Technology Foresight: The ASTEC Shipping Partnership's Experience with the Delphi Survey

1997
TECHNOLOGY FORESIGHT:
THE ASTEC SHIPPING PARTNERSHIP'S
EXPERIENCE WITH THE DELPHI SURVEY

by Lance Schultz

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PREFACE

From September 1994 to December 1995, the Australian Science, Technology and Engineering Council (ASTEC) applied 'foresight' processes to explore and evaluate the future science and technology (S&T) needs of Australia to the year 2010. Its study drew on the outcomes of a broad range of consultative mechanisms, key issues 'roundtables', consultancy and partnership studies.

This Occasional Paper presents the experience of the ASTEC Shipping Partnership in using the Delphi survey technique to conduct a technological foresight exercise of the future needs of the Australian maritime industries to the year 2010. The Shipping Partnership's Report was published in September 1996 under the title: *Australian Maritime Industries: Priorities in Science and Technology*.

The Shipping Partnership was one of the five ASTEC partnership studies which involved collaborative work with interested organisations. Four of the five partnerships used scenario building as their main foresight tool. The Shipping Partnership, a 17 member group, comprising industry, government, research and learned society members, alone used the Delphi survey technique.

This Occasional Paper concludes that, despite the Shipping Partnership Delphi survey's limitations, particularly its relatively small scale, the Shipping Partnership's experience with the Delphi survey did prove to be a useful exercise, the results of which are already becoming apparent at the time of writing in improved dialogue between research users and producers and in action taken on the Report's key recommendations.

The Occasional Paper was prepared by Lance Schultz, Secretary, Shipping Partnership and Partner, LMS Consulting. Comments are welcome, and should be addressed to:

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1 Foresight can be described as a process which leads to a better understanding of the forces likely to shape the long term future and which therefore should be taken into account in policy formulation, planning and decision-making. Foresight is not forecasting – rather, foresight acknowledges that a range of possible futures exist and seeks to better inform government, business and communities to help shape the future. For a comprehensive discussion of technology foresight see: Australian Science, Technology and Engineering Council (October 1996), *developing long-term strategies for science and technology in Australia: findings of the study: matching science and technology to future needs 2010*, AGPS, Canberra.
ABOUT ASTEC

The Australian Science, Technology and Engineering Council (ASTEC) was established as a statutory authority in 1979 under the *Australian Science and Technology Council Act 1978*.

ASTEC is a principal source of independent advice to the Commonwealth Government on a wide range of policies and programs related to S&T which are of concern to Commonwealth departments and agencies, higher education institutions and private enterprise. It works closely with the Prime Minister's Science and Engineering Council and other major bodies providing policy advice to the Government.

ASTEC is in a unique position to provide advice to the Government because of its independent status, its broad, longer-term perspective and its links to the Australian S&T community and to industry.

The Council is empowered to operate by conducting inquiries, gathering information, engaging consultants, appointing committees and producing reports.

Chaired by Professor John Stocker, ASTEC currently has ten members (listed in Appendix A) who broadly represent all areas of the S&T community, many with strong industry links.
# CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>CHAPTER ONE: DISTINGUISHING FEATURES OF THE SHIPPING PARTNERSHIP FORESIGHT EXERCISE</td>
<td>2</td>
</tr>
<tr>
<td>CHAPTER TWO: CONDUCT OF THE EXERCISE</td>
<td>6</td>
</tr>
<tr>
<td>CHAPTER THREE: PROCEDURAL OUTCOMES</td>
<td>15</td>
</tr>
<tr>
<td>CHAPTER FOUR: CRITICAL SUCCESS FACTORS</td>
<td>21</td>
</tr>
<tr>
<td>CHAPTER FIVE: COST-BENEFITS CONSIDERATIONS</td>
<td>29</td>
</tr>
<tr>
<td>CHAPTER SIX: CONCLUSIONS</td>
<td>32</td>
</tr>
<tr>
<td>POST SCRIPT</td>
<td>33</td>
</tr>
<tr>
<td>APPENDIX A: MEMBERS OF THE AUSTRALIAN SCIENCE, TECHNOLOGY AND ENGINEERING COUNCIL</td>
<td>34</td>
</tr>
<tr>
<td>APPENDIX B: ASTEC OCCASIONAL PAPERS</td>
<td>35</td>
</tr>
</tbody>
</table>
INTRODUCTION

This Occasional Paper has a three-fold purpose:

first, it serves as a guide to other industry sectors or organisations who may be contemplating using the Delphi survey as a foresight tool. Delphi surveys have not been widely used in Australia for science and technology foresight purposes and the lessons derived from them have not been recorded in a way that would readily assist others who may wish to use the technique for these purposes;

second, the paper discusses a number of issues which will need to be taken into account in any evaluation of ASTEC’s technology foresight exercise, including a preliminary cost-benefit analysis of the Shipping Partnership’s Delphi exercise. It is intended that the experience recorded in the Paper will be useful should the exercise be repeated at some future date;

third, it contributes to international understanding of Delphi technology foresight. Japan and a number of other Organisation for Economic Cooperation and Development (OECD) member countries, (eg Germany, the United Kingdom and France) have conducted large-scale Delphi exercises for technology foresight purposes. The paper provides an input into what is hoped will be a continuing exchange of ideas, experiences, problems and lessons learnt between OECD member countries on their Delphi technology foresight experiences.

Chapter One discusses the Shipping Partnership study’s distinguishing features and special characteristics and the similarities and differences between it and other Delphi studies. The classification developed by Martin and Irvine (1989) is used for comparative purposes.

Chapter Two records and provides comment on the Shipping Partnership’s experience with the Delphi survey. The experience is recorded in a format that readily permits comparison with the procedures adopted in recent government technology foresight exercises in other countries.

Chapter Three discusses some procedural outcomes from the exercise: timeliness, survey scope, survey response rates and the balance in the representation of industry, government and research interests in the various stages of the exercise.

Chapter Four discusses the Australian experience in the light of a number of critical success factors for technology foresight suggested by international experience. The chapter can be regarded as a first iteration - an exploration - in world’s best practice in the use and application of the Delphi survey for foresight purposes. Chapter Five continues the discussion in the previous chapter by focussing on cost-benefit considerations.

Chapter Six presents the conclusion that Delphi surveys conducted at the macro-level can be a useful foresight tool, but a number of caveats apply to this statement. This chapter is followed by comment in the form of a Post Script on what the study has revealed about the views, attitudes and expectations of the respondents when thinking about the future of the Australian maritime industries.

CHAPTER ONE: DISTINGUISHING FEATURES OF THE SHIPPING PARTNERSHIP FORESIGHT EXERCISE

The 1995-96 ASTEC Shipping Partnership foresight exercise was one of many foresight exercises undertaken internationally in recent years. These exercises vary considerably in terms of their approaches, degrees of specificity, aims and objectives, survey populations and methodologies.

In their seminal book, *Research Foresight: Priority-Setting in Science* (1989), Martin and Irvine suggest a classification by which various research foresight exercises can be compared and contrasted. Their classification includes features such as the characteristics of the organisation performing the exercise, degrees of specificity in terms of breadth of coverage, aims, objectives and functions of the exercise, research orientation, the balance achieved between various 'intrinsic tensions' in foresight exercises, such as between 'science-push and 'demand-pull', time-horizon and methodological approaches.

ASTEC's overview of international foresight experience: *Matching Science and Technology to Future Needs; An International Perspective* (1994) indicates a number of relevant studies to compare with the Shipping Partnership Delphi survey approach, namely the *ASTEC Future Needs 2010* study, the 1992 Japanese (NISTEP) Delphi survey, the 1994-96 Japanese-German 'mini-Delphi', the UK Technology Foresight Transport study, which used a postal Delphi, and the UK 'Policy Research in Science and Medicine (PRISM)' Wellcome Trust study, which used a combination of Delphi survey and panel-based scenario analysis methodologies. These studies are distinguished by their use of the Delphi survey, either as the study's only foresight tool, as in the case of the Japanese Delphi, or in combination with other methods (eg the PRISM study).

Table 1 uses a modified version of the Martin and Irvine classification to compare these foresight approaches. The Martin and Irvine classification has been modified to:

- exclude classifications not relevant to the group of studies (eg many of the authors' suggested characteristics of the performing organisation such as 'national academies' and 'science-based companies' and the classification group 'orientation and structural characteristics of research');

- include two further categories, namely survey respondents and number of topics and/or sub-areas investigated. Also, actual time horizons, rather than short-term, medium-term and long term classifications, are shown in Table 1, since it was found that use of these terms is relative. For example, both the ASTEC Future Needs 2010 study, which had a 15 year horizon, and the NISTEP study, which had a 30 year horizon, describe themselves as 'long term' studies.

Table 1 includes the Martin and Irvine classifications relating to balance or relative emphasis between various 'intrinsic tensions' in foresight (eg between 'science-push and 'demand-pull', 'top-down' and 'bottom-up approaches' and allocation of responsibility to 'interested parties' and 'third parties'). However, it is important to note that the emphasis given to each of these varies according to the specific stages of the various studies, where they apply. It is difficult to give an overall assessment that is true for all stages. For example, the Shipping Partnership was established using a 'top-down' approach, but, once established, its operating procedures were 'bottom-up'. Further, while the PRISM study strikes a good balance between 'science-push and
'demand-pull', the latter is best represented in the interview and panel discussion phases of the study.

