OPTIMAR

Optimization in Maritime Transportation and Logistics

Researcher project 2005-2009

Project description

Norwegian University of Science and Technology

1. Background

The demand for maritime transport services is increasing consistently, and there are no signs that the world economy will rely less heavily on maritime transport in the future. There is an increased need for optimization-based decision support systems (DSS) to handle the complex ship routing and scheduling challenges that the shipping industry faces. Transportation routing and scheduling stand out as one of the major success stories of Operational Research. However, relatively little research has been done in ship routing and scheduling internationally. The research group at NTNU within ship routing and scheduling is today one of the most active and internationally renowned groups and need to increase their size and activity to remain and strengthen this position. This can be achieved through the project OPTIMAR – "Optimization in Maritime Transportation and Logistics".

1.1 The shipping activity worldwide

Maritime transportation is the major transportation mode of international trade. The world fleet has experienced continuous growth during the last few decades with a total capacity of more than 800 million deadweight tons in 2002 (UNCTAD, 2003). The fleet consists of more than 39 000 ships over 300 gross tons (ISL Bremen, 2001). The world's seaborne trade has experienced a similar increase to that of the world fleet capacity. In 2002, the world trade was nearly 6 000 million tons representing almost a 50 % increase compared with 1990 (UNCTAD, 2003).

The ocean shipping industry has a monopoly on transportation of large volumes between continents. This activity will probably increase in the future with the continuous growth in the world population, the rising standard of living, increased globalization resulting in international groups of companies collaborating and merging, greater product specialization, and, finally, the depletion of local resources. With an increase in these deep-sea activities we also need feeder systems for so-called short-sea shipping. Consequently, such regional shipping activity is expected to increase as well. In addition, we will probably see growth in the area of short-sea shipping due to heavy pressure on road networks and air corridors.

Seaborne activities are heavily dependent on the services that the world's fleet can offer. Usually, we distinguish between three general modes of operation in shipping: *industrial, tramp* and *liner*. In industrial shipping, the cargo owner or shipper also controls the ships. Industrial operators try to ship all their cargoes at minimal cost. Tramp ships follow the available cargoes, like a taxi. A tramp shipping company may have a certain amount of contract cargoes that it is committed to carry, and tries to maximize the profit from optional cargoes. Liners operate according to a published itinerary and schedule similar to a bus line. These three modes are not mutually exclusive. A ship may be easily transferred from one mode to another, and a shipping company may operate its fleet in different modes simultaneously.

1.2 The need for optimization-based decision support systems in the shipping industry

The fleet size of shipping companies may change over time, and the fleet may contain various types of ships, ships of different sizes, ships with different cost structures and with different other ship-specific characteristics. Although the fleet size and mix of shipping companies may differ considerably, they have one main objective in common, namely to utilize their fleets (fixed or variable) optimally.

It is clear from the above that there is a considerable need for, and potential benefits from, decision support systems (DSS) in ship scheduling. We want to point at some trends in ocean shipping that will probably influence both the need for optimization-based DSS for maritime applications, and the shipping industry's acceptance of and benefits from such systems.

Mergers, acquisitions and collaborations: During the last couple of decades we have witnessed consolidation in the manufacturing sector resulting in bigger actors on the demand side for maritime transport services. This has given the shippers increased market power compared to the shipping companies, resulting in squeezed profit margins for the shipping companies. In order to reduce this imbalance, there have been many mergers among shipping companies in the last decade. Many shipping companies have entered into pooling and collaboration efforts in order to increase their market power and gain flexibility in the services that can be offered. This trend results in larger controlled fleets and it becomes much harder to determine the fleet schedules. Therefore, the need for sophisticated optimization-based DSS has increased.

New generation of planners: Decision-makers and planners in the shipping industry are traditionally experienced, often with a sea-going background. As the fleets become larger, their ship routing and scheduling problems become much harder to handle. In recent years we have seen that shipping companies have started employing planners with less practical but more academic background. This new generation of planners is more used to computers and software, and therefore is often much more open to new ideas such as using advanced optimization-based DSS for applications in maritime transportation.

