JOINT EFFORT ON ESTABLISHMENT OF ARKTRANS – A SYSTEM FRAMEWORK ARCHITECTURE FOR MULTIMODAL TRANSPORT*

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SUMMARY

Several stakeholders have participated in the development of the Norwegian system framework architecture for the transport domain, ARKTRANS, including the authorities for sea, rail, road and air transport. This paper aim to share out experiences from a working process point of view, by describing the motivation behind the joint effort, the work done during the project's first one and a half years, organisation of the work, challenges, and also conclusions from the work. User involvement and formal techniques from the software engineering domain are focused.

INTRODUCTION

ARKTRANS is the Norwegian system framework architecture for the transport domain. The Norwegian Ministry of Transport and Communications took the initiative to the establishment of ARKTRANS together with the Norwegian transport authorities for sea, road, rail and air. The work on the architecture is partly financed by the Research Council of Norway. In 2001 a pilot study was conducted, and the project started in January 2002.

This paper aims to describe the starting point for the ARKTRANS project, the working methods in the project, the experiences drawn so far, and also the future activities in the project. The development of a system framework architecture has lot in common with development of software architectures. Thus, the work with ARKTRANS has been planned and carried out with software engineering methods in mind.

MOTIVATION BEHIND THE ARKTRANS PROJECT

The current traffic situation is dominated by severe problems mainly related to road transport, like congestions, a high number of casualties, and air pollution. Increased use of other transport modes, preferably rail and sea, will improve the situation (5)(18).

A restored balance between the transport modes in favour of sea and rail transport, will presuppose a more extensive use of multimodal transport chains. Multimodal transport chains involve several stakeholders, and the establishment and management of such chains usually require a considerable amount of coordination and information exchange. Coordination and information exchange, as well as deviation and incident detection, can be automated or supported by means of Intelligent Transport Systems, ITS. Delays in one part of a chain may for example be detected and reported in time to enable corrective actions in the remaining chain. Openness and interoperability between ITS solutions are prerequisites. A system framework architecture for the transport domain will arrange for such solutions. The framework architecture may also benefit the transport business in general by promoting safety (19)(22), by increasing the efficiency of the management of the transport services, and it may also arrange for new and improved services.

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CHALLENGES IN THE ARKTRANS PROJECT

From a software engineering point of view, the work has been challenging for many reasons:

1. Comprehensiveness: The transport domain is very wide and encompasses a large number of stakeholders with quite different roles, interests and objectives. The stakeholders also represent different transport modes. Thus, the architecture has to capture a large number of user needs.
2. Harmonisation: ARKTRANS is harmonised across transport modes as well as across personnel transport and freight transport. Even though the similarities are most conspicuous, ARKTRANS has to cope with differences with respect to terminologies and working procedures.
3. User involvement: The need for ARKTRANS has to be communicated to many stakeholders in an intelligible way, and the stakeholders must be able to influence on the results. Preferably, stakeholders should feel ownership to the results.
4. Sufficient level of details: ARKTRANS is not a system architecture for a specific system, but a system framework architecture for a domain. Thus, details about the inner parts of systems are not of interest. Focus is on interoperability.
5. Conceptual model: Despite of the focus on interoperability, technical specifications of interfaces are not enough. A common understanding of the transport domain with respect to roles, overall functionality, information, organisation and relations are also prerequisites. Such grounding will give a context on which the interoperability can arrange for new and improved services.

SOFTWARE ENGINEERING METHODOLOGIES

A system framework architecture is a specification of ICT solutions for a set of systems belonging to a product family, or to a domain, as for ARKTRANS ITS solutions and the transport domain. The framework will define aspects like functionality, behaviour, information, interfaces, and technical solutions in such a way that aims like interoperability are achieved. It should be easy to interact with systems that are developed according to the system framework architecture.

Methods for establishment of a software architecture descriptions are applicable for the development of a system framework architecture description. Thus, the ARKTRANS architecture description is established according to such methods. Several software engineering methods and guidelines are available. A common line can be drawn from the older waterfall methods and to more up to date methods: needs are analysed; systems are design; and systems are implemented. However, the new methods are more iterative, and activities are performed in parallel. Most of guidelines state that different aspects of the system must be specified.