Martin and Irvine explain their terms as follows:5

**holistic** refers to foresight concerned with the entire spectrum of fields;

**macro-level** refers to foresight focussing on a limited number of research fields;

**meso-level** refers to foresight concerned with a single scientific field or technology sector;

**micro-level** refers to assessments of future prospects at either the level of projects or individual scientific specialities;

**direction setting** relates to the use of foresight in determining broad guidelines for science policy;

**anticipatory intelligence** relates to contributing background information on emerging trends in science and technology;

**consensus generation** refers to the use of systematic analytical and consultative procedures to promote greater agreement among scientists, funding agencies and research users on identified research and development (R&D) needs or opportunities;

**advocacy** refers to the deployment of foresight to promote policy decisions in line with the preferences of specific stakeholders; and

**interested parties** refers to scientists working in the area and those directly benefiting from research while **third parties** refers to neutral individuals or bodies, ie specialists from other fields or independent advisory councils.

Using this classification, the ASTEC Future Needs 2010 study is described as a 'long term holistic, national level exercise with an emphasis on demand-pull, stressing the functions of direction-setting, anticipatory intelligence and communication and education. Implementation is directed primarily towards Commonwealth Government responsibilities'.6 The Shipping Partnership study could be classified as a medium-term, macro-level exercise, stressing the functions of priority-setting and consensus-generation. Implementation is directed towards a range of industry, government and research interests.


Table 1: A comparison between the key features and distinguishing characteristics of the Shipping Partnership Delphi survey study and other selected technology foresight studies

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<td>Characteristics of the performing organisation</td>
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<td>- High level government advisory boards and central policy bodies</td>
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<td>- Independent public sector advisory councils</td>
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<td>- Academic funded</td>
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<td>Level of Specificity</td>
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<td>- Holistic</td>
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<td>- Macro-level</td>
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<td>- Meso-level</td>
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<td>- Micro-level</td>
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<td>Functions</td>
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<td>- Direction-setting</td>
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<td>- Determining priorities</td>
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<td>- Anticipatory intelligence</td>
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<tr>
<td>- Consensus generation</td>
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<tr>
<td>- Advocacy</td>
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<td>- Communication and education</td>
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<tr>
<td>Balance between various 'intrinsic tensions'</td>
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<tr>
<td>- Science-push/demand pull</td>
<td>Demand</td>
<td>Demand</td>
<td>Science</td>
<td>Science</td>
<td>Demand</td>
<td>Science</td>
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<tr>
<td>- Top-down/bottom up</td>
<td>Bottom up Third</td>
<td>Bottom up Third</td>
<td>Top down Third</td>
<td>Top down Third</td>
<td>Bottom up Third</td>
<td>Top down Third</td>
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<tr>
<td>- Interested parties/third parties</td>
<td>Time horizon (years) 15</td>
<td>Time horizon (years) 15</td>
<td>Time horizon (years) 30</td>
<td>Time horizon (years) 30</td>
<td>Time horizon (years) 10-20</td>
<td>Time horizon (years) 15</td>
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<tr>
<td>- Informal/formal</td>
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<td>- Qualitative/quantitative</td>
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<tr>
<td>Survey respondents (second round) 135</td>
<td>na</td>
<td>2,385</td>
<td>405-Japan</td>
<td>459 German</td>
<td>80</td>
<td>330</td>
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<tr>
<td>Areas covered</td>
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<tr>
<td>- Topic statements</td>
<td>76</td>
<td>na</td>
<td>1,149</td>
<td>132</td>
<td>75</td>
<td>51</td>
</tr>
<tr>
<td>- Sub-areas</td>
<td>9</td>
<td>16</td>
<td>16</td>
<td>4</td>
<td>9</td>
<td>3</td>
</tr>
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</table>

Source: Author's assessment of the studies, based on published materials.
Key features and characteristics of the Shipping Partnership study

The Shipping Partnership’s study had its origins in the wider ASTEC Future Needs 2010 study. The study was conducted by a partnership of government, industry, research and learned society members, under the auspices of an independent public sector advisory council.

The study was a macro level study of the Australian maritime industries, which comprise the heavy (mainly steel) naval construction, modernisation and conversion and repair industry, the light-weight (aluminium) fast ferry industry, the shipping industry and the marine technology industry. The Partnership Report’s recommendations encompassed all these sectors.

The focus of the Shipping Partnership’s study was on determining priorities, consensus-generation and communication and education. Through analysis of the Delphi survey results, combined with strategic thinking by the partners, the Partnership identified 36 topic statements with a first claim for consideration as Australian S&T priorities, the majority of which formed three priority clusters. Consensus-generation was promoted by the Delphi procedures and encouraged in Partnership discussions. Communication and education, an intrinsic part of the process fostered by the macro-level Delphi survey, is being further developed in the post-foresight phase.

The Shipping Partnership study had a demand-pull focus. It focused on the science, technology and skills required to meet the future needs of the Australian shipping, shipbuilding and other marine industries. Its approach to its work plan and operations was bottom-up. Although having key interested parties as members, the ASTEC Council oversaw its work as a third party.

Striking a balance between the ‘intrinsic tension’ in foresight studies between ‘science-push’ and ‘demand-pull’ is critical to the success of a foresight exercise. The issue is discussed further in Chapter Four (Critical Success Factors).

Like its parent study, the Partnership Partnership’s study adopted a 15 year time horizon. This horizon is particularly suited to the Partnership study’s subject area because it focuses attention on anticipated developments beyond the scope of the current Australian ship construction projects and industry strategic plans and takes account of the long lead times for R&D investments. While 15 years was the intended horizon, a high percentage of respondents thought that the period or event associated with most topic statements would have first occurred, either between the years 1995 and 2000 or between the years 2001 and 2005. For this reason, the study should be classified as a short to medium-term horizon study, rather than a long-term horizon study.

The Partnership’s use of the Delphi survey determined that its methodological approach would be formal and quantitative. The study was based on 135 respondents from a survey population of 550. The study investigated developments identified in 76 topic statements which were divided into 9 sub-areas of investigation. These were: ship design, ship manufacture, ship ownership and operation, research and development, transport, warship design and production, industry suppliers, the Exclusive Economic Zone (EEZ) and cargo handling.
CHAPTER TWO: CONDUCT OF THE EXERCISE

This Chapter records the procedures involved in conducting the 1995-96 Shipping Partnership Delphi survey. The left-hand column in the following tables (Tables 2-4) indicates the key steps in the process, while the right-hand column provides comment, where appropriate, on what actually happened at the various stages. The comments are based on interviews with participants and the author's own analysis of written materials, such as published reports, working papers and (with ASTEC's permission) ASTEC files. The comments are intended to be constructive and focus on lessons that can be learnt from the exercise.

As in the case of other foresight exercises, three stages are distinguished: pre-foresight, main foresight and post-foresight. The post-foresight phase is further divided into two phases relating to disseminating the results and specific follow-up action, respectively. The presentation in this chapter reflects the representation of tasks for each stage in Martin and Irvine's framework in Research Foresight Priority-Setting in Science (1989).

Pre-foresight stage

This stage took three months, between May and August 1995. The stage encompassed the initial decisions to undertake the study, setting the process in train, forming the Partnership, planning and identifying objectives.

Table 2: Steps in the pre-foresight stage

<table>
<thead>
<tr>
<th>Steps</th>
<th>Comments</th>
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<tbody>
<tr>
<td><strong>Decision-making processes</strong></td>
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</tr>
<tr>
<td>May 1995. ASTEC takes the decision to form a Shipping Partnership</td>
<td>ASTEC Partnerships had already been established in health, urban water, youth and information and communications technologies. ASTEC agreed that a further partnership was needed in a heavy engineering industry to complement the above areas. The choice of shipping as the subject area reflected, at least in part, the Chairman's personal interest in this field as Chairman of South Australian Ships and Chairman of the Australian Maritime Engineering Cooperative Research Centre.</td>
</tr>
<tr>
<td>Forming the Partnership</td>
<td>Shipping interests were invited to join the Partnership through a high-profile launch. Invitations were extended to maritime-related industry peak bodies, industry, government, research and learned society bodies. 15 members signed up within two weeks, comprising 5 industry members, 4 government departments, 3 learned societies, 2 cooperative research centres and ASTEC. Full Partnership members contributed $10,000 each to the study. Most contributions were received within the first few weeks, thus enabling the Partnership to begin on a good financial footing.</td>
</tr>
<tr>
<td>Partnership Chairman</td>
<td>The Executive Director of the Australian Maritime Engineering Cooperative Research Centre was elected Chairman of the Shipping Partnership.</td>
</tr>
<tr>
<td>The decision to conduct a Delphi survey.</td>
<td>By the time the Partnership met for the first time, the decision to conduct a Delphi survey as the Partnership's foresight tool was a fait accompli. The ASTFC Chairman and a number of other ASTEC Council members were of the view that, as the other partnerships had gone down the scenarios path, the Shipping Partnership would be the appropriate partnership to test the Delphi survey in Australian conditions. The fact that the proposed</td>
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<tr>
<td>Organisational aspects</td>
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<tr>
<td>Oversight</td>
<td>The Partnership itself, with secretariat support from ASTEC, combined the functions of an oversight committee and main working group.</td>
</tr>
<tr>
<td>Link with the ASTEC Council and the ASTEC Future Needs 2010 study</td>
<td>The ASTEC Chairman was ASTEC’s representative on the Partnership and provided the link with the Council and the broader study. The Chairman, or a member of the ASTEC Secretariat, attended all Partnership meetings. A member of the ASTEC Secretariat was Secretary to the Shipping Partnership (for the pre- and main foresight phases of the study).</td>
</tr>
<tr>
<td>Objectives</td>
<td>ASTEC identified four objectives for the Partnership which were used to explain its purpose and to recruit members⁷. They were referred to in Partnership discussions as the Partnership’s ‘initial objectives’ which were modified in an interactive way to meet changing needs. For example, the Partnership placed less emphasis on developments in the Asia-Pacific region when it became clear from the survey results that global collaboration was more important for technology transfer and collaboration for the Australian maritime industries.</td>
</tr>
<tr>
<td>Funding</td>
<td>The Partnership became self-funding at an early stage, with members contributing A$10,000 each (an exception was made for the learned societies). Members’ investment in/support for the Partnership was reflected in their willingness to attend meetings and to contribute time and effort in drafting and commenting on sections of the Report.</td>
</tr>
<tr>
<td>Background papers</td>
<td>To stimulate ideas and to encourage discussion within the maritime industry communities, Partnership members contributed a background paper on their areas of specialisation. Background papers were prepared on such issues as ‘Future Directions in the Australian Shipbuilding Industry’, ‘Future Trends in Ship Design’ and ‘Defence Shipbuilding, Repair and Maintenance’. These papers were made available to participants in the August 1995 Roundtable (see below) and subsequently published as Shipping Partnership Background Papers⁸.</td>
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⁷ The Partnership’s initial objectives were to:
- foresight the S&T underlying the development of an innovative and competitive shipbuilding, ship repair and maritime support industry in Australia and the Asia-Pacific region;
- identify opportunities for Australian innovations to be used in sea transport in the Asia-Pacific region;
- identify skill needs for this area to 2010; and
- identify additional opportunities, particularly in the Exclusive Economic Zone (EEZ) context, which would give rise to marine industry development opportunities.