Developments in software and hardware: The fast technological development in computers and communications also weighs heavily for the introduction of advanced optimization-based DSS in shipping companies as in other business areas. Many earlier attempts failed due to restricted computer power, making it hard to model all the important problem characteristics and to facilitate a good user interface. However, today's computers enable an intuitive user interface to be implemented, something that is crucial for acceptance by the planners. In addition, there have been significant algorithmic developments. This, together with advances in computing power, gives the possibility to find good solutions to hard problems in a reasonable amount of time.

Shift from industrial to tramp shipping: Christiansen, Fagerholt and Ronen (2004) observed in a survey that most research contributions are in industrial shipping, while only a few are in the tramp market. Industrial shipping is practiced by large extracting and manufacturing companies that have their own division controlling a number of ships for the transportation of their own cargoes. However, in recent years this has changed. Many such companies are now focusing on their core business and have outsourced the transportation to independent shipping companies. Therefore, the emphasis has shifted somewhat from industrial to tramp shipping. Increasing global competition results in shifting industrial shipping operations from being considered "cost centers" into "profit centers" and compels them to become more involved in the spot market. This also brings new challenges and opportunities for optimization-based DSS for maritime transportation planners.

Focus on supply chains: In most ship scheduling studies reported in the literature, the supply chain perspective is missing. Recently, we see an increasing competition between supply chains even more than between shipping companies. Shipping companies must consider themselves as total logistics providers, or at least as a part of a total logistics provider, instead of only a provider of sea transport services. We see an increasing emphasis on integrating maritime transportation into the supply chain. This brings new interesting challenges to the research community in routing and scheduling, such as inventory routing, collaboration, and cost and/or profit sharing along the supply chain.

1.3 Operations Research and Ship routing and scheduling

Transportation routing and scheduling have been an extensive research area the last decades. This has resulted in enormous progress in developing theory, models and solution methods and implementing optimization-based DSS in the transportation industry. In fact, transportation routing and scheduling stands out as one of the major success stories of operations research (OR). However, relatively few contributions exist for ship routing and scheduling. Christiansen et al. (2004) give several reasons for the low level of attention to ship routing and scheduling. They state that one essential explanation is the long tradition of conservative thinking in the ocean shipping industry, making it unreceptive to new ideas such as the use of optimization-based DSS. In the last decade, this has changed within many sectors in the shipping industry, and we have especially experienced this in vertically integrated companies responsible for their maritime transportation activity. In general, the shipping industry has expressed a considerable need for optimization-based DSS in order to stay in business where the profit margins are squeezed to a minimum.

In spite of the conditions discussed above we observe significant growth in research in maritime transportation. The first review of OR-work in maritime transportation appeared in 1983 (Ronen, 1983), and it traced papers back to the 1950's. A second review followed a decade later (Ronen, 1993), and recently a review of the developments over the last decade appeared (Christiansen, Fagerholt and Ronen, 2004). The increasing research interest in OR-based maritime transportation is evidenced by the growing number of references in the review papers. The first review paper had almost forty references covering several decades. The second one had about the same number of references most of which were from a single decade, and the most recent one has almost double that number of references for the last decade. Finally, a volume on transportation in the renowned handbook, *Handbooks in Operations research and Management Science* is devoted to Maritime transportation (Christiansen et al., 2004) and will appear in 2005.

Fortunately, much of the research within transportation routing and scheduling can be adjusted to solving ship routing problems. However, ship fleet planning problems are different than those of other modes of transportation because ships operate under different conditions. Christiansen et al. (2004) provides a comparison of the operational characteristics of the different freight transportation modes. Hence, there is a need to develop solution methods for solving particular ship routing and scheduling problems, while utilizing the research from the general transportation routing area.

