BEYOND THE LIMITS OF COASTAL ENGINEERING

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The limits of coastal engineering are seen to be technical (uncertainties) and socio-political (projects may be rejected by the approvals processes and by the courts). We identify two types of approval processes and call them traditional and contemporary. The traditional process is shown to have certain advantages (projects are approved) and obvious deficiencies (poor evaluation of impacts). The contemporary process is discussed in detail and is shown to be flawed also. The paper identifies from experience where this process fails, how it can be improved and how engineers must involve themselves in order to improve the likelihood of project approval.

Three limits of coastal engineering are identified in this paper. The first limit: Traditional approval processes often result in daring, experimental designs, which test and sometimes exceed the limits of existing coastal science and engineering knowledge. The second limit: Contemporary project approvals require assessments of impacts with greater accuracy than we can provide with present technology. This is a the result of uncertainties in our data, models and computations. The third limit: Because of the uncertainties in our studies, modelling and design, project assessment becomes necessarily a combination of objective input (hard numbers) and subjective input (experience). Since the public and legal processes do not understand or have little tolerance for uncertainties and subjective decisions, projects can easily be delayed, postponed or cancelled, because it appears as if the project has not been studied sufficiently.

RATIONAL DEVELOPMENT OF SCIENCE AND ENGINEERING

Let us first trace some of the history of rational development in Science and Engineering. With the enlightenment (beginning in the 17th Century), “scientific” work began and the laws of nature became better understood. For more than two centuries, it appeared that this understanding would ever increase to a point where we would clearly understand these laws of nature, how to deal with them and even how to make improvements. Scientific method was the

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paradigm. Anything was considered possible, given the right environment. This is known in sociological jargon as the modern era (Kamphuis, 2006).

Sometime later we slowly began to discover that we will not be able to solve all the world’s problems with science. A new era began with thinkers such as Nietzsche (1844-1900) and Heidegger (1889-1976). In sociological jargon this new period is called the postmodern era³. This new awakening needed some time to take hold, but it is now generally accepted that mainstream thinking is postmodern. Coastal engineering entered its postmodern era in about 1970. Much modern thinking (Yes, we can! - given enough funding, effort, education and research) still exists, however, particularly in the areas of science and technology⁴, which are the direct descendents of the modern age. Coastal Engineering is no exception.

Postmodernity has several hallmarks. The two most important ones are uncertainty (regardless of effort, the answers will always have a substantial error band), and pluralism (there is more than one way of approaching problems, solving problems and evaluating their success). With respect to engineering designs this means there are no perfect solutions, just optimum solutions that minimize uncertainties and there will be other solutions that are optimum for different boundary conditions. For example, if the boundary conditions are merely physical, such as incident waves and water levels, the optimum design solution for a coastal erosion problem would to build a continuous, strong shore protection scheme. However, if the boundary conditions also include sociological parameters, such as recreational opportunities, habitat and water quality (just another way of approaching the problem), the optimum solution will be quite different. A third major hallmark to be accounted for in present-day engineering is sustainability (all projects must

² Sociologists use the terms modern and postmodern. These are flags that identify rather complex societal developments and they have become generally adopted into our lexicon - Modern: Belonging to the era when we thought everything was possible - the era when society was certain it made progress; or alternatively: embodying the concepts of progress and that everything is possible. Postmodern: Belonging to the era when we discovered that the premises of the modern era are false; we realize everything is not possible and that progress is an illusion, because as we make new discoveries, the end goals always seem to move further away (like a mirage).

³ It is of particular interest that between 1900 and 1925 the most rigorous of the sciences (Physics) made a parallel, scientifically-derived discovery of the end of the modern age in the form of Quantum Theory.

⁴ In fact, some of the scientists instrumental in the development of Quantum Theory, such as Einstein and Schrödinger, refused to believe its implications.

⁵ Quantum theory, for example, does not calculate what happens (as is done in Newtonian Physics, but probabilities of what might happen.
take into account the future and the rest of the world). This is not a hallmark of postmodernity; it came more recently as a result of increased environmental consciousness and a shrinking global village.

**DESIGN**

Kamphuis (2000) describes the “ideal design sequence” shown in Figure 1. Design is application of knowledge (theory and experience) and data to solve a practical problem. Most designs need to go beyond a desk study, and normally we design by using (physical or numerical) modelling to improve on the desk study (essentially a refinement by trial and error). And it would be ideal to have funding for post construction monitoring to see how well the design functions. The sequence in Figure 1 is ideal, but only if we look at design per se. An up-to-date design, no matter how good, must also be approved (Figure 2).