Main foresight stage

This stage was the longest stage (13 months). It began with a Roundtable in August 1995 to develop topic statements for the Delphi survey and ended with the launch of the Partnership Report in September 1996. The stage encompassed the Roundtable, two Delphi survey rounds, analysis of the survey findings and their implications, a Workshop to review the Partnership's preliminary conclusions and recommendations and the production and launch of the Partnership's Report.

The stage was 4-5 months longer than originally planned. There were two main reasons for this. First, the discovery of a processing error in the first round results that were included with the second round questionnaire required the dispatch of another second round questionnaire. An extended deadline of a month was provided as it would have been difficult to ensure a high response rate over the coming December/January holiday period. Second, the Partnership decided that it would produce a comprehensive report, commenting and making recommendations on the survey findings, rather than publishing a report which merely topped and tailed the ABS consultancy group's report, as was originally envisaged. (The ABS consultancy group's report was intended to provide a summary of the survey results, rather than provide policy recommendations. It was published in full in the Annex to the main Report.)

This stage, the core of any foresight exercise, typically involves detailed design of the process, strategic analysis, agreement on the more promising options and conveying the results to decision-makers in government and industry.

Table 3: Steps in the main foresight stage

<table>
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<th>Steps</th>
<th>Comments</th>
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<tr>
<td>Organisational aspects</td>
<td>The Partnership engaged an Australian Bureau of Statistics consultancy group to assist with the design and development of the Delphi survey. The ABS group also provided statistical advice and assistance, including the processing of the questionnaire. They consulted extensively with the Partnership through the design and analysis stages of the survey.</td>
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<tr>
<td>Engagement of consultants</td>
<td>The aims of the Roundtable were to increase awareness of the Delphi technique, to identify topics that were likely to shape the future of the Australian maritime industries over the next 15 years and to formulate a questionnaire which would meet the objectives of the survey. The Roundtable was attended by 80 representatives from industry, government, research organisations, academia and private enterprise. Plenary sessions and small group sessions were used to draw up a list of 80 topic statements which was eventually refined to 76 statements for inclusion in the survey. The Roundtable included a dinner at Parliament House and an address by the then Federal Government minister responsible for civil ship construction. The topic statements, however, were formulated in a very restricted time-frame after the conclusion of the Roundtable. The ABS consultants played a key role in converting prospective statements into analysable statements for survey purposes.</td>
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The Partnership drew on the Guidance Notes and the Delphi Questionnaire used in the UK Technology Foresight Program to prepare its own survey instrument. This had the advantage of providing a readily-available format but meant that the Australian survey was constrained by the UK model. A number of minor changes were made to the UK model to reflect Australian conditions (e.g., the Australian federal government structure and reference to skills constraints).

The survey had 35 columns for each of the 76 topic statements which sought panellists' views on such matters as:

- the likely degree of impact on wealth creation and quality of life;
- the period within which the development will have first occurred in Australia;
- the necessity of collaboration (within Australia, globally and/or within APEC);
- Australia's current position versus other countries in scientific and technological capability, innovative capability, production capability or service delivery and exploitation and commercialisation potential (i.e., whether Australia was considered to be at the leading edge, had average performance or lagged behind); and
- constraints on the occurrence in Australia, namely, social or ethical acceptability, technological feasibility, technology transfer, industrial or commercial constraints, lack of funding, economic viability, standards, regulatory or policy constraints and Commonwealth or States issues.

To assist respondents, the terms used were fully explained in the Guidance Notes for the survey. These also explained how respondents were to use sets of numerical ratings to give their responses to each area of the questionnaire.

The people surveyed were given discretion, according to their level of expertise, whether or not to respond to a particular topic. They were also given an opportunity to suggest new topics, to comment on the likely and desirable trends in expenditure on research and development and in workforce skills in the maritime industries and include written comments on each individual topic statement or make any other comments, if they so wished. For each topic statement, they were asked to identify their level of expertise in the subject, i.e., unfamiliar, somewhat familiar, familiar, very familiar, or expert.

Respondents' replies remained confidential to the ABS consultancy group and no information was released which might have identified individual respondents.

A small pilot test, which involved maritime industries people, university students and a representative of the Partnership, was conducted in Melbourne and resulted in some changes being made to the questionnaire before printing.
## The survey

### Identifying the survey panellists

The first step in conducting the survey required identification of an appropriate group of people with expertise across a broad range of maritime interests to constitute the panel or survey frame for the survey. Each Partnership member nominated 10 candidates with expertise in at least one maritime field who, in turn, were asked to nominate 10 others. Collation of the nominations resulted in a final group of 550.

### Delphi survey-first round

The initial batch of survey forms was mailed in September 1995 to the 550 panellists with a letter from the Minister with responsibility for civil ship construction seeking their assistance in completing the questionnaire and a pre-paid reply envelope. The launch of the survey was accompanied by several marketing activities, such as publication of advertisements in industry and business bulletins, newsletters and magazines, designed to improve the survey response rate. Despite these activities, the response rate a week before the closing date was such that the ASTEC Secretariat made a large number of follow-up contact calls encouraging participation in the survey. 164 first round responses were received, a response rate of about 30 per cent.

### Delphi survey-second round

The ABS consultancy group collated the results of the first round and recorded the first round self-rated expert responses shown for each topic statement and question on the second round questionnaire. Discovery of a processing error indicated that the collated first round responses were incorrect for two columns inviting multiple responses, thus requiring the dispatch of a corrected second round questionnaire, described as the second round, second dispatch questionnaire. As in the case of the first round, the ASTEC secretariat was obliged to contact over 90 respondents to the first round who had not replied by the final week for responses. 135 responses (83 per cent of first round responses) were received, representing a final overall response rate of 24.5 per cent.

### International perspective

A shortened version of the Australian Delphi survey was printed and distributed at the FAST'95 conference and exhibition, held in Travemuende, Germany in September 1995, seeking a perspective from overseas international experts attending the conference. The results were considered by the Partnership but, as the response rate was poor, the findings were not considered in the final analysis of the Australian results. Rather an international perspective was provided by a paper on 'International Trends in the Maritime Industries and Implications for Australia', drafted by the Secretariat and an industry member of the Partnership and subsequently included as a chapter in the Partnership Report.

## Survey results

### Analysis of the results

This was conducted in two stages. First, the ABS consultancy group analysed the results based on the round two results and presented their findings at a Partnership meeting in April 1996. The consultants discussed possible interpretations of the results with the Partners. They prepared a report describing the methodology, the findings of the survey and response counts which was published in full in the Annex to the main Shipping Partnership Report. Second, Partnership members provided comment on the sub-sector groups of topic statements, according to their particular expertise, thus ensuring that all topic statements were considered and commented upon.
The Partnership followed a five-step approach to establishing priorities based on an assessment of each topic statement’s combined wealth creation and quality of life impacts and Australian capabilities (see Box 1). This approach resulted in 36 of the 76 topic statements being identified as having first claims for consideration as S&T priorities in Australia. Twenty-nine of these statements formed themselves logically into main clusters around a nucleus topic statement, or two or three joint nucleus topic statements. The priority clusters thereby determined related to priority areas which had emerged separately in the Partnership discussions as key areas, namely fast ship transportation for passengers and cargo, maritime defence opportunities and EEZ resources and management.

The Partnership did not put itself in the position of picking winners. Its recommendations were based on the responses it received to a Delphi survey of informed opinion, using a 5 step rationale basis for determining priorities (Box 1) which was described fully in the Report.

The Partners invited 2-3 people from each industry sub-sector subject area to meet with them to consider the findings and to comment on the proposed recommendations. A summary report on the findings was prepared for this purpose. The workshop played an important role in the process by helping to refine, validate and support the Partnership’s conclusions and recommendations.

Two reports were prepared: a main report of 165 pages, incorporating the ABS consultancy group’s report of 88 pages, and a summary report of 30 pages for distribution to interested parties.

The Partnership made 18 recommendations addressed to industry, cooperative research centres, the Federal Government and to itself. The report contained an Action Plan for implementing the recommendations, nominating lead agencies and others with a stake in implementing a particular recommendation. Support for implementing the recommendations was sought in the ‘post foresight’ stage.
Box 1. The five steps for establishing S&T priorities in the maritime industries.

**Step 1: Assessment of wealth and quality of life impacts.**

**Rationale**
Foresight is ultimately concerned with how S&T contribute to wealth creation for Australian industry, Australian economic well-being and quality of life.

**Method**
Topic statements were examined for their assessed ability to contribute jointly to wealth creation and quality of life (i.e., a sustainable industry).