The establishment of a system architecture description is a vital part of the most common system development processes and methodologies. According to IEEE 1471-2000 on the Recommended Practice for Architecture Description of Software Intensive Systems (7), the term architecture in this context is “the fundamental organisation of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution”. The architecture description is “a collection of products to document an architecture”. The IEEE standard prescribes the least common multiple on what should be included in a complete architectural description. Concepts such as viewpoints, views and stakeholders are defined.

Parallels can be drawn from the ISO RM-ODP framework (8) and from the Converge guidelines for transport system architectures (13) to the concepts of IEEE 1471-2000. RM-ODP identifies a wide set of viewpoints, while Converge operates with a more limited number of what they call architectures. Converge is used in a number of transport projects. Both RM-ODP and Converge give guidelines with respect to the specification process, but the specification techniques are not focused. Converge is not up to date with respect to an object oriented system specification approach.

The Rational Unified Process, RUP, is built to be architecture-centric and fits into an object oriented approach (11). In RUP, the architecture is mainly developed in the elaboration phase, which is an early phase in the development. The development of the architecture goes close with the development of use cases, and the development of both influence on the development of the other. The different phases of RUP are organised partly in parallel. This organisation of the development arranges for an iterative development.

Both RM-ODP and Converge are relevant to ARKTRANS and are used as a basis for the selection of relevant viewpoints. The concepts of IEEE 1471-2000 are adopted in the ARKTRANS architecture description, as they are likely to be those in lead in the future. RUP has influenced the work process. In contrast to a system architectures for a specific ITS, a system framework architecture like

ARKTRANS will not contain many details with respect to the software architecture (software components, use of design patterns, etc. (6)). Such software architectures may of course be developed based on ARKTRANS to provide standardised components, however, for ARKTRANS itself this is not required.

THE PILOT STUDY

As described in (1), there has been a national R&D program on Intelligent Transport Systems, ITS, within Norway, a program financed by the Norwegian Government and managed by the Research Council of Norway. The philosophy of this ITS program, with respect to why it has been initialised and how it is carried out, has been integration, interaction, multimodality and internationalisation. The work and coordination of this R&D program lead to ARKTRANS.

The pilot study did run during 2001. The main deliveries from the pilot study were a set with preliminary roles related to the area of transport, a reference model draft dividing the transport domain into five sub-domains, functional decomposition drafts for each of the sub-domains, and a set with scenarios illustrating possible use of, and advantages from solutions based on, an architecture framework like ARKTRANS.

Two of the main inputs to the work were the defined set of user needs and functional areas from the European project KAREN (2)(3), and also the work on the US National Architecture for ITS conducted by the US Department of Transportation (21). The work in ISO (9)(10) also served as input to the pilot study. The main differences made in relation to the international work were that ARKTRANS focuses on multimodality and aims to harmonise freight and passenger transport.

The results from the pilot study (16) stated that there is a need for a multimodal system architecture, and this need was the basis for the ARKTRANS project. The pilot study also showed that the proposed approach to the work was rational.

THE ORGANISATION OF THE ARKTRANS PROJECT

The establishment of ARKTRANS is a joint effort by Norwegian transport authorities: the Public Road Administration, the Norwegian State Railways, the National Rail Administration, Avinor (the Norwegian Civil Aviation Administration), and the Norwegian Costal Administration; and also representatives for transport users and providers of transport services. The project is formally organised with a steering committee and a reference group. SINTEF holds the project management.

The steering committee is an important instrument when it comes to anchoring of ARKTRANS at high level in the transport authorities and also in the Ministry of Transport and Communications. The members of the steering committee also have contacts and influence that may benefit ARKTRANS in the future.

The ARKRANS reference group, composed of a wide spectre of stakeholders within the transport domain, is kept up to date about both the work progress and the deliveries from ARKTRANS. This is mainly done by means of seminars, newsletters, and a Web site.

Much of the work has been conducted in several, task-oriented work groups. Work group members are identified and invited with help from the network of the reference group. The participants are stakeholders possessing relevant roles, and they represent all transport modes. Thus, the work groups are able to harmonise across transport modes. The work group structure is dynamic. Work groups are established, merged, and split according to plans, but also according to needs that arise during the work.