1.4 The research group within ship routing and scheduling at NTNU

The research group at Department of Industrial Economics and Technology management (IØT) within OR has specialized in discrete optimization the last two decades. In the last decade, maritime applications within OR have been one of the primary focused areas. The reason for this is fourfold:

1) Discrete optimization is central in ship routing and scheduling problems,
2) For Norway, maritime transportation has been and will continue to be one of the primary industries, so it has been relatively easy to get in touch with the shipping industry,
3) Many challenges in maritime transportation planning are untouched by researchers, and
4) We have a close cooperation with Department of Marine Technology at NTNU and MARINTEK.

Our activity within the field has been noticed internationally. This has resulted in several invitations to present tutorials, give ordinary presentations at international conferences, give lectures at international PhD schools and write chapters in renowned handbooks and journals. The Department IØT has educated and is presently educating several PhD students with a focus on maritime transportation.

2. Strategic significance and relevance to society

Proper planning of fleets and their operations through OPTIMAR research activity has the potential of improving economic performance, reducing shipping costs for the shipping companies, improving flexibility and customer service and reducing damage to the environment. OPTIMAR can enhance the research activity within ship routing and scheduling in Norway and by this strengthen the research position internationally.

The Department of Industrial Economics and Technology Management (IØT) has for decades focused on areas within transportation, logistics and supply chain management from an organizational, economic and OR point of view. Recently, IØT has chosen *one* strategic priority field, and that is Supply Chain Management. Related to this prioritized area, a group of researchers at IØT is established with Professor Marielle Christiansen as manager. IØT is responsible for several courses within optimization where transportation and logistics issues are focused. In several of these courses, maritime transportation applications are presented. In the last years, we have had vacant positions as associate professors and professors in OR. This means that there is a great need to educate PhD students and post docs in the field.

Norwegian University of Science and Technology (NTNU) and SINTEF: More than half a decade ago, "Næringslivets idéfond ved NTNU" was established with four prioritized research areas. Transportation and logistics was one of the areas, and there has been an ongoing activity in the whole period resulting in several projects such as SMARTLOG. The activity within transportation and logistics is great both at the university and SINTEF/MARINTEK with a close cooperation in several projects. The research group in OPTIMAR will cooperate with the other research groups within transportation and logistics in Trondheim and Oslo, and that would benefit all parts with new knowledge, methodology and prototypes to become commercialized.

Research community in Norway and worldwide: As mentioned above, researchers within OR in Norway have contributed significantly to the maritime transportation and logistics field and achieved a renowned position internationally. However, there is a lot of remaining challenges within the field that are highly demanded. The group in Norway is one of the strong groups to continue this research in cooperation with internationally experts within transport optimization.

Maritime transporters: Proper planning of fleets and their operations has the potential of improving economic performance and reducing shipping costs for the shipping companies. This is often a key challenge faced by the industry actors in order to remain competitive. In addition, improvements in transportation logistics will result in improved flexibility and customer service. In a study (Fagerholt and Lindstad, 2000) of the supply services to an offshore oil and gas field, a model was developed that revealed a cost reduction potential for the supply ships of more than 25 %. Substantial savings were implemented by the operator, STATOIL. Other shipping companies have also experienced reductions in transportation and logistics costs. However, the improvement potential is highly dependent on the efficiency of the operations before such optimization-based DSS are implemented.

Society: Maritime transportation is the major conduit of international trade, and a positive result of increasing fleet utilization can be reduced damage to the environment due to reductions in transport operations. The central policy objective of the European Union for the upcoming years is to improve the quality and efficiency of the European transportation system by shifting traffic to maritime and inland waterways, revitalizing the railways and linking up the different modes of transport. In order to achieve such objectives, the fleets have to be utilized in an efficient way in order to be competitive with other modes of transportation. Further information regarding the European transport policy is available in the European Commission's White Paper (2001) "European Transport Policy for 2010: Time to Decide".