**Step 2: Identification of Australian capabilities.**

**Rationale**
S&T and innovation can only contribute to wealth creation and quality of life if they are embodied in commercial products, processes, services or regulatory activities.

**Method**
The Partnership used a weighted formula to arrive at a composite rating for Australia's capabilities (i.e., S&T capability, innovation capability, production capability or service delivery and exploitation and commercial potential) for each topic statement.

**Step 3: Identification of topic statements rated highly on both wealth creation/quality of life grounds and for positive overall/above average overall Australian capabilities.**

**Rationale**
Topic statements rated high on both grounds should have the greatest claims for consideration as priorities.

**Method**
A comparison was made between topic statements with high capability ratings and those with high wealth creation/quality of life impacts ratings.

**Step 4: Exclusion of non-starters**

**Rationale**
The Partnership considered there was no point in pursuing topic statements which respondents rated low on wealth creation/quality of life impacts and on Australian capabilities.

**Method**
The lowest rating topic statements identified in Steps 1–3 above were excluded from further consideration as S&T priorities at this stage.

**Step 5: Identification of S&T priority clusters**

**Rationale**
The sub-sector categories in the Delphi survey (e.g., ship design, industry suppliers) included topic statements which were related to one another or to topic statements in other categories. In assessing overall priorities it is logical to treat these inter-related topic statements as groups or clusters.

**Method**
By identifying high-rating nucleus topic statements, it was possible to identify clusters of topic statements with linkages and logical connections between individual items. In establishing rankings among priorities, consideration was given to the wealth creation/growth potential of the industry/industry sub-sector to which they belonged.
Post-foresight stage

This stage comprised two phases. The first phase, from September to December 1996, included the Report's launch and the publicity surrounding the launch, dissemination of the Report's findings, consultations and initial action taken to encourage implementation of the Report's findings. ASTEC's participation in the exercise ceased at the end of this phase. The second phase, beginning December 1996 and expected to last to September 1997, centres on the implementation and follow-up action to specific recommendations for which the Partnership itself is uniquely placed to contribute and to ensure that follow up action is taken. A work plan on follow up activities needing attention will be discussed at the proposed Partnership meeting in April 1997. It is envisaged that the April 1997 meeting will also consider a sunset clause for Partnership activities.

Table 4: Steps in the post-foresight stage

<table>
<thead>
<tr>
<th>Steps</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Phase</td>
<td></td>
</tr>
<tr>
<td>Report launch</td>
<td>The Report was launched by a senior Cabinet Minister, the Federal Minister for Industry, Science and Tourism, in the presence of 40 invited guests at a main Australian shipbuilding yard in Victoria. The Report attracted considerable coverage in the trade press but little national media coverage.</td>
</tr>
<tr>
<td>Institutional processes to determine</td>
<td>The Partnership adopted an <em>accommodation strategy</em>&lt;sup&gt;9&lt;/sup&gt; of seeking modifications to existing policy. The Minister for Industry, Science and Tourism stated in his media release for the Report launch that the Government welcomed the main thrust of the Shipping Partnership's recommendations and that it would take them into account when considering proposals for industry-government research initiatives.</td>
</tr>
<tr>
<td>resource allocation priorities</td>
<td></td>
</tr>
<tr>
<td>Dissemination of research results</td>
<td>The Report was tabled in Parliament and distributed to all Members of Parliament, providing an opportunity for federal legislators to comment on the Report. The Minister for Science and Technology intends to make a statement in Parliament on the Report in March 1997 at the end of the current three month consultative phase.</td>
</tr>
<tr>
<td></td>
<td>The Shipping Partnership Chairman drew relevant recommendations to the attention of a wide range of government departments and agencies for their consideration and appropriate follow-up action. The Chairman also undertook a range of activities aimed at encouraging implementation of the Report's recommendations. These activities included giving presentations at industry association meetings, writing to heads of government departments and agencies specifically mentioned in the Report's Action Plan and to others who had a significant role in implementing the Report's recommendations.</td>
</tr>
</tbody>
</table>

Second phase

Project definition and program execution

1500 copies of the Summary Report and 500 copies of the main report were disseminated widely. The Summary Report is available on the world wide web\(^{10}\) and the main report is available through Australian Government Bookshops.

A Partnership sub-committee of Canberra-based officials and an industry representative met to consider and oversee two specific project proposals arising from the study, namely an international competitiveness benchmarking study and an economic impacts study.

The Partnership is following a gradual approach to implementing its key recommendations relating to the development of an Australian shipbuilding industry development program, covering such elements as strategic marketing, design and production process improvement, collaboration and technology transfer. It is proposed that the program will provide the framework for a number of related projects that are ready to go. These include a proposed benchmarking study and an economic impacts study, complemented by other activities envisaged for the program.

The Partnership is currently drawing up an action plan covering actions relating to implementation of its recommendations. The action plan will have a 12 month sunset clause for Partnership activities.

CHAPTER THREE: PROCEDURAL OUTCOMES

The previous chapter discussed the procedures followed in the Shipping Partnership's foresight exercise, applying the foresight process model developed by Martin and Irvine (1989). The authors claim that their model 'should prove helpful in understanding why certain foresight exercises achieve significantly greater impact on priority-setting than others.'

It is now necessary to look beyond the Partnership's adherence to foresight procedures to examine a number of procedural outcomes of the exercise, such as timeliness in synchronising the results with the findings of other studies, clarity of topic statements, survey response rates, the ratio between the responses from 'experts' and total responses and the balance between industry, government and research participation in the study at its various key stages.

Timing

The Shipping Partnership was the last of the ASTEC partnerships to be established and had the longest planned program of activities, including a two-stage Delphi survey. Once it became clear that the process would not be completed within the same time-frame as the rest of the study, the ASTEC Council decided to treat it as a separate study.12

The fact that the two studies were out of step had important implications for both studies. The main study noted that overseas studies had identified the critical future importance of manufacturing-related S&T and that 'overseas studies have identified the high significance of precision and control in management, and new materials, which did not emerge from the ASTEC foresight study.' The Shipping Partnership Delphi questionnaire included half a dozen topic statements relevant to precision and control in ship construction and to the production and use of new materials. Opportunity could have been taken to expand on and draw out the implications of these topics for the main study.

Conversely, the key forces for change identified in the main study, namely global integration, applying information and communication technologies, environment sustainability and advances in biological technologies are relevant to a large number of the Partnership's Delphi topic statements and would have been useful in initial scenario analysis to help to identify a larger number of 'possible futures' topic statements for the Delphi survey.

Scope of areas to be investigated

The Shipping Partnership first decided the subject areas to be covered by the survey and then used the 1995 Roundtable to draw up a list of topic statements for each of these sub-sector areas. While this was necessary to focus the scope of the study, it could mean that some potentially important developments were not examined (eg topic statements spanning sub-sector boundaries and non-mainstream topics).

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12 ASTFC, Future Needs 2010, p. 366
13 Ibid., Foreword.
Respondents were invited to write suggestions for additional topic statements in boxes at the end of sub-sector groups of topic statements in the questionnaire. They nominated a total of 68 'additional topic statements', only 8 fewer than the 76 topic statements included in the survey.

However, an examination of these additional topic statements revealed that 33, or just under a half, were variations of the listed topic statements and a further 20 could be regarded as 'comment' on the topic statements. The remaining topic statements could be divided evenly into three main categories:

- additional environment topics (eg 'effective, environmentally-benign, surface coatings prevent fouling of ships by marine organisms');
- alternative government policy development scenarios (eg 'Australia has abandoned any pretence of maritime capability and imports all requirements'); and
- a series of topic statements relating to wing-in-ground effect craft (eg 'large ekranoplan (400 passenger 400 km/hr) working the east coast of Australia will redefine Australian transport systems for passengers and freight and tourism').

The fact that most developments associated with the topic statements in the questionnaire are expected to be realised before the year 2000 led to the criticism by some Partnership members that the topic statements chosen were not visionary enough. Against this, it could be argued that, given the large number of comments by round one respondents that they found many of the survey topics to be 'too difficult' or 'not for Australia', the Partnership would probably have received far fewer questionnaire responses if its selection of topic statements had been more 'visionary'.

Comments received from round two respondents did not suggest that the topics lacked vision. The Partnership concluded, therefore, that the inclusion of any further visionary statements would have produced more negative responses from people who took the time to fill in the questionnaires; and that the questionnaire was pitched at the right level for the present position of Australia and the attitude of Australians in the maritime industries.

The relevance of the Royal Society's criticism of the UK postal Delphi survey

The Royal Society criticised the UK Technology Foresight postal Delphi survey, claiming that it proved to be 'largely worthless to date and was held in low esteem by many panellists'. Its particular criticisms of the UK Delphi survey, and their relevance to the Australian study are examined in Table 5. The Society's criticisms of the UK survey are listed in the first column. The relevant comparable Australian experience is described in the second column, while the third column provides comment.

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14 For example, 'Politicians should place road, rail, air and sea transportation on a level playing field.'

Table 5: The Royal Society's criticisms of the UK Technology Foresight Delphi survey and their relevance to the Shipping Partnership Delphi survey.