During the first year of the project, four work groups with 7-12 participants addressed issues defined by four sub-domains of the ARKTRANS reference model. The work group addressing the fifth sub-domain, the Terminal Management, did not start up until the beginning of the second year, but is now about to catch up with the work on the other sub-domains. In the beginning, the work went on without any need for coordination between the work groups. However, at the end of the first year, the overall parts of each sub-domain were to some extent explored, and the four work groups were merged into one larger group to arrange for better coordination. The work on the identification of the required interactions between the sub-domains started by means of scenario techniques.

During the first half of the second year of the project, a large number of overall interactions between the ARKTRANS sub-domains were identified, and it was time to go further into some of the details.

New work groups are established: one dealing with multimodal route information; one dealing with management of multimodal transport chains; and one dealing with traffic control. In additional, a work group is focusing on technology and generic solution like the use of business transactions frameworks.

The work groups have meetings every second or third months. Mostly, the meetings take place as workshops. Researchers from SINTEF manage the groups and collect and harmonise the inputs and the work done. The researchers also have contact with national and international projects working with different approaches to the area covered by ARKTRANS.

ARKTRANS has a loose coupling towards a set of demonstrators. Loose in the sense that the demonstrators are independent projects or activities that are planned and will go on in any case, independent of ARKTRANS. However, the demonstrators address issues that are of interest to ARKTRANS. They may provide information to case studies that may clarify issues of importance to ARKTRANS, and they may realise solutions or implement interactions that provide input to the specification of the architecture. As the work goes on, we also hope that some of the demonstrators may test solutions specified in ARKTRANS and provide feedback about the applicability. We foresee some conflicts with respect to the interests of ARKTRANS and the demonstrators. ARKTRANS focuses on generic, long-term solutions for the whole transport domain, while the demonstrators go for specific solutions on specific problems that have to find their solutions as soon as possible. However, so far we have met very a positive attitude. The collaboration is voluntary, and it seems as if many of the demonstrators are able to see that collaboration may benefit both sides.

THE ARCHITECTURE FRAMEWORK ESTABLISHMENT PROCESS

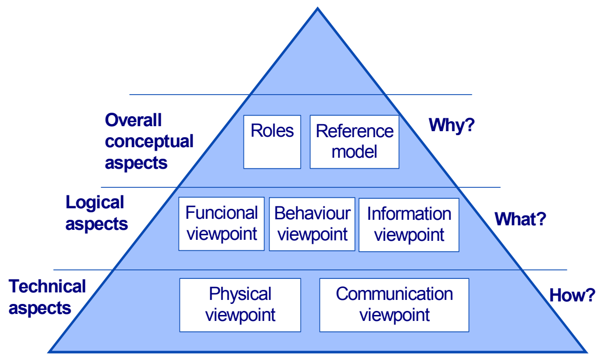

Figure 1 ARKTRANS Content

The work process has been iterative, and the system framework architecture description has been continuous worked on with stakeholders in work groups. At first we started the work on the conceptual aspects, the reference model and the roles. Second, we concentrated on the logical aspects; working with on the functional view, behaviour view, and parts of the information view. During the process, the work with each view has provided input to the refinement of other views as well as overall concepts.

WORKING WITH THE CONCEPTUAL ASPECTS

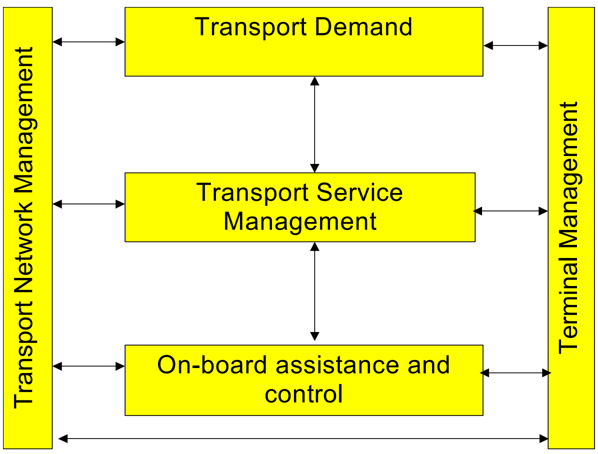

Figure 2 ARKTRANS Reference Model

The overall conceptual aspects are documented by means of a reference model and a set of roles. The reference model and the roles have been refined in parallel.

