the Municipality of Trelleborg reorganised from unstructured to structured coordination of the different units of the organisation. The 4 main lessons learnt in their efforts of improving efficiency and to meet the challenges of a world undergoing rapid changes were [108]:

1. Define the horizontal coordination as a strategic goal.
2. Be visible and clear in order to break down old traditions and structures.
3. Parts of decision making should be centralised and other parts decentralised, and the split should be determined with focus on coordination.
4. The over-all efficiency of the organisation is one of the main objectives and should be monitored, since reorganising towards horizontal coordination requires more administrative efforts due to new units, processes etc.

3.3.3 Case Study – Nonnegata in the Municipality of Trondheim

A Norwegian case study [6] by Hafskjold and Bertelsen followed a corridor rehabilitation project, where a highly trafficked road was completely renovated with new pipes, some electrical cables and surface installations. Some suggestions for improvements were identified in the study, based on possible areas of improvement:

- Provision of updated information on subsurface installations. Some unknown installations caused delay that required rescheduling of a tight project plan.
- Better systems for coordinated management of subsurface installations. Some of the partners changed their view on participation during the project, and some wanted to be included at a late stage.
- Procedures securing acceptable conditions for road-users and residents when rehabilitation works are to be carried out. A broad range of users of the road, ranging from large trucks to school children, require different types of attention during the construction work.

Figure 8: From the Nonnegata case study area. Left: June 30th, 2008, Right: September 16th, 2008

4 IDEAS FOR IMPROVED TOOLS FOR COORDINATION OF INFRASTRUCTURE REHABILITATION

This chapter discusses some ideas for improved infrastructure coordination. Some are briefly discussed and should be considered as ideas for future follow up.

Some relevant challenges have been highlighted by the reference group for this project:

- There are few incitements for taking third party viewpoints or disadvantages into account for a project. Cost for third party is rarely included in project budgets or cost.
- It is unlikely that a system for mutual information of planning projects will function unless stakeholders are obliged to report into the system (a voluntary system is not sufficient).
- Budgets are not coordinated; therefore it is also difficult to coordinate activities. Perhaps some budgets could be allocated for coordinated activities?
- Projects with public/private cooperation (OPS) have shown a great potential. This type of project is mainly suited for large construction projects, such as a new main road.
- For rehabilitation type projects, an efficient model could be where a large party (public or private) is in charge, and other and smaller parties can join when it is beneficial. In practice, this is the case for many pipe rehabilitation projects in Norway, where the large party is the municipal water and wastewater utility, and minor parties typically are cable companies.
- It’s necessary to distinguish between cooperation concerning planning and coordination concerning excavation.

Based on these comments, some ideas are proposed in the following.

4.1 Criteria for assessment of co-infra rehabilitation

There is a need for criteria to determine when and how to coordinate infrastructure projects and a methodology to compare and select the best. An example of such a methodology might be the Electre Tri method, which enables comparison of different criteria without a common unit (e.g. such as money). The Electre Tri method uses performance profiles where different objects are valued for a number of criteria. The performance profiles (rather than a total score) for objects are compared, and the object with the most suitable profile is ranked as the one that best meets the required criteria. This method is used in CARE-W, where pipes are compared based on a number of criteria such as hydraulics, likelihood of failure, consequences of failure, water quality issues, possibility to coordinate with other projects, etc. The pipe with the least favourable profile is ranked as the best candidate for rehabilitation.

Criteria should consider cost to the society, including third party consequences. Such disadvantages may be loss of trade, noise, and disruptions. A reasonable principle seems to be that the society, e.g. represented by the municipality, should bear the disruption cost. Such cost born by the municipality could partly be financed by fees, such as pavement degradation fees.

The potential of Lice Cycle Analysis (LCA) or Life Cycle Costing (LCC) should be explored. LCA is a tool for sustainability analysis, and there exist standardized methods for sustainability analysis which include:

- Environmental aspects
- Social aspects
- Economic aspects

4.2 Penalty systems or permit requirements

Many cities have developed penalty systems of different kinds. As described in the City of London Case Study in section 3.3.1, the City introduced Pavement degradation fees, PDFs. The purpose is to encourage fewer unnecessary excavations.

A few cities in Norway practice lane or sidewalk rental fees. Someone who uses space dedicated to parking must pay the parking fee for the entire time. This is a current matter of debate in Norway.