![Diagram of ideal design process](image1)

**Figure 1. Ideal design process (Kamphuis, 2000).**

![Diagram of design procedure including approval](image2)

**Figure 2. Design procedure including approval.**
Our design philosophy is normally still inspired by an enchantment with science and the “scientific method”. It is believed that if we have the best available data, collected by the latest instrumentation (which is better than anything developed before) and we use the best available modelling techniques (improvements on earlier techniques) in a rational manner our solutions are the best available solutions, an improvement over anything that came before, and should be so respected. In fact, life is different. Society has changed considerably since the scientific method and its derivatives were developed.

The design procedure in Figure 2 incorporates approval. This reflects postmodern thinking. Figure 2 says that design needs to take into account other viewpoints than the strictly science/engineering concepts. These are expressed through the approvals process. At that point, stakeholders from different backgrounds have an opportunity to contribute to an optimum solution.

APPROVALS PROCESSES

We can identify two types of approvals processes: traditional and contemporary. In the traditional process, approval is granted by a small power group (usually government for coastal projects). This process could be described as autocratic. The power group commissions the work and it is interested in seeing the project successfully completed. The focus is on project implementation. “Secondary problems” may not receive much attention and hence environmental implications of the project may not be studied thoroughly. Since projects are usually approved for their economic benefit, there will be ecological and environmental risk. In the more up-to-date versions of the traditional approval process, there is usually some commitment to mitigate whatever significant environmental damage occurs. Kamphuis (2005) invented the term GAMSI decision (Go Ahead and Mitigate Significant Impacts).

The contemporary approval process is much more democratic. Approval is granted only after the “stakeholders” – a diverse group of people, consisting of representatives of governments, owners, affected individuals and groups, and all individuals or groups who think they might possibly be impacted – have had opportunity to express their reactions. This approvals process is much more complicated, because of the many, often conflicting voices. At most, only some of the stakeholders are in agreement with the project and/or its engineering design and there is often considerable interest within the stakeholders to block the project. Environmental impacts are no longer considered “secondary problems” in this contemporary process; in fact the process prides itself on its focus on the environment and sustainability⁶. A project may show economic benefit, but that alone no longer guarantees approval.

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⁶ For more detail on the interaction of economy and environment, see Kamphuis (2005).
The traditional approvals process reflects modern thinking (a progression from idea to a single undisputable design to implementation), while the contemporary approval process has all the hallmarks of postmodernity (it attempts to deal with uncertainties in the design, reflects the pluralistic view of all the stakeholders and is concerned with sustainability).

**EXAMPLES OF APPROVALS PROCESSES**

Kamphuis (2005) gave three detailed examples. The drilling islands constructed in the Canadian Beaufort Sea were shown as an example of traditional approval. Drilling for oil in a remote area was done without extensive stakeholder involvement. A relatively small, focused group of oil interests made GAMSI decisions even though there were many unknowns. Many islands were eventually built. Obvious issues were: very experimental designs were realized in a very hostile environment, extended periods of open water posed a significant threat to island stability, ice forces and shear resistances of the islands were very uncertain and the water was very cold, so that an oil spill would take decades to clean up. Fortunately, the impacts from these islands on the environment were eventually found to be limited. This was mainly due to careful design, construction and decommissioning of these structures.

A second example of traditional approval in Kamphuis (2005) is the ongoing reconstruction of the Dubai shoreline. Again, despite many unknowns GAMSI decisions are made by a compact power group. As a result, a number of very large prestigious and exciting projects are being realized. The structures are, however, very close to shore, major environmental impacts must be expected, and mitigation for these impacts will need to be very innovative.

In both the above cases, the downside of the traditional decision making process is that major shortcuts were made so that many aspects and impacts were insufficiently studied or perhaps are ignored. The upside is that prestigious projects of national importance were in fact realized. This is not always the case for projects subjected to a contemporary approvals process as will be seen below.

The third example discussed in Kamphuis (2005) concerns the contemporary approvals process used when designing large structures along the Dutch coast of the North Sea. These projects required extensive stakeholder involvement, which caused the studies in preparation of these projects to be very detailed and executed with the utmost of care. The first of two similar projects was the design of an artificial airport island offshore. Figure 3 presents alternative sites and layouts for the island and the borrow areas, an indication of a contemporary process, incorporating pluralism regarding possible sites.
Impacts were studied extensively and an abbreviated list of the types of impacts investigated (Flyland, 2002) was given in Kamphuis (2005). The impacts form part of major impact chains and examples of primary and secondary impact chains are shown in Figures 4 and 5.

Figure 3. Design alternatives for proposed island airport (Ref: Flyland, 2002)

Figure 4. Primary Impact Chain
In any such investigation there are uncertainties in the measurements and calculations. These uncertainties increase as the focus of study is further removed from the site and further down the impact chains. This growth of uncertainties is shown schematically in Figure 6 and resulted in many of the airport island studies being at limit of present-day knowledge of engineering and ecology.