<table>
<thead>
<tr>
<th>The Royal Society's criticism</th>
<th>Shipping Partnership Delphi experience</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>The questions were often too vague to give analysable answers.</td>
<td>The same criticism was made by the survey respondents.</td>
<td>The key word is 'often'. The Australian Bureau of Statistics consultancy group played a key role in converting prospective statements into survey analysable statements. Presumably, topic statement definition will improve with experience in using the surveys.</td>
</tr>
<tr>
<td>The response rate for the first round Delphi appears to have been at most 33%.</td>
<td>The response rate was 30% for the first round and 24.5% for the second round</td>
<td>Response rates for voluntary, time-consuming, complex surveys of this kind are of this order. (See also the comparison of the Shipping Partnership's Delphi response rates with the response rates of other Delphi surveys in Table 6 below.)</td>
</tr>
<tr>
<td>Well over half of the respondents were typically no more than 'casually acquainted' with any given issue.</td>
<td>The Shipping Partnership questionnaire did not have a 'casually acquainted' category. The ratio of responses from self-rated experts to all respondents averaged 50% for all topic statements. However, there were wide variations across subject areas, from an average of 62% for industrial supplier and R&amp;D topics to an average of 44% for cargo topics.</td>
<td>A 1992 Japanese assessment of the reliability of Delphi forecasts found that there was little difference in the forecast success rates of 'experts' and 'non-experts'. Indeed, international experience suggests there are advantages in including non-experts in the survey population to counter expert bias. The skewed distribution towards the middle of the range of self-rated expertise (on a scale of 1-5) suggests that people in both surveys were taking the level of expertise question seriously.</td>
</tr>
<tr>
<td>The timing was such that many key panel recommendations were formulated before the Delphi results were available.</td>
<td>The Shipping Partnership's recommendations were formulated after the ABS consultancy group had reported on the survey findings and discussed these with the Partnership</td>
<td>This seems to be a major Royal Society criticism of the conduct of the UK exercise.</td>
</tr>
<tr>
<td>The cost in terms of time and money were out of proportion to what the survey contributed to panels' thinking.</td>
<td>The Partnership's recommendations were firmly based on the survey results</td>
<td>Chapter 5 discusses cost-benefit considerations relating to the Partnership's use of the Delphi survey as a foresight tool.</td>
</tr>
</tbody>
</table>
The Royal Society’s comments focus on problems experienced with the Delphi survey and its cost-effectiveness as a foresight tool. Particular criticism seems to be directed at the conduct of the UK Technology Foresight exercise, whereby, in its view, key panel recommendations were formulated before the Delphi results were available, thus marginalising the potential benefits of the survey.16

Comparative response rates for first use of Delphi surveys

Table 6 compares the response rates for the Shipping Partnership Delphi survey with the response rates achieved in the first use of Delphi surveys for foresight purposes in other countries.

Table 6: Response rates for the first use of Delphi surveys for foresight purposes in Japan, the UK and Australia (percentages)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>First round</td>
<td>34</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>Second round</td>
<td>27.5</td>
<td>16.5</td>
<td>24.5</td>
</tr>
<tr>
<td>(final response)</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

16 The UK-based firm, Segal Quince Wicksteed (SQW), played a key role in helping the UK Government to set up and manage the UK Foresight Programme and its follow up activities. While accepting the validity of some of the Royal Society’s criticisms, ie that the UK Delphi questionnaire was too complicated and the results were not available in time to influence the panel reports sufficiently, they report that:

'In our experience the most effective (though still expensive) form of wider consultation was the programme of regional workshops held for each sector.

In small groups (usually a mixture of organisations), participants were able to debate in depth not just 'hard' issues such as technological developments, but also 'soft' issues which can be barriers to innovation, (such as infrastructural constraints, regulations, skills) which are more difficult to formulate as unambiguous Delphi statements.

Although Delphi results are not a precise forecast, the Delphi report provides excellent source material to stimulate people to consider possible developments and their implications for individual businesses. The results present a graphic picture of the future business environment to which businesses will have to adapt or die, eg, changes in intra and inter-firm communications, relationships between large firms and their suppliers, information capture and processing, and electronic marketing, selling and transactions.

In our dissemination programme of workshops, we have drawn extensively on Delphi results to illustrate points, to make people think and to stimulate high quality discussion between the various communities. Delegate reaction has almost always been favourable to this approach of bringing Foresight to life through practical examples. For example, one interesting and important conclusion is that, contrary to much conventional wisdom, wealth creation and improving the quality of life are frequently not incompatible.' (Communication with the author, February 1997).

17 The UK Transport Delphi response rates for the first and second round were 35% and 47%, respectively. (Source: PREST: communication with the author, February 1997.)
As can be seen, low response rates seem to be the order for the first use of the time-consuming and complex Delphi surveys. Hariolf Grupp, Head of the Technological and Industrial Change Department, Fraunhofer Institute for Systems and Innovation Research (ISI), Karlsruhe, Germany (which conducted the German Delphi surveys), commented in a recent article that ‘...as a rule of thumb, detailed and time-consuming questionnaire surveys with a response rate of some 15 or 20 per cent are considered successful’.  

The 1971 Japanese Delphi survey was the first in a series of quinquennial surveys in that country. Although a response rate of 80 per cent has been claimed for the survey, if one takes into account the initial refusal rate of 57 per cent (3,400 of the 6,000 experts invited to participate refused to do so) and subsequent losses in the two stages, the figures for the first round and second round responses would be more conventionally calculated at 34 per cent for the first round response and 27.5 per cent for the second round, final response.

**Balance between industry, government and research interests**

International experience with the Delphi suggests the need to involve industry, government and research interests in the survey and stresses the need for a balance between these interests. Indeed, Japan’s Science and Technology Agency (STA) goes to great pains to ensure that these interests are well-represented at all stages.

Table 7 shows the balance between industry, government and research interests at key stages of the Shipping Partnership experience. It will be noted that industry interests were well-represented at all stages – at the Roundtable, which proposed the list of topic statements for the Delphi survey, in the survey population and in the final list of respondents.

Table 7 also shows a relatively disproportionate research representation at the Roundtable stage (but not at subsequent stages). This may have affected the balance between straightforward ‘demand-pull’ and ‘science-push’ topics in the survey, though, as will be seen in Chapter Four (Table 8) most survey topic statements combined supply and demand considerations.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Industry</th>
<th>Government</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundtable</td>
<td>50</td>
<td>17.5</td>
<td>32.5</td>
</tr>
<tr>
<td>Survey panellists</td>
<td>58</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>Second round respondents</td>
<td>55</td>
<td>25</td>
<td>20</td>
</tr>
</tbody>
</table>

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**Notes:**


19 See discussion in Martin and Irvine (1989) p. 188, Note 17.

20 NISTEP officials told an ASTEC exchange officer (1996) that they see little point in national advisory councils conducting Delphi surveys if there is not a substantial industry and academic grouping within the country.
Topic statement definition

The Shipping Partnership’s experience with a macro-level Delphi also suggests that special attention needs to be given in these exercises to specifying which sector or subsector a particular topic refers to, since macro surveys by definition cover a number of industry sectors.

While foresight discussions in the Partnership straddled all four industry sectors covered by the survey (ie the naval construction, fast ferry, shipping operations and marine sectors) and these discussions were useful for identifying areas of synergy (eg the possible use of light-weight vessels in military or EEZ surveillance roles) there were times when it would have been useful to further distinguish between the various sectors when formulating the topic statements.21

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21 For example, the survey topic statement: Australia has gained a substantial share of the regional market for specialised ships, received the highest overall ranking for Australian capabilities. However, ‘specialised ships’ can refer to a number of vessels, such as fast ferries or naval off-shore patrol combatants. A considerable number of respondents who expressed views on this topic felt compelled to stipulate the sector to which their comments referred.
CHAPTER FOUR: CRITICAL SUCCESS FACTORS

Several conclusions about critical success factors have emerged from international reviews of foresight exercises. These include the appropriateness of the approaches and techniques applied, the authority, legitimacy and credibility in the way the exercise is conducted and the need to strike the right balance between 'technology push' and 'demand-pull'. An examination of international experience, focusing on Delphi surveys, reveals two additional critical success factors relating to using Delphi surveys as a foresight tool: understanding the instrument and openness in conducting the exercise, combined with flexibility in interpreting the survey results. The Shipping Partnership's experience with the Delphi survey is discussed in the light of these success factors.

Appropriateness

One of the main conclusions to emerge from the 1996 OECD STI review of international foresight exercises is that there is no 'perfect' or right foresight approach: each approach has its own strengths and weaknesses and individual countries might adopt quite different approaches to suit their circumstances.

Martin and Irvine (1989) place stress on ensuring that the approaches and techniques used for foresight are appropriate to the type of exercise undertaken, according to the level of specificity of the study (at the holistic, macro-level, meso-level or micro-level) or to the aims and objectives of the study (direction-setting, determining priorities, consensus-generation etc). Some approaches are better suited to specific purposes than others. Martin and Irvine assert that anticipatory intelligence needs to be carried out at an holistic or macro-level, otherwise it is extremely difficult to monitor developments in cross-disciplinary areas. They note that Delphi surveys are particularly suited to consensus-generation, but may be not as well-suited as other methods, such as scenario analysis, for direction setting.

The 1995 PRISM model

In an ASTEC Commissioned report for the Future Needs 2010 study: Recent Foresight Studies: Implications for Australia (1995), Bourke and Butler cite, as one of the 'more interesting examples of a foresight project pursued outside government' the 1995-96 PRISM study on Foresight in Science: An experiment in the field of cardiovascular research. According to the Martin and Irvine classification, discussed in the previous chapter, the PRISM study could be classified as a medium-term, micro-level exercise, using a combination of formal quantitative and informal qualitative methods and stressing the functions of determining priorities, consensus-generation, advocacy and communication and education.

The approach used in the PRISM study of 'grounding the inquiry in a careful bibliometric profile of existing strengths in cardiovascular and related research in comparison with international practice' appears to be relevant to the particular type of study and the field of research being

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23 Bourke and Butler (1995), p.27.
studied, but may not be relevant to studies in other fields. In a number of categories investigated by Bourke and Butler and relevant to the Shipping Partnership study, such as *Modelling, Simulation and Prediction of Complex Systems, Materials and Management and Business Process Engineering* very few publications were identified by the key word searches and, where identified, the Australian presence was, at best, modest.

Bourke and Butler commended the PRISM study for combining the advantages of different approaches (eg combining a short term (five year) Delphi survey on such topics as the potential for scientific advance, for different types of interventions, for improving infrastructure and for exploiting the results of cardiovascular research with scenario analysis).