3. Main Objectives

Our vision is threefold:

- *Significant improvements in vessel fleet utilization reducing transportation and logistics costs, reducing environmental impact and improving customer service through developing models and efficient solution methods for challenges within ship routing and scheduling.*
- *Make a good foundation for commercializing optimization-based DSS within some of the focused research areas both nationally and internationally.*
- *Remain and strengthen the position as a central node in the research area of ship routing and scheduling. Enhance the national and international research network within the field.*

Operative objectives:

- Educating two Ph.D. students in maritime transport and logistics optimization.
- Qualifying the Post doc to a full professor within maritime transport and logistics optimization.
- More than 10 papers in internationally renowned journals.
- Increase the level of visits to Norway from internationally leading researchers in transport optimization.
- Increase the research collaboration with the international research community by visits (long term and short) to internationally leading research groups in the field.
- Develop prototypes for end-users and have a near cooperation with the end-users.

4. Research Areas

In OPTIMAR we want to focus on problems most relevant for the shipping industry. The research will be based on real planning challenges. The potential topics we want to focus on are market and contract evaluation and selection, optimal fleet design and liner network design at the strategic level. At the tactical level, ship routing and scheduling will be prioritized, where we want to focus on tramp ship scheduling problems with fixed and flexible cargo quantities and integrated inventory management and ship scheduling problems. We need to develop new theory, models, exact methods and heuristics to solve the focused problems. Depending on the feedback from the shipping industry and the background and interest of the Ph.D .students, we will give more attention to some of the areas than others.

4.1 Focus on strategic challenges within maritime transportation and logistics

Strategic decisions are long-term decisions that set the stage for tactical and operational ones. In maritime transportation strategic decisions cover a wide spectrum, from the design of the transportation services to accepting long-term contracts. Most of the strategic decisions are on the supply side, and these are: market selection, fleet size and mix, transportation system/service network design, maritime supply chain/maritime logistic system design, and ship design. Due to characteristics discussed earlier maritime transportation markets are usually competitive and highly volatile over time, and that complicates strategic decisions.

Design of the optimal fleet is one of the main strategic issues for shipping companies. This deals with both the type of ships to include in the fleet, their sizes, and the number of ships of each size. In order to support decisions concerning the optimal fleet of ships for an operator, we have to consider the underlying structure of the tactical or even operational planning problem. Thus there is a significant overlap between strategic and tactical/operational decisions. In OPTIMAR, we want to develop models for fleet size and mix decisions and network design decisions that require evaluation of ship routing strategies.

In addition, the fleet size and mix decisions have to be based on an estimate of demand for the transportation services. The demand forecast is highly uncertain, and in the literature, various demand patterns are considered where either the size of the cargoes or the frequency of sailing is specified. Simulation is a simple approach that is used to consider stochastic conditions and uncertainty and is used in shipping applications, see for instance Darzentas and Spyrou (1996), Richetta and Larson (1997), and Fagerholt and Rygh (2002). Stochastic conditions can also be approached both by deterministic and stochastic optimization models. An example of using deterministic optimization models with penalties to achieve more robust solutions is one alternative. To our best knowledge, there are no published papers where stochastic optimization models are used for strategic planning in the shipping industry. The only one discussing the issue is by Jaikumar and Solomon (1987), where a model for determining the minimum number of tugs needed to move barges between ports on a river is presented. They discuss how their model can be extended to incorporate stochastic demands.

There have been a few studies on vessel fleet design issues, and these are described in (Christiansen, Fagerholt and Ronen, 2004) and (Christiansen et al., 2004). The potential for improving these strategic decisions is probably significant. As already, discussed, we have seen a trend from industrial to tramp shipping, with much more interaction with the market. This high degree of market interaction probably makes the vessel fleet design issue even more important and complex, as one now has to make some assumptions on future market development to determine the optimal fleet. These integrated market analyses and fleet design issues are an open area within maritime transportation, and in OPTIMAR we want to develop theory, models and methods for such strategic planning issues.