The reference model was initially created by the researchers based on studies of the transport domain and ideas about a suitable organisation. One aim was to create a simple model that transport stakeholders can have in mind. The organisation was to be related to the stakeholders' interests in the transport of freight and passengers. A stakeholder with a specific role should preferably have to relate to one sub-domain of the reference model. Another aim was to harmonise freight and passenger transport. The reference model divides the transport domain into five sub-domains. Each sub-domain relates to a set of roles and provides functionality to these roles. The sub-domains are also defined by means of their internal objectives (what is to be achieved) and their responsibilities towards the outside world (what is to be provided to the other sub-domains). The reference model also visualises the overall need for interoperability.

The reference model has been presented to a wide spectre of stakeholders in the reference group and in the work groups. They verified the organisation into sub-domains, and also the relations between the sub-domains. In most cases, the stakeholders easily could localise themselves and their activities according to the reference model.

A set of roles is defined. There were two main challenges working with the roles:

- To support multimodality, multimodal roles were needed. However, the representatives for each transport mode need to be able to identify and match their own modal roles to the multimodal roles. A captain operates an aircraft, a shipmaster operates a ship, a driver drives a car and an engine driver runs a train. What to name the multimodal role for these terms?
- Most people see themselves as *one* person having *one* role in their daily work. However, one stakeholder may possess more than one of the generic roles specified in the architecture. At times it has been a challenge to discuss and verify the roles hold by a person, especially when the roles belong to different sub-domains in the reference model.

The multimodal roles were mapped to terms used within each transport mode. In that way stakeholders can recognise themselves even though the multimodal role terminology may not match the terminology they are familiar with. Both the multimodale roles, as well as the modal terms, were commented upon and completed by the stakeholders. This was done both in work groups, but also in meetings with separate stakeholders.

The use of multimodal roles simplifies the specification of an architecture framework. By means of these roles, a system framework architecture that encompasses all transport modes and freight as well as personnel transports and can be specified in a more generic way.

WORKING WITH THE LOGICAL ASPECTS

One of the main decisions to be taken was whether an object-oriented or a structural breakdown approach should be taken in the development of ARKTRANS. Due to the comprehensiveness of the transport domain, we decided to use both. With respect to the functionality, each sub-domain of the reference model was specified further by a functional decomposition. Behaviour issues (e.g. the interactions between the sub-domains of the reference model) and information models are however specified by means of object-oriented methodology.

The result of the functional decomposition is a functional hierarchy providing a structure and a terminology for multimodal functionality. The functions were documented at heading level by use of mind maps. The use of mind maps made it easy to establish a hierarchical structure and to change the structure and make new groups of functions. This work was done in the work groups. The functionality was also specified in prose that reflected decisions taken by the work groups.

As the functional decomposition in the functional view was decided upon, we used object-oriented system specification methods to specify information, interactions and dependencies.

We applied use case techniques as specified by Cockburn (4) to capture user requirements and to specify possible use of functionality. The scenarios in the use cases are at a high level, as the framework architecture does not deal with the detailed functionality in specific systems. In the behaviour view, the overall information flows are so far denoted in UML swim lane diagrams (20) and described in prose.

The information view specifies the required information. Conceptual information models are denoted. These are crucial with respect to the definition of the syntax as well as the semantics of information (classes, attributes, relations, formats, etc.). The models specify common sets of information elements that are used when interfaces and information exchange are defined.

The information view is to a large extent based on TRIM (14). TRIM is a kind of a domain model for freight transport, and has evolved for some years on basis of knowledge achieved during work in several freight transport projects. Thus, a lot of experience and knowledge is captured into the model. However, the nature of the establishment has lead to structures that may not be optimal. Thus, the most ideal for ARKTRANS would be to disregard TRIM and to develop an information model based on knowledge from TRIM and the work done in ARKTRANS. However, TRIM is used as the basis for information models for several systems and has proofed its relevance. Thus, the decision so far has been to use TRIM and to develop it further in collaboration with work groups and demonstrators. During the first year of ARKTRANS, TRIM has been documented by means of UML class diagrams (20), and the structure has been improved in collaboration with demonstrators. The details in the model are so far not discussed in ARKTRANS work groups. However, TRIM is established based on requirements captured from other stakeholders within the transport domain.