When it became evident that the first round responses to its Delphi survey were fewer than it had hoped for, the Shipping Partnership considered what additional work might be needed to complement the Delphi survey, including adopting the PRISM idea of workshop scenario panels to complement the Delphi survey results.

However, it concluded that scenario workshops at such a late stage in the exercise would not have added much foresight value since many of the types of questions explored by the PRISM scenario workshops had already been included in the Delphi. Further, the scenario workshops most likely would have involved the same participants in the original Roundtable and the survey, given the small size of the maritime expert communities in Australia. Rather, the Shipping Partnership chose to hold a workshop with 2-3 invited participants from each survey sub-sector area which acted as an informal ‘light touch committee’ to assess and validate the Partnership’s conclusions and recommendations.

Nevertheless, the PRISM idea of combining methodologies does seem to have merit and, in retrospect, the Shipping Partnership’s study would have been the better for it. Scenario workshops, at the *beginning* of the exercise, would have been a useful means of incorporating greater foresight into the choice of questions investigated in the Delphi survey, but these were precluded by the time span proposed for the study.

*The need to devote adequate attention to all three stages of the exercise*

Martin and Irvine stress the importance of giving due care and attention to the main procedures in all the three pre-foresight, main foresight and post-foresight stages in their conceptual model. In suggesting this structure of the foresight process, they state that their intention is to:

> ‘provide an *heuristic* model enabling a better understanding to be developed of the nature and role of the different tasks in foresight, how the various elements are interrelated, and the likely effects on the overall priority-setting process of a failure to execute successfully any of the main steps involved.’

They point out that many foresight exercises have failed because they gave insufficient attention to the issues which need to be addressed in the pre-foresight or the post-foresight stages. The previous chapter used Martin and Irvine’s conceptual framework to discuss the procedures in the Shipping Partnership exercise. All the necessary steps proposed in the framework were followed, even though, in retrospect, even greater care and attention could have been given to some key procedures in the pre-foresight and main foresight stages.

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Authority, legitimacy and credibility

Martin and Irvine comment that one of the ‘broader’ lessons that emerged from their review is that authority, legitimacy and credibility are fundamental to success in foresight. In priority-setting exercises like the Shipping Partnership study, authority, provided through the involvement of high-level officials in determining terms of reference is required to ensure policy impact; legitimacy is most commonly guaranteed by involving experts and opinion-makers from the main stakeholders; and credibility is provided by adhering as much as possible to ‘the established norms of social science which stress systematic approaches to theory construction and data generation’.25

In the Shipping Partnership experience, the nomination of senior officials from four relevant government policy advising and R&D funding departments, as well as key industry/industry associations, Cooperative Research Centres and learned societies, ensured that the project was seen as authoritative. If, after assessing the Shipping Partnership’s recommendations, the Government feels that implementation of some or all of the recommendations is appropriate, the involvement of senior officers will help to ensure that the recommendations are implemented.

Organisational problems prevented a key industry association, representing fast-ferry sector interests, from confirming its membership for 11 months and, while then formally a member of the Partnership, it seemed often to be not represented at its meetings. However, had the association stood aloof from the exercise altogether, the Partnership’s authority would have been undermined.

The Partnership’s own broadly-based membership of 17 members, representing government, industry and research interests, combined with high-level member representation and near full attendance at its meetings, gave the project legitimacy. As was noted in Table 7 in the previous chapter, this balance of interested parties was reflected in the composition of the participants in the original Roundtable to draw up a list of survey topics, in the proposed survey population and in the number of second round respondents. The results of the survey were fed back to the Roundtable participants and to the second round respondents, thus completing the consultation-feedback loop. The Chairman’s presentations and consultations in the post-foresight stage, aimed at encouraging implementation of the Report’s recommendations and wide distribution of the Report, involved a wider audience in the consensus-generation and communication and education processes.

The Australian Bureau of Statistics consultancy group’s help with the design and development of the Delphi survey, their provision of statistical advice and assistance and their processing the survey data lent credibility to the project. The ABS consultancy group’s report on the survey was published in full in the Annex to the main Shipping Partnership Report. The Partnership’s own analysis of the results and their 5-step approach to developing priority clusters was transparent, systematic and contestable.

While the study’s statistical and strategic analysis adhered to ‘the established norms of social science’, the bottom line is that the survey findings came from a case study of 135 people with some expertise in at least one maritime industry area. With a final response rate of 24.5 per cent, it is difficult, as the ABS consultancy group’s report points out, to infer with reasonable levels of

25 Ibid., p. 335.
confidence the survey results, beyond those who did respond, for the maritime industry as a whole. Further, there is no reliable way of checking the completeness of the survey frame.

Balance between science/technology push and demand pull

The 1996 OECD STI Special Issue on Government Technology Foresight Exercises claimed that:

'... successful foresight involves balancing 'science/technology push' with 'market pull' - in other words, identifying likely demands relating to the economy and society as well as scientific and technological opportunities.'

All the studies with which the Shipping Partnership’s study was compared in Chapter One would claim that they managed to strike the right balance between ‘science-push’ and ‘demand-pull’ for their purposes. Even the 1992 NISTEP Delphi survey, which is described in Table 1 as having a ‘science-push’ emphasis, sought input from a large number of experts from science-based companies and other research users and struck a balance between industry, universities and government interests in the 16 oversight subject area panels.

For studies using Delphi surveys, the selection of topic statements is a good indicator of the balance between the emphasis on ‘science-push’ and ‘demand-pull’ in the study. Table 8 classifies the 76 topic statements in the Shipping Partnership survey into three categories: ‘demand-pull’ statements, combined ‘demand-pull’-‘science push’ statements, where supply and demand considerations are implicit in the topic statement, and ‘science-push’ statements. Examples are given for each category. Respondents were asked to express their view on when the events might occur, Australian capabilities, likely constraints etc.

As can be seen from Table 8, the majority of topic statements in the questionnaire were in the combined ‘demand-pull’-‘science-push’ category. There was a large number of ‘science/technology push’ statements and a only a few ‘demand-pull’ drivers of change-type statements in the questionnaire.
Table 8: Balance between ‘demand-pull’ and ‘science-push’ in the Shipping Partnership Delphi topic statements

<table>
<thead>
<tr>
<th>Category</th>
<th>‘demand-pull’</th>
<th>‘combined ‘demand-pull’– ‘science push’</th>
<th>‘science-push’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of topic statements in the category</td>
<td>6</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Examples</td>
<td>Hub port facilities, which target product distribution and future markets, have been developed. Environment regulations have a significant impact on ship design.</td>
<td>Shipping and storage technology, which provides a competitive advantage in the transport of quality perishable food products, is in widespread use. Commercially available technology is in widespread use in warships. Intelligent marine traffic management for navigation in congested and environmentally sensitive waters is widespread.</td>
<td>New materials, ie other than conventional steels and aluminium, are in widespread use. Mechanisation, automation and advanced robotics are in widespread use in ship manufacture. Dust control technology allows loading and discharge of powdered bulk cargoes at increased rates. Technology which reduces all vessel emissions to background levels has been developed.</td>
</tr>
</tbody>
</table>

Understanding the Delphi survey

Delphi surveys have been used in Japan for foresight purposes for over 25 years. Further, Japanese private sector involvement in the surveys and support for research and development has traditionally been high. In contrast, Delphi surveys have not been used widely in Australia and private sector support for research and development has not been great. The ASTEC Future Needs 2010 project was the first major, comprehensive attempt to develop a technology foresight culture in Australia.

That respondents found the questionnaire difficult to understand and interpret is evident in the following sample of written comments by respondents to the round one questionnaire:

‘I found that many of the ‘topics’ in this questionnaire obscure and even nonsensical. It seems in an effort to be comprehensive a lot of superfluous material has been added.’

‘I think a simpler document with less options for answers may have given a more meaningful result.’
What is a ‘topic statement’?

The Shipping Partnership’s Report describes Delphi topic statements as statements which ‘postulate developments which are considered to be relevant to, and likely to shape the future of, the Australian maritime industries over the period to 2010’. The survey questionnaire asks the survey panellists to comment on ‘topics’ that are considered likely to shape the future of the maritime industries.

The written comments by round one respondents indicate some confusion over the nature of the topic statements presented in the questionnaire. Statements such as, ‘don’t agree with the proposition’ ‘statement not true’, ‘they are not in use’ and ‘is this true?’ suggest that these respondents considered the topic statements to be statements of fact. Other comments, such as ‘we have not encountered this problem’, ‘Australia is too remote to pull business’, ‘we do not make this equipment’ and ‘wishful thinking’ suggest an unwillingness to consider possible future choices for Australia, while comments such as ‘not at present, but is the way to go’, ‘benchmarking is not as wide spread as it could be’ ‘Australia has the expertise to lead in this field’, ‘would be seen as highly desirable by all ship owners’, ‘worthwhile’ and ‘this is very necessary! Now’ give strong indications of preferred developments and, by implication, preferred futures for the maritime industries.

In its Future Needs 2010 study ASTEC discussed looking to the future in terms of:

- **expected futures** - the analyses of experts based on current trends and extrapolations;

- **preferred futures** - those a community wants to achieve - individual values, strategies of corporations and community organisations and government policies; and

- **possible futures** that provide a range of options for a world which might change significantly over time - focussing on critical uncertainties and trend-breakers.

Using this framework, it can be seen from Table 9 below that the majority of topic statements in the Shipping Partnership Delphi survey were in the *expected futures* category. Many of the statements in this category are identified by the inclusion of the phrase ‘in widespread use’ or the word ‘substantial’, which indicate an expected and - in some cases - quantum change to the current position. Twenty-six statements were in the *possible futures* category and it was this group of statements with which respondents to the first round seemed to have had the most difficulty. There were only 7 statements in the *preferred futures* category but, if the above samples of written comments is any indication, respondents would like to have seen more statements in this category in the questionnaire.