After extensive technical study, the island airport was judged not to be economically justified (by the Dutch government). A second major project – an expansion of the Port of Rotterdam was also planned in a similar North Sea environment (Figure 7). Because of the similarities, the methodology for this project could build upon the earlier airport studies. This time all the studies deemed necessary were completed. Although uncertainties in the results (Figure 6) did not allow all processes to be completely understood, the potential impacts were judged not to be significant, and it was decided to go ahead with the port expansion and to mitigate all unforeseen significant environmental impacts. Note that this was again a GAMSI decision. However, this time much was known about all aspects of the project, so the GAMSI decision contained very few unknowns.
This GAMSI decision, however, regardless of the effort in the study and design, led to objections from individuals and advocacy groups that were apparently not present at the table during the approval process. They simply introduced new, possible far field impacts. An appeal was made to the Supreme
Court\(^7\) and the decision to go ahead with the project was reversed because the newly raised issues were deemed not to have been studied sufficiently. This has led to a stoppage of the project and another loop of very detailed studies. Procedurally, the Supreme Court decision was correct – the significance of all possibilities should have been studied. But technically the new, more detailed studies will contain uncertainties that are almost as large as before. The answers will only provide slightly better insight into the biological, ecological and social issues. In the end yet another GAMSI decision will need to be made with slightly fewer unknowns. And then what? Can other advocates introduce further issues that require further study?

The positive side of this third example is that the contemporary approvals process, even though is involves stakeholders from many backgrounds and made the studies more complex, produces much more sustainable, environmentally friendly and sociologically acceptable results. The negative side is that it was possible to introduce new issues after a decision was made, and on the basis that these new issues had not been studied sufficiently the project was postponed for further analysis. This could in principle be repeated after the new studies are completed. Large, state-of-the-art, expensive technical studies of very complex processes were simply set aside through a possibly poorly informed non-technical procedure or possibly through reaction to political and/or social pressure. Thus a project of great economic importance has been delayed.

**ANALYSIS OF THE CONTEMPORARY DECISION MAKING PROCESS**

The contemporary decision making process is ideal, in principle. It is democratic, takes into account many varying viewpoints and takes care of ecology, environment and sustainability. It may be visualized by combining Figures 2 and 6 with an expansion of what the approvals process entails. This is shown in Figure 8.

The stakeholders come from widely varying backgrounds. They will have very different individual risk perceptions and will also have varying aversions to risk. They are free to pursue personal and organizational biases they bring with them to the table. With respect to uncertainties, they expect science and engineering solutions to be perfect (possibly because they have been so informed by modern thinking engineers and scientists?). They do not expect nor want uncertainties. They feel free to regard imperfect results as useless for decision making and use that argument to suit their purposes. These are perfect ingredients for stalemates, unclear decisions and postponed projects.

\(^7\) The Dutch “Raad van State” is not exactly a Supreme Court. It is a body consisting of lawyers, judges and other citizens that monitors the quality of government decisions. But its decisions, like those of the Supreme Court are binding and cannot be appealed.
To improve chances of success of the contemporary decision making process, experience points to a number of opportunities. It must first be recognized that stakeholders meetings are necessarily an exercise in education, diplomacy, bargaining and goodwill. So they need strong leadership and can be helped by a competent facilitator who is conversant with all the viewpoints. Secondly, the aim of the decision process should always be clear. Third, any studies should provide an integrated evaluation of the impacts and required mitigations. Clear decisions must be made based on this evaluation.

Experience also has shown that all relevant stakeholders should be present at the table from the beginning of the discussions and that all possible concerns should be opened up for discussion and study at that time. The best method to meet these two criteria is to hold public meetings starting very early in the project, particularly to provide consensus on identification of relevant interest groups and stakeholders and on formulation of the ideas and questions to be discussed. All subsequent discussions and decisions should be transparent and available to the public and the press.

Clearly, the stakeholders need to be educated. There should be thorough discussion at stakeholders meetings about the expected uncertainties of the

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8 After such early public involvement, it is possible to ask of groups and concerns that surface later: Where were you, when we organized this?
studies, how the results are to be used, individual perceptions and aversions to risk, and inherent biases. It should be clear that no participant has a veto over any decision. And it must be understood that any decision will eventually be some form of a GAMS decision. There will always be unknowns generated by the large uncertainties in the studies.

Finally, an integrating evaluation policy must be formulated. Evaluation of all the impacts and their significances should be thoroughly transparent. Participants should expect the evaluations to be both objective (using hard data and results) and subjective (based on experience and judgment). Consequences of all impacts must be properly weighted to provide an integrated evaluation of overall risk and damage.