Market/contract evaluation and selection are closely related to fleet size issues. A shipping company has to find the best split between fixed long-term cargo contracts and spot cargoes. This split should be based on estimation of future prices, demand and the shipping pattern of other shipping companies in the same segment. In addition, the use of forward contracts and geographical swaps of cargoes with other shipping companies is relevant for the shipping companies. We are not aware of any published work within this area, so this important area will be focused in OPTIMAR.

Optimal fleet design and market/contract evaluation and selection will be studied for the industrial and tramp ship companies mentioned in Section 4.2.

Liner network design and contract evaluation: Liner ships are employed on more or less fixed routes, calling regularly at many ports. In contrast to industrial or tramp ships a liner ship serves demand of many shippers simultaneously, and its published route and frequency of service attract demand. The major challenges for liners at the strategic level are the design of liner routes and the associated frequency of service, fleet size and mix decisions and contract evaluation for long-term contracts. Very little OR research has been done for liner ships, see (Christiansen et al., 2004), so there is a great need to focus on the many challenges for this mode of operation. Also here, we see the trend of mergers resulting in large fleets and a need for design of new liner networks. For instance, Wilhelm Wilhelmsen doubled its fleet lately by acquisition. Industrial partners are currently being sought among liner ship owners.

4.2 Focus on tactical challenges within maritime transportation and logistics

4.2.1 Tramp ship routing and scheduling

Many shipping companies operate in the tramp market where the underlying tactical planning problem corresponds to pickup and delivery of bulk cargoes at maximum profit. Normally, a tramp shipping company engages in both contracts and takes optional cargoes when profitable. When the controlled fleet has insufficient capacity to serve all contracted cargoes, the cargoes can be serviced by spot charters.

Our research group has worked with such problems for a long period of time. We have developed a set partitioning approach for the problem and a hybrid search heuristic. The heuristic is implemented in the decision-support system Turborouter. Both solution approaches are described in (Brønmo et al., 2004). Here we have run real cases from Klaveness, Jebsen Management, Broström Tankers and Iver Ships.

In OPTIMAR we want to further develop the hybrid search heuristic to include for instance tabu search, see Aldaihani and Dessouky (2003), Cordeau and Laporte (2003) and Toth and Vigo (1997). This research will have commercial interest, in addition to interests for the scientific research community.

The set partitioning approach with columns generated a priori can be solved for cases of limited size only. We need to develop an exact method for solving cases of real size. This can be based on the set partitioning approach where the columns are generated during the solution process. There exist numerous research on this solution approach (see Desrosiers et al., 1995), and we want to adapt the existing research to the tramp ship scheduling problem and utilize the special structure in this type of problem to develop an efficient solution approach. If the algorithms developed become efficient the approach can be used commercially. In addition, the solutions from the set partitioning approach can be used as benchmarks for the heuristics

4.2.2 Tramp ship routing and scheduling with flexible cargo sizes

In most ship scheduling studies reported in the literature, the fleet scheduling is often performed under tight constraints with no flexibility in cargo quantities. Realizing the potential of relaxing such constraints, Fagerholt (2004) considered flexibility in shipment sizes and time windows. The additional costs of imposing little flexibility in cargo quantities may in the end be distributed to all participants in the supply chain. (Brønmo, Christiansen and Nygreen, 2004) has included flexible cargo sizes into the set partitioning approach for the tramp ship routing and scheduling problem. In OPTIMAR we want to extend the exact methods and heuristics described in 4.2.1 such that the algorithms can handle flexible cargo sizes.

4.2.3 Integrated inventory management and ship scheduling

In industrial maritime transportation, the transporter has often a twofold responsibility. In this segment large quantities are transported, and normally considerable inventories exist at each end of a sailing leg. In some situations, the transporter has both the responsibility for the transportation and the inventories at the sources and the destinations. This result in problems called inventory routing problems. Recently, Kleywegt, Nori and Savelsbergh (2004) gave a short survey of the inventory routing literature. Such problems can be defined in the following way (Dror and Ball, 1987): "The inventory routing problem is a distribution problem in which each customer maintains a local inventory of a product such as heating oil and consumes a certain amount of that product each day. Given a central supplier, the objective is to minimize the annual delivery costs while attempting to insure that no customer runs out of the commodity at any time." In this problem there is an imbalance between the supplier and consumer. In ship scheduling problems this is different. Both at the supplier and consumer large quantities are loaded/unloaded. This result in another structure of the planning problem and, hence, other solution approaches are needed. Very little research has been done on such types of problem in the OR-literature. Further development of methods for solving such types of combined inventory management and ship scheduling problems are highly demanded as we see a trend towards an integration along the supply chain.