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Table 9: Shipping Partnership survey topic statements in the expected, preferred and possible futures categories.

<table>
<thead>
<tr>
<th>Category</th>
<th>Expected futures</th>
<th>Preferred futures</th>
<th>Possible futures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of topic statements in the category</td>
<td>43</td>
<td>7</td>
<td>26</td>
</tr>
<tr>
<td>Examples:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A systems integration approach to ship manufacture, using modular assembly, is in widespread use.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australian shipbuilders with certification to ISO 9000 series are able to deliver vessels with certification of compliance with regulations.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-discharging vessels are in widespread use in a range of trades.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced information technology which facilitates cargo movement is in widespread use (eg EDI, chartering via internet, paperless trading)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia has gained a substantial share of the regional market for specialised ships.</td>
<td></td>
<td></td>
<td>Widespread use of virtual reality has provided significant improvement in ship design.</td>
</tr>
<tr>
<td>Intelligent marine traffic management for navigation in congested and environmentally sensitive waters is widespread.</td>
<td></td>
<td></td>
<td>New materials, ie other than conventional steels and aluminium, are in widespread use.</td>
</tr>
<tr>
<td>A sustainable Australian industry base is capable of the design and development of all types of warships.</td>
<td></td>
<td></td>
<td>A solution to cleansing ballast water of exotic organisms has been developed.</td>
</tr>
<tr>
<td>Marine farming has substantially replaced the fishing of wild stocks.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It is believed that respondents would have had less difficulty in responding to the topic statements if more time had been spent explaining the survey instrument to the nominated survey panellists. This would also have provided an opportunity to explain that some statements referred to expected futures which were extrapolations of current trends, some referred to preferred futures and others referred to possible futures, for which there may be only weak signals of the changes that might occur, and which by taking action, the Australian Government and industry can influence the turn of events to Australia’s advantage.

The comment made earlier in this chapter that the study would have benefited from greater brainstorming, including scenario analysis, at an early stage to help select the topic statements for the survey would presumably have resulted in more topic statements in the possible futures category and given the survey a more visionary and longer-term focus.

**Openness in the process and flexibility in interpreting the Delphi results**

The ASTEC Future Needs 2010 Report stresses the importance of ‘openness’ in foresight processes which ‘allows non-conformist views to be given equal weighting with conventional ones and allows the possibility of identifying emerging paradigms’.27

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27 ASTEC (1997), *Foreword.*
Similarly, Martin and Irvine (1989) caution against drawing too formal a link between foresight and priority-setting - a caution which is particularly relevant to foresight exercises based on Delphi surveys which have an in-built bias towards consensus-generation:

‘The two tasks are separate: the role of foresight is indicative not prescriptive. The primary aim is to explore and assess the merits of alternative research options, not to make definitive judgements on priorities. This always needs to be kept in mind when planning a foresight exercise since too close a relationship with resource allocation will ... generally result in conservatism and a stress on protecting status quo interests, whether disciplinary, sectoral or institutional.’

The Shipping Partnership’s priorities and recommendations, based on the priority-rationale outlined in Box 1 in Chapter Two, were not intended to be prescriptive. In the Foreword to its Report, the ASTEC Chairman wrote:

‘Learning, by definition, is an ongoing process. The Shipping Partnership’s findings - its identification of S&T priority areas and its list of recommendations relevant to the future of Australia’s maritime industries - should be seen, therefore, as a further step in the dialogue among members of the Partnership and between the Partnership, industry and government.’

The Partnership Chairman’s consultations in the post-foresight phase highlighted a point of more general application to technology foresight exercises, namely that, while wealth creation and quality of life are the two goals of technology foresight, too little emphasis tends to be given to the latter in the formation of topic statements, in the analysis of the results and in the formulation of recommendations. In response to views expressed in these consultations, and as a further indication of its openness in approach, the Partnership agreed to construct a new ‘commercial ships and pollution prevention priority cluster’ to better reflect the salience of these issues in the survey results.

The UK Technology Foresight Transport Panel Report, commenting on the consensus-generating characteristic of Delphi surveys, pointed out that the original philosophy behind the development of the Delphi method was that ‘extreme’ responses could be associated with particular points of view and important items of information. This evidence should be fed back to the respondents, so that they might be able to be better informed as to the reasons for the lack of consensus. But, as in the case of the UK and many other Delphi studies, this feature was not incorporated in the Shipping Partnership study, partly because of time pressures and partly also because of the agreed two-stage survey questionnaire process.

While no formal analysis was undertaken of the consensus-generating effect of the two-round Shipping Partnership survey, there appears to have been a minor shift in the views expressed by respondents towards an earlier time frame for the realisation of developments in many topic statements and from the ‘Australia at leading edge’ and ‘Australia lagging’ categories towards the ‘Australia average performance’ mean position for assessed Australian capabilities in S&T, innovation, production and commercialisation.

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CHAPTER FIVE: COST-BENEFIT CONSIDERATIONS

As in the case of the ASTEC Future Needs 2010 study, the benefits from the Shipping Partnership's study can be discussed under two basic headings:

- *process* benefits, (eg through involving industry and government in forward-thinking and improving dialogue between researchers and industry), and

- *product* benefits, (eg the production of a useful set of action-focused priorities and recommendations).

International experience suggests that the process benefits of foresight are as important, if not more so, than the immediate outputs (eg forecasts, lists of priorities).\(^{31}\) Those aspects of the foresight process which are deemed to be most important are often referred to as the ‘five Cs’ (Martin and Irvine, 1984).\(^{32}\) They are:

- communication - bringing together disparate groups of people and providing a structure within which they can communicate;

- concentration on the longer-term - forcing individuals to concentrate seriously and systematically on the longer-term;

- co-ordination - enabling different groups to co-ordinate their future R&D activities;

- consensus - creating a measure of consensus on future directions and research priorities; and

- commitment - generating a sense of commitment to the results among those who will be responsible for translating them into research advantages, technological developments and innovations for the benefit of society.

As indicated in Chapter Two, the Australian maritime industries and maritime research communities are relatively small. Members in one community have contact, even if infrequent, with members in other communities and each year there are a number of occasions, such as meetings, workshops and conferences, when members of the various communities come together. Representatives of the Shipping Partnership knew one another before they first met at Partnership meetings and this familiarity facilitated dialogue at meetings. The Partnership and its study, therefore, did not have a major *communication* role to play in *bringing together disparate groups*, though it did have a role to play in focussing discussion on future S&T developments likely to affect member organisations, collectively or individually.

The Shipping Partnership Delphi survey, like other Delphi surveys, did require the survey panellists to *concentrate on the longer-term* and to spend some time doing this. In addition to the time spent completing the questionnaire, a considerable number of respondents, particularly the second round respondents, spent a great deal of time thinking about the topic statements and providing written comments as, for example, the following comment:

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'Over the next three years my scenario is that international competitors will be seeking to enter the high speed vessel construction industry. Although Australia is currently a world leader in construction, we are small in comparison to any prospective international builder. It is unlikely we will be able to meet all world demand for fast vessels. Unmet demand will be dangerous for the Australian industry as it makes it attractive for competitors to move in and take up unmet demand. Larger international competitors will be likely to have the advantage of economies of scale working for them. This means that they will be able to reduce production costs to a point where they may be competitive with Australia. I don't think we can avoid this likely scenario. We should see it as inevitable and quickly move on to developing the next phase of high speed vessel technology.'

On some questions, more than 20 per cent of the respondents provided considered written comments.

While the Partnership did not see itself as a coordination committee for future R&D activities relating to its recommendations, Partnership discussions in the post-foresight stage led to agreement on follow-up activities, including initiating a world's best practice benchmarking study.

The Delphi survey approach, and the agreement-by-consensus approach followed in Partnership meetings, generated a sense of commitment to the results among those who will be responsible for translating them into research advantages, technological developments and innovations. Partnership representatives included senior officials responsible for advising government on marine industries and naval construction issues and for program management in these areas. A sub-committee of Canberra-based Partnership members met in the post-foresight phase to discuss implementation of key recommendations in the Report.

The foresight process resulted in three products; publication of Background Papers, prepared for the August 1995 Roundtable meeting, a 20 page Summary Report which was distributed widely to members of the Australian maritime communities and the main Partnership Report: Australian Maritime Industries Priorities in Science and Technology, which contained the survey results, Partnership analysis and comments on the survey findings and a list of 18 recommendations. The main Report also included, as an Annex, the full Australian Bureau of Statistics consultancy group report on the survey.

When launching the Shipping Partnership's Report, the Minister for Industry, Science and Tourism, a senior Cabinet Minister, stated that the Government 'welcomed the main thrust of the Shipping Partnership's recommendations' and that 'the Government would take into account the report's recommendations when considering proposals for industry-government research and development initiatives'. The Federal Minister for Science and Technology intends to make a statement in the Federal Parliament in March 1997 on the Government's response to the Report and its recommendations.

The Partnership's recommendations relating to benchmarking have been taken up by the relevant government authorities. Preparations for an international competitiveness study are underway. The benchmarking study could be regarded as a down-stream product of the exercise. It is quite possible that the process will result in other down-stream products, such as a study on skills requirements for the industry, as discussions proceed in the post-foresight phase.

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While it is too soon to contemplate making an assessment of the reliability of the Shipping Partnership Delphi Survey’s forecast of developments, it is worth recording that a 1991 Japanese assessment of the reliability of Delphi forecasting, which focused on 530 topics in the earlier 1971 survey which had been forecasted to be realised by 1991 (ie within 20 years), found that 28 per cent of the topics had been fully realised and a further 36 per cent partially realised. In other words, the forecast trends had been realised for just under two-thirds of the statements in the 1971 survey. It is not surprising, therefore, that Japanese authorities consider that Delphi-type forecasting in their country has been sufficiently reliable to form a basis for the development of long-term R&D strategies.