4.3 Portal for planned infrastructure activities

Some portals exist, such as the “excavation club” in Bergen, Norway, described in section 3.2 of this report. The portal gives an overview of some planned and ongoing projects. It is useful for many different stakeholders. However, efficient coordination requires long term plans (ideally 3-5 years), as described in section 2.3.1. The Bergen portal is therefore a great leap forward, but not sufficient for long term planning. This is mainly due to the fact that long term plans only exist in very limited form, and not so much because of the portal itself.

Other similar portals are being developed both commercially and by municipalities in Norway.

4.4 3D (or 4D) planning of infrastructure rehabilitation

Enhanced 3D planning is being developed rapidly, with tools such as Building Information Management, or BIM (www.buildingsmartalliance.org). Since tools for modelling of construction in 3D already exist, there may be a possibility for development for use in other areas, such as infrastructure.

An article in the Norwegian popular journal *Teknisk Ukeblad,* January 2009 [113], describes how an important aspect of BIM is related to challenges for this technology to work in the existing communication lines and systems. A software tool is not sufficient unless it functions within existing frames of cooperation and work methodologies. Possibly new ways of collaboration must be developed, something that takes time and resources in addition to the software itself. These challenges have been the subject of Anita Moum’s PhD “Exploring relations between the architectural design process and ICT – learning from Practitioners’ Stories” [114].

4.5 A Master Plan for Underground Infrastructure

Some cities (such as Singapore and Helsinki) are currently working on Master Plans for use of the underground. In the case of Singapore the need for such a plan was initiated by lack of sufficient surface areas.

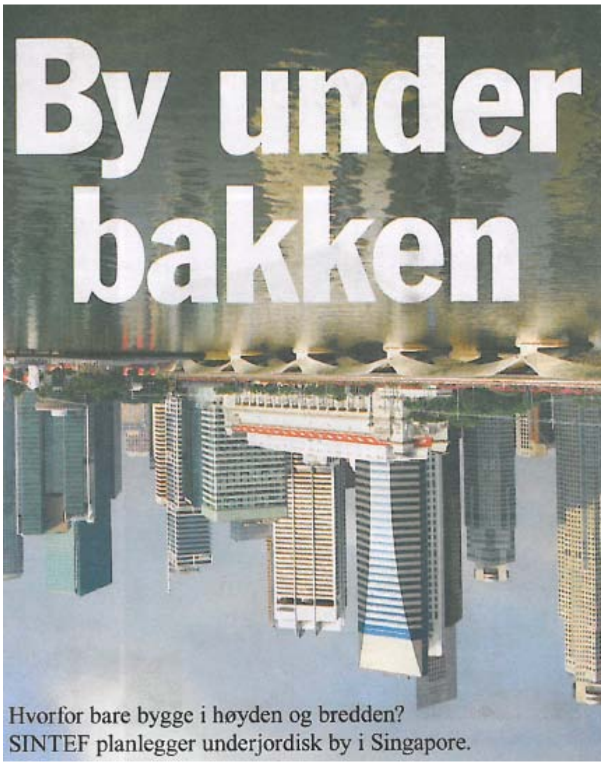

Figure 9: A city under ground. Why build upwards only? SINTEF is planning subsurface city in Singapore. Facsimile from DNBNor real estate journal, Jan 20th, 2009.

But many cities without lack of space could also benefit from planning the underground installations. This would also be very useful to define and coordinate activities among the different infrastructures in the underground. Such a master plan could cover topics such as:

- An overview of different 'underground stakeholders'
- Current rehabilitation plans, short term and long term
- Other construction plans, short term and long term
- Relevant legislation, standards, norms, and other construction practices
- Common understanding of "rules for use of underground" and corrective measures for failure to follow rules
- Tools for coordination of plans
- Definition of co-infra activities, potential areas for cooperation

5 CONCLUSIONS

An increasing level of complexity in our infrastructure requires more efforts in coordination. The main conclusions drawn from the work with this report are:

- Before effective communication can take place, good plans must exist. And before good plans can be made, it is necessary to have accurate information about infrastructure.
- Coordination must take place at different levels: management, common systems, and sharing of data. Out of these three, management is probably the most important success factor.
- Coordination of both long term plans and project execution are important. Two important challenges are that infrastructure owners make plans for very different time horizons, and that systems to communicate information about project execution only exist to a limited extent.
- Lack of budgets or different budget periods may represent an obstacle to coordination, as well as different commercial interests.
- Information about infrastructure and plans for development are for some sectors considered business secrets, and therefore restricted.
- The public sector, i.e. the municipalities, must take a responsibility for successful coordination of infrastructure projects, because it is in general the public who benefit from it.

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