This problem has many similarities to the ship scheduling problem with flexible cargo sizes. However, the number of cargoes is not given in advance, neither is the number of ship calls at a port. Further, we have no predetermined loading and unloading port for a particular cargo. In addition, we have to keep track of the inventory levels. There must be sufficient product in consumption inventories, and the inventory in production ports cannot exceed the inventory storage capacity.

Integrated inventory management and ship scheduling with full ship load
Statoil will face this type of planning problem when starting the production of gas at the field Snøhvit. The liquefied natural gas (LNG) will be stowed in storage tanks at Melkøya and transported by LNG-ships to terminals in Europe and America. Professor Marielle Christiansen and two master students (Frich and Horgen, 2004) have been cooperating the last half year with Statoil on these issues, and in OPTIMAR we want to continue the research on finding efficient solution methods to the combined inventory routing and ship scheduling problem where the LNG vessel is fully loaded at Melkøya and totally unloaded at one of the terminals. There is also an expressed need to extend the analyses and include larger parts of the supply chain and spot trade into the models. This will be focused in OPTIMAR.

Integrated inventory management and ship scheduling with partial loads
Christiansen (1999) studied a real ship scheduling and inventory management problem for transportation of ammonia for Norsk Hydro ASA. The overall solution approach is described in Christiansen and Nygreen (1998a, 1998b). It is based on a Dantzig-Wolfe decomposition approach with two types of subproblems. The solutions from the subproblems are synchronized in the master problem. Another solution approach to the same ship planning problem was developed by Flatberg et al. (2000). They have used an iterative improvement heuristic combined with an LP solver to solve this problem. However, no comparisons in running time or solution quality of the results in Flatberg et al. (2000) and Christiansen and Nygreen (1998a) exist. This problem is very challenging and there is a huge need to work further on with the solution approaches presented by Christiansen (1999) and Flatberg et al. (2000). In addition, new solution methods, both exact and heuristics should be considered, studied and developed. In OPTIMAR this research will be given high priority.

Integrated Inventory management and ship scheduling with several products
Both the LNG and ammonia cases are distribution of a single commodity. Ronen (2002) presented such a problem with multiple products. A MIP model for the problem was formulated, and two approaches for solving the shipments planning problem were used. In OPTIMAR we want to develop exact and/or heuristics for this type of challenging problem. Exxon Mobil owns such a planning problem in transportation of chemicals, and we have taken an initiative to start cooperation with them.

5. Relation to other Activities and Research Programs

Activities addressing similar challenges will be linked to OPTIMAR. The three most relevant ongoing or just completed programs are TOP, SMARTLOG and INSUMAR.

TOP is a short name for "Improved Optimization Methods in Transportation Logistics" which is a Strategic Institute Program 2001-2004 at SINTEF Applied Mathematics funded by The Research Council of Norway. In addition to activities at SINTEF Applied Mathematics in Oslo, TOP has also funded some network activities with participation from NTNU, Molde College, SINTEF Industrial Management and MARINTEK. The TOP Advisory Committee has members from end user organizations, the Research Council and Professor Bjørn Nygreen from NTNU. Nygreen is also supervisor for Geir Brønmo, the only PhD candidate funded by the TOP program. Brønmo has mainly worked on maritime planning problems and he will finish his work in 2005. TOP has also contributed financially to other maritime research activities at the Group of Managerial Economics and Operations Research at NTNU. OPTIMAR can be seen as a continuation of the TOP program, but with greater focus on optimization of maritime transportation.