Delphi approaches are costly. Table 10 provides a rough estimate of costs to date for the Shipping Partnership, covering the pre-foresight, main foresight and the first phase of the post-foresight stages. The Table shows these costs in the following categories: survey costs (consultancy costs for providing statistical advice and assistance, including the processing of the completed questionnaires and postal costs), secretariat assistance (the cost of providing ASTEC secretariat staffing support - February 1995 to August 1996 - for the exercise, based on an estimated two-thirds of an officer’s time devoted to the project), report production, printing and meeting costs.

Table 10: Estimated costs of conducting the Shipping Partnership Delphi study

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey costs</td>
<td>$57,000</td>
</tr>
<tr>
<td>Secretariat support costs</td>
<td>$100,000</td>
</tr>
<tr>
<td>Report production and printing costs</td>
<td>$38,000</td>
</tr>
<tr>
<td>Meetings: (Roundtable, Workshop)</td>
<td>$15,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$210,000</td>
</tr>
</tbody>
</table>

Source: Shipping Partnership Budget files

These costs to ASTEC were defrayed by Partnership contributions amounting to $140,000, or two-thirds of total costs. Survey participants in-kind contributions amounted to an estimated additional $60,000 (estimated executive costs in completing the questionnaires and participants’ costs of attending the 1995 Roundtable). Although the ABS consultancy group quoted and charged $57,000 for survey related costs, their experience with the complexity of the Delphi methodology indicates that future repetitions of the survey would cost substantially more.

Table 11 provides a comparison of the Shipping Partnership’s estimated total costs with the estimated total costs of two other ASTEC partnerships which used other foresight approaches. It can be seen that, while the Delphi survey option was the more expensive option, it was not inordinately so.

Table 11: Comparison between the estimated costs of conducting the Shipping Partnership study and other selected ASTEC partnership studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Estimated costs ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping Partnership (Delphi)</td>
<td>210,000</td>
</tr>
<tr>
<td>Water (scenario analysis)</td>
<td>180,000</td>
</tr>
<tr>
<td>Youth (scenario analysis and opinion survey)</td>
<td>160,000</td>
</tr>
</tbody>
</table>

Source: ASTEC estimates
CHAPTER SIX: CONCLUSIONS

It is clear from this examination of the Shipping Partnership's experience with the Delphi survey as a technology foresight tool that the Delphi technique has a number of advantages:

first, it provides a distillation of views of a wide range of experts which can be used to build a rational basis for determining priorities and recommendations for action on specific issues. A number of Partners found the technique’s quantitative methods for arriving at indicative priorities across sectors attractive. However, particular attention needs to be given to the choice of participants in the roundtables, or other means of proposing survey topic statements, and to topic statement definition;

second, the macro-level Delphi survey is well-suited for considering likely longer-term developments, although this potential was not exploited as fully as it could have been in the Partnership survey, since the majority of respondents considered that the postulated developments would have occurred in the short-to-medium term. As has been suggested earlier in this Paper, it is believed that more effort up front devoted to brainstorming or scenario analysis would have resulted in the study having a greater long-term focus;

third, the Delphi survey technique seems to have been reasonably good in generating the process benefits, described as the foresight process ‘five Cs’ - encouraging communication, fostering concentration on the longer-term (with the above caveat), providing a means of coordination, encouraging consensus and generating commitment to the foresight results.

On the other hand, the Delphi process was expensive and time-consuming, for both organisers and participants. Delphi survey procedures require a great deal of care and attention, particularly in the pre-foresight design phase to formulating topic statements and to identifying the survey population, as these steps are crucial to survey outcomes. They also require diligence in administering the survey, rigour and flexibility in interpreting the survey results and determination to persevere over a long, drawn-out process and to overcome the inevitable set-backs.

As the first major technology foresight exercise applying the Delphi survey technique in the Australian maritime industries, the Delphi survey encountered many problems associated with the absence of a foresight culture in those industries. Hopefully, this will improve as a result of the exercise.

In short, despite the limitations that have been noted in this Paper, particularly its relatively small scale, the Shipping Partnership's study using the Delphi survey did prove to be a useful exercise, the results of which are already becoming apparent in improved dialogue between research users and producers and in action already taken on some of the Report’s key recommendations.
POST SCRIPT

A few comments are in order on what the survey revealed about the approaches, views, aspirations and expectations of the respondents.

It is clear from a comparison of the written comments received from the first and second survey rounds that the respondents to the Delphi survey were 'learning by doing'. In their first round comments, respondents indicated that they were having difficulty coming to terms with the questionnaire by questioning the facts, relevance and intent of the topic statements. However, by the second round, respondents showed signs of engaging in dialogue on the issues raised in the topic statements (eg by giving their reactions to first round response figures). Many of these second round comments were particularly useful in drawing out implications from the survey results. They were taken into account by the Partnership when commenting on individual topic statement outcomes (Chapter 4 of the Shipping Partnership’s Report).

It is clear from the respondents views and comments on EEZ sub-sector topics that Australia as a nation has yet to come to terms with the implications and responsibilities associated with acquiring vast 'oceans of wealth' under the United Nations Law of the Sea Convention. While most respondents expressed views on the EEZ sub-sector topics, few considered they had expertise in the area. This was also reflected in the virtual absence of suggestions for additional topic statements for this area.

It was notable that many participants in the survey were seized with the importance of Australia having viable shipping, shipbuilding and marine industries. Many hoped that the survey would bring about a sea change in government, industry, union and public attitudes to these industries which would be reflected in greater government leadership and increased industry and government R&D expenditure and skills training.

Respondents recognised that the days of large shipbuilding in Australia were over and that opportunities would lie in niche markets. The fast ferry industry's success in export markets was welcomed as a sign of the phoenix rising and received a great deal of empathetic comment and support from respondents from other industry sectors. Recognition of export opportunities in the Asia Pacific region, possible joint-ventures and collaboration and technology transfer opportunities involving countries in the region did not receive as much emphasis as might have been expected, given Australia’s growing economic engagement with these fast-growing regional economies.

Finally, it is evident that the Delphi survey results contain a rich source of data and information relevant to the future of the Australian maritime industries which the Partnership has only just begun to tap and which warrants further exploratory time and effort.
APPENDIX A: MEMBERS OF THE AUSTRALIAN SCIENCE, TECHNOLOGY AND ENGINEERING COUNCIL

Professor John Stocker
Chairman and Chief Scientist

Professor Ron Johnston FTSE (Deputy Chairman)
Director, ACIIC
Faculty of Engineering
University of Sydney

Professor Lyn Beazley
Professor of Zoology
Department of Zoology
The University of Western Australia

Mr Donald Blesing
Agribusiness adviser

Professor William J Caelli
Head, School of Data Communications
Queensland University of Technology

Dr Doreen Clark FTSE
Managing Director
Analchem Bioassay Pty Ltd

Dr Elizabeth Heij
Chief, CSIRO Division of Horticulture

Professor John de Laeter AO FTSE
Department of Applied Physics
Curtin University of Technology

Professor Helene Marsh
Head of Department
Department of Tropical Environmental Studies and Geography
James Cook University of North Queensland

Dr Carolyn Mountford
Executive Director
The Institute for Magnetic Resonance Research
University of Sydney

Mr John D Vines
Executive Director
The Association of Professional Engineers, Scientists and Managers of Australia
APPENDIX B: ASTEC OCCASIONAL PAPERS

1988
1 Key Technologies and their Role in Economic Development of Small Countries
2 Superconductivity
3 After the Myers Report: Improving the Management of Technological Change
4 Government Purchasing Policy and Industrial Innovation

1989
5 The Contribution of Science and Technology to Australia's Balance of Payments to the Year 2000 - Service Sector
6 Comments on the ASTEC Review of CSIRO
7 The Contribution of Science and Technology to Australia's Balance of Payments to the Year 2000 - Manufacturing Sector
8 The Contribution of Science and Technology to Australia's Balance of Payments to the Year 2000 - Private Sector
9 Public Policies for the 'Exploitable Areas of Science': A comparison of the United Kingdom, Japan, the Netherlands, and Sweden

1990
10 Report on Overseas Study Tour of Science and Technology, Policies in Selected Small Countries (Netherlands, Norway, Sweden and Finland)
11 Decision Making and Evaluation in Publicly-Funded Science and Technology
12 The Interaction Between National and International Programs in Science and Technology, With Particular Reference to Europe
13 Education For Change: The Role of Engineering in Australia in a Changing World Economy

1991
14 Funding the Fabric: Should Commonwealth Government Competitive Research Granting Schemes Contribute more to Research Infrastructure Costs?
15 The Assessment of Impacts of Climate Change by Working Group 2 of the Intergovernmental Panel on Climate Change
16 The Demand and Supply of Scientists and Engineers in Australia
17 Seminar Proceedings: Setting Directions For Australian Research, October 1990
18 Science, Technology and Australian Federalism: Getting the Best from the System
19 Major National Research Facilities: Expressions of Interest

1992
20 Research Data in Australia: Proceedings of a Workshop held on 14 November 1991
21 Research and Technology: Perspectives on Industry
22 Submission by ASTEC to the ASTEC Review Committee
23 Research and Technology in Tropical Australia - Symposia
24 Research and Technology in Tropical Australia - Survey
25 Indonesia and Australia, Science and Technology Linkages - Case Studies of Remote Sensing, Telecommunications and Biotechnology

1993
26 Small Things-Big Returns: The Role of Nanotechnology in Australia's Future
27 Gene Technology: Issues for Australia

1994
28 Energy Research and Technology in Australia