The whole approval process is complex. It will be cumbersome and will require much bargaining between the stakeholders and decision makers. Crucial to any success is an awareness of “win-win” solutions and skills to develop them. The awareness needs to be cultivated in the meetings and is based on the recognition that no-one can be perceived to loose and that there are no perfect solutions, just optimum solutions. Participants must be prepared to trade in expectations and biases to reach such optimum solutions.

THE ROLE OF ENGINEERS

Engineers can contribute greatly to the success of such a decision-making process in several ways. It means that the engineers must work with the approvals process rather than compete with it. Their contribution requires that they must think outside the technical box and that they will need to cultivate the trust and respect of all sides. Engineers need to understand sustainable development and all impacts (environmental, social, political, etc.). They must be ready and able to explain the design process at stakeholder meetings and should be able to advise the various stakeholders. Engineers may be called upon to advise the decision makers directly and they will need to convince the decision makers that their detailed and continued involvement is essential for the eventual success of the project.

One particular contribution engineers can make is to create awareness that the numbers provided by the studies contain large uncertainties, and that impact assessment and risk analysis require both (objective) mathematics and (subjective) judgment. Uncertainties and judgment are both considered to be “unscientific” by the public and they are often the reason projects do not obtain approval. Engineers must play a key role in justifying the use of such uncertain, subjective results as decision making tools and this knowledge needs to be clearly communicated to the public, the stakeholders and the decision makers throughout the decision making process. Another major opportunity for engineers is that they are often in a unique position to act as facilitators, since they are probably most familiar with most of the issues.

In the end, in spite of the best efforts by the decision makers, the stakeholders and the engineers and no matter how few unknowns remain in the
GAMSI decision, the project may still be derailed. The approach, suggested above, will increase the chances for project approval, but does not guarantee it. For example, there may be (possibly new) advocacy groups that object to the final decisions. Usually the opponents’ purpose is to stall (or perhaps even stop) the project. It is essential that any such last minute interventions be treated by the decision makers and the courts as objections coming from outside the decision-making process. Thus, if they are to be settled in the courts the objectors must present arguments to show that the (completed) decision-making process was flawed, either in substance or process. Hence any decisions made must stand up to litigation and scrutiny of the courts and engineers are once again able to play key roles at this stage.

**CONCLUSIONS**

The limits to coastal engineering, discussed in this paper are technical limits (Figure 6), which can turn into socio-political issues because of the processes used to approve contemporary projects. The uncertainties in study and design results tend to leave a perception among the public, the stakeholders and the courts that projects have been insufficiently studied and opponents to the project can use this to delay or postpone the project.

The task of the engineer is not complete when a design is submitted. It is essential that the engineer continue to work toward project approval and communicate engineering realities such as uncertainties to shareholders and the decision making body.

The traditional approach to decision making (decisions made by small power group) has historically resulted in many successful projects and has provided opportunities to push the technological envelope to develop new methods. However, in many cases, environmental risks were consciously accepted. Because that has resulted in some environmental disasters, because shorelines are coming under ever-greater population pressure, because there is a great increase in public interest in the shoreline and because many societies are used to a democratic political process, the public objected to the traditional method of approving coastal projects and wanted to have a say. That voice was granted by inviting stakeholders to review the projects and comment on project approval.

In principle this contemporary approach should work to everyone’s satisfaction. However, the detailed studies required for the decision making process will always contain uncertainties (Figure 6) and these open the door to advocacy groups, intent on stopping the project for private reasons. The contemporary project approval process is therefore seriously flawed, because it often becomes mired down and projects are postponed temporarily or permanently, ostensibly because the studies were not extensive or conclusive enough.

In short, the traditional approach has lead to wonderful, completed projects that often push technical limits, but may impact the environment.
contemporary approach’s focus on sustainability, the environment and public participation has lead to a very difficult process, often followed by litigation and regularly resulting in stalled or even postponed projects. Obviously neither approval process is satisfactory.

All decisions made under both processes are a form of GAMSI decision (Go Ahead and Mitigate Significant Impacts). The GAMSI decisions are similar, except that the impacts are generally much more carefully studied in the contemporary process than in the traditional process and as a result there are fewer unknowns when the decisions are made. For the traditional approval process the remedy is simple. It needs to pay greater heed to the environmental consequences of the designs so that the GAMSI decision is based on smaller unknowns. For the contemporary approval process, in which everything appears to be done right, technically and procedurally, the recipe for success is more complex. Some possible suggestions to meet this more difficult challenge have been given.

In addition, engineers can and must play a major, multi-faceted role in the decision-making process. They need to provide the best possible studies, designs and impact studies, blend uncertain numbers with experience and judgment, communicate this process clearly, advise stakeholders and decision makers, and be prepared to defend the designs and give expert evidence in court. This extent of involvement is unfortunately contrary to the practice preferred by most engineers, which is to concentrate on the technical aspects and to leave socio-political implications to others. So these are our new marching orders.

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