SMARTLOG: A knowledge-building project with user involvement (KMB) that is a cooperation between SINTEF Industrial Management, MARINTEK and NTNU with duration until end of 2006. The main goal is to develop knowledge about logistics-solutions which are necessary for (Norwegian) industry to meet the challenges in the future global network economy. The four areas in focus are: I Strategic positioning, roles and incentives, II Development and design of dynamic value chains, III Development and design of dynamic distribution systems, and IV Coordination and management. In OPTIMAR we want to continue the focus on value chains, but change the focus to maritime value chains.

INSUMAR: (Integrated supply chain and maritime transportation planning) is a project partly supported by NFR with partners from NTNU, MARINTEK, NHH and National University of Singapore. The main objective is to create the methodological basis for improved planning decisions for actors in global maritime transportation and their manufacturing/process industry customers. A key issue is a better and closer cooperation between the maritime transporter and the shipper by sharing important information. This will give potential for improved supply chain performance. The result from this project will be important input to OPTIMAR for the planning problems containing supply chain issues. PhD student Roar Grønhaug is studying the supply chain of silicon products for Elkem ASA with Professor Marielle Christiansen as supervisor.

6. Dissemination

We will publish at least 10 papers, participate at international conferences regularly, organize a research workshop and an industry seminar, cooperate with other programs in organizing industry seminars and include OPTIMAR results and theory in NTNU courses.

In OPTIMAR, we will publish at least 10 papers in international renowned journals and participate at internationally renowned conferences several times yearly.

We will organize at least one workshop with national and international expert participants. The invited researchers will be well reputed in the area of OR with speciality in supply chain optimization and/or transport optimization. In addition, we will during the whole project period exchange our new knowledge with our cooperating research communities. This exchange will take place in small seminars or more informal visits.

To disseminate results to industry, we will organize an open industry seminar. In addition, we will participate in the organisation of industry seminars together with other programs like SMARTLOG and give presentations at such seminars. For industrial partners, we will give "special-talks" when visiting them.

At NTNU there are several courses where it would be natural to use the results from OPTIMAR as examples or as new theory. Therefore, we will seek to contribute to the content of the courses and to give guest lectures in these courses.

7. Organisation

OPTIMAR will be organised as a project consisting of two PhD scholarships, a post doctoral and OR scientists in Norway and abroad. Professor Marielle Christiansen will be the project manager.

7.1 OPTIMAR Management

Professor Marielle Christiansen shall be the OPTIMAR manager. An OPTIMAR Advisory Committee will be composed of representatives from end-user organisations in maritime transportation, the Research Council of Norway, and Dr. Geir Hasle from SINTEF. The OPTIMAR Advisory Committee will meet once a year.

7.2 Doctoral and post doctoral scholarships

We are searching for two PhD candidates with a master thesis in Operations research or Optimization. The supervisors will be Professor Marielle Christiansen and Professor Bjørn Nygreen. To ensure a close cooperation each of the supervisors will become the main supervisor for one of the PhD students and the co-supervisor for the other PhD-student.

The post doctoral will have a PhD in optimization in maritime transportation and logistics and should show to a great activity in the area.

7.3 International co-operation

We will work in cooperation with renowned researchers from outstanding international research groups in Canada, Denmark, New Zealand Sweden, UK and USA. Some of them will visit Trondheim for shorter periods and each of the doctoral students will be stimulated to spend at least six months visiting one of the groups. We have already got invitations from Auckland, Missouri and Montreal, see the attached letters.

7.4 National collaboration

We will collaborate with other strong Norwegian research groups in transportation and logistics optimization. Some candidates are:

- Department of Informatics, University of Bergen
- Department of Informatics, University of Oslo
- Molde College
- Department of Optimization, SINTEF Applied Mathematics
- Department of Economics and logistics, SINTEF Industrial Management
- Group of Logistics, SINTEF MARINTEK

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