WORKING WITH THE TECHNICAL AND GENERIC ASPECTS

A work group dealing with technical and generic issues, that are of common interests to many ITS solutions, was established by the end of the first year of the project. In the beginning, the work group concentrated on general discussions to map the current status of different technologies. The group will address generic solutions to logical and technical problems that will benefit a wide spectre of ITS solutions. Issues such as wireless communication and business transactions for the transport domain have so far been addressed. The technical aspects are to be documented by means of a physical and a communication view. Generic business transactions are however a part of the behaviour view.

STAKEHOLDER’S INVOLVEMENT

The ARKTRANS project has to a large extent succeeded in anchoring of the work in the transport society. We have achieved involvement, and a large number of stakeholders have recognised the benefits by participating, and they have provided inputs and comments. User involvement has mainly been arranged by means of the reference group, work groups and collaborations with demonstrators.

The use of work groups, concentrating the work according to the reference model, has encouraged the iterative way of working. Topics were discussed, the researchers did document the results, and the topics were brought back to the work group. Some topics were also covered in several workgroups, and the results from one group were discussed in other groups. This way of working has given an iterative development of ARKTRANS, which we look upon as a positive contribution to stakeholder’s involvement.

One of the main contributions to the stakeholder’s involvement has been the reference model. All functionality serving a specific role, e.g. the transport user, belongs to the same sub-domain of the reference model. The model has made it easy for the stakeholders to identify their position in the domain, and also to identify the positions of the other stakeholders. A stakeholder with a defined role can focus on one sub-domain, and will not have to study the others. It is our belief that such an organisation will benefit the work by simplifying user involvement and understanding. The assumption has also been confirmed by feedback from work groups and stakeholders.

A main intention when ARKTRANS was initiated was the use of demonstrators to prove selected parts of the architecture framework. So far, the demonstrators have mainly contributed by commenting on the conceptual and logical aspects. One important outcome has been a better insight into some of the problem areas covered by ARKTRANS, and also a closer relationship with other stakeholders. Some solutions are now about to be realised. Soon we will be able to prove some of the specifications by means of implementations. We have received positive feedback from the demonstrators.

DELIVERIES FROM ARKTRANS SO FAR

Documentation on roles, the reference model and also the views representing the logical aspects have been continuous worked out. Preliminary documents that show the current state of the architecture description have served as working documents within the project. At certain checkpoints more official, but preliminary versions are published. Version 2 of the preliminary ARKTRANS documentation is available (17). However, more updated working drafts are also distributed to those participating in the work groups and others on request. By the end of 2004, more formal working procedures for maintenance and further development have to be decided upon. Official versions of ARKTRANS updates must be provided according to predefined rules.

A presentation folder of ARKTRANS has been made, and an ARKTRANS newsletter (written in Norwegian) is sent to a large number of stakeholders twice a year. ARKTRANS has been presented on several national and international conferences and on meetings within the transport domain. We also have an ARKTRANS seminar every year.

The content of ARKTRANS is to be presented at the 10th World Congress on Intelligent Transport Systems and Services (15).

RELATED WORK

There are several system framework architectures for the transport domain. However, up till now most of the work has been related to road transport. The US National Architecture for ITS (21), and also the European parallel KAREN (2)(3)(12) focus on road transport. The ISO TICS architecture (9), (10) also presents superior parts of an architecture that mainly addresses road transport.

ARKTRANS is based on the work mentioned above. However, ARKTRANS is conspicuous in several ways: ARKTRANS harmonises across all transport modes as well as personnel and freight transport; ARKTRANS organises the functional view according to a reference model; a behaviour view describes interactions between ITS solutions; an information view defines common conceptual information models; and terminals (ports, freight terminals, passenger terminals, etc.) and the terminals' interactions with the other parts of the transport domain are also focused.

Converge(13), KAREN (2)(3)(12), and the US National ITS Architecture (21) use DFD (Data Flow Diagrams) to denote very comprehensive functional views. However, some of the functions may be realised as parts of the same ITS. The ARKTRANS policy is that information flows between such functions are internal matters to the ITS. They should not be dictated by ARKTRANS. It is of course impossible to predict all the possible physical organisations of functionality into ITS solutions. Hence, information flows may be internal to an ITS as well as external. However, so far we have focused on information flows between the sub-domains of the reference model. Our hypothesis is that much of the same information also may flow between sub-systems within each sub-domain. Demonstrators may give us some answers, and we have to consider this issue as the project goes on.

The ISO TICS architecture (9)(10) uses UML use case diagrams and UML sequence diagrams (20). In ARKTRANS we have used UML swim lanes (20) to illustrate the interactions better at an overall level. We will use sequence diagrams to specify the interactions further. Some of them may be quite complex business transactions, and sequence diagrams will together with state diagrams describe the solutions.

KAREN and the US National ITS Architecture do not specify common information models. They define the information flows one by one. For KAREN the specification of the information content of information flows is done by prose. Thus, the information flows are not standardised in such a way that they ensure interoperability between different ITS solutions. In ARKTRANS we plan to specify the information that is exchanged in details to ensure interoperability.

KAREN and the US National Architecture for ITS operate with functional areas. Thus, functionality supporting one type of operation is specified in the same part of the architecture, and stakeholders possessing a wide spectre of roles may use these functions. This approach may promote a better understanding of processes as all relevant functionality is grouped together. However, it may be quite difficult to focus on the complete set of functionality for one specific role, as this functionality may be dispersed across several functional areas. In ARKTRANS all functionality serving a specific role or a set of related roles, e.g. those of transport companies, are grouped together. Thus, a stakeholder with a defined role will not have to relate to functionality not relevant to him/her. However, links can be drawn between functionality within the functional areas of for example KAREN and functionality in the sub-domains of the reference model of ARKTRANS. The functional areas and the reference model represent different views on the transport domain. The detailed functionality may however to some extent be overlapping.

The ongoing deployment processes for both the US National ITS architecture as well as KAREN/FRAME, are well organised, and ARKTRANS have to consider similar processes to achieve deployment.

CONCLUSIONS AND FURTHER WORK

The conclusions presented in this paper is collected and discussed by the participants both of the reference group and the work groups.

THE MAIN CHALLENGES

ARKTRANS is to be multimodal. This forces the project to have focus on generic terms in all the work being done and documented. All the stakeholders though, are used to their own, modal terms. For some areas this did cause challenges. For roles and interactions we tried to map multimodal terms to modal terms. This caused positive feedback.

Some of the stakeholders have participated in more than one work group, and some issues also had to be discusses in several work groups, e.g. the reference model. After a while, we saw that some people did work with the same topics over and over again in several work groups. This led to a feeling of "bad rework". Common meetings for several work groups solved the problem. Thus, it is a challenge to compose the work groups, and to manage the group work plans and organisation in an optimal way. Several groups should have common meetings when feasible, and work groups should be split when more focus is a necessity.

The choice of language has been a topic for discussion. The report from the pilot study was written in Norwegian to simplify user involvement. ARKTRANS is dependent on international contacts. Thus, English documentation is a necessity. Stakeholders from some of the transport modes are quite familiar with English due to cooperation with international partners. This is the case for air and sea transport. The decision was to document the results in English. However, newsletters and presentation material are to be in Norwegian as well. We also have Norwegian terms on the sub-domains of the reference mode, the roles, the functions, and the interactions.

POSITIVE EXPERIENCES

The most positive aspect with the work so far, has been the work groups. The reference model has proved to be very efficient as a starting point for the work. The groups did meet quite often, and that contributed to an open and confident atmosphere, which again inspired the work. The meetings took place at the location of the different participants, which gave each a better insight in the other's work situation. The groups have changed a bit during the project due to changing topics and also due to changing approaches to the topics. These changes in the work groups have reflected the flexibility in the organisation of the project, and are looked upon as very positive for the project.

The use of formal methods and the appurtenant techniques have been a positive experience. This especially counts for the use of UML swim lanes diagrams to document interactions.

FURTHER WORK

In 2003 we will continue the work on the functional, behaviour and information views. The team of researchers will spend time with the participating stakeholders to collect information about ongoing projects and activities that might serve as input, or demonstrators, to ARKTRANS. Many stakeholders also take a large interest in the newly stared work group on multimodal route information. Obviously, there is a need for solutions that can improve and simplify the exchange of such information.

THE WORK PROCESS

The results and deliveries from ARKTRANS so far, have achieved much positive attention and feedback, both from the stakeholders and also from national and international interest groups. We interpret this attention and feedback as acknowledgement of the way the work has been organised and performed in ARKTRANS.

The conclusion is therefore that the work process in ARKTRANS so far has proved to be successful; however, we will continuously evaluate the way of working, and take necessary actions to ensure optimal progress.

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