
Dublin Port Post 2040 Dialogue – Paper 6

WHAT WOULD MOVING DUBLIN PORT INVOLVE?

12th October 2020

It has been suggested that Dublin Port should be moved so that 260 hectares of port lands could be redeveloped, primarily to provide much needed housing. An obvious question, though surprisingly seldom asked, is how much would it cost to free up the lands of the port for development?

Before the 260 hectares of Dublin Port lands could be developed, a new port would have to be built on the east coast to accommodate the cargo and passenger traffic that currently pass through Dublin Port. There is no alternative option:

- All of the other ports in the range from Greenore to Waterford are far too small individually or in aggregate to handle Dublin Port's throughput – in 2019, their total throughput was just over one quarter that of Dublin Port.
- The Port of Cork is a small port in a large harbour and is both too small and too far away from Dublin Port's hinterland – in 2019 its throughput was one third of Dublin's.
- Ports on the west coast, such as Shannon Foynes, could not serve as replacement ports for Dublin Port primarily because of their geographical location far away, in nautical terms, from Ireland's markets.

We have termed the new port that would need to be built DP2.0.

This paper seeks to answer the question as to how much it would cost to free up the lands of Dublin Port including, but not limited to, the cost of constructing DP2.0. In doing this, important environmental issues have been identified and project timelines for both the permitting phase and for the construction phase have been estimated.

More often than not, a simple question which seeks a simple answer requires a complex response and so it is with the question of how much it would cost to free up the 260 hectares of Dublin Port land for development.

However, if a simple answer is demanded, then the best estimate which we in Dublin Port Company (DPC) can give is that it would cost, at 2020 prices, €8.3 billion. In addition, we believe that it would take not less than 20 years from today to achieve this objective. However, we also believe that it would be extraordinarily difficult to secure planning permission because of environmental impacts. Furthermore, it would take at least ten years just to resolve this planning challenge.

The cost estimate of €8.3 billion comprises the cost of constructing the new port, replicating port buildings and equipment and a variety of land costs, including the remediation of port lands to make them ready for development.

The estimates we have made (which include contingencies on top of costs derived from detailed bills of quantities) are first estimates and are the subject of many qualifications and much explanation.

For example, the cost of €8.3 billion is stated at 2020 prices. If construction cost inflation ran at 2% per annum over the next 20 years, and if all of the expenditure took place between 2031 and 2040, then the actual cost could be €11.2 billion.

It is a universal feature of megaprojects that the best early days cost estimates are undermined by a range of factors and the passage of time is but one of these factors. This happens because megaprojects are inextricably laden with risks at all stages. There are project scope risks – will the envisaged project provide too much or too little capacity for future demand?

There are consenting risks – can the project get all of the necessary planning and environmental consents to allow it to be constructed? There are design risks – can the detailed design capture all of the cost elements so that when the project goes to tender a contract emerges which can deliver the project at an agreed price?

These are the *known unknowns* of all megaprojects and they are a recurring feature of megaprojects everywhere which incur large cost overruns¹.

The inability to provide firm and reliable estimates for the cost of megaprojects long before a decision to proceed with the project might be made is not due to incompetence or laziness. It is a simple reality which has to be accepted because of the nature of megaprojects.

It is far more likely than not that the cost estimates in this paper are on the low side.

Examples of cost overruns on megaprojects

Project	Cost overrun (%)
Boston's artery/tunnel project	196
Humber bridge, UK	175
Boston–Washington–New York rail, USA	130
Great Belt rail tunnel, Denmark	110
A6 Motorway Chapel-en-le-Frith/Whaley bypass, UK	100
Shinkansen Joetsu rail line, Japan	100
Washington metro, USA	85
Channel tunnel, UK, France	80
Karlsruhe-Bretten light rail, Germany	80
Øresund access links, Denmark	70
Mexico City metro line	60
Paris–Auber–Nanterre rail line	60
Tyne and Wear metro, UK	55
Great Belt link, Denmark	54
Øresund coast-to-coast link	26

¹ Table taken from *Megaprojects and Risk*, Bent Flyvberg, Nils Bruzelius and Werner Rothengatter, 2003. The overruns are based on constant prices and do not, therefore, include the impact of construction cost inflation. The baseline cost against which the overruns are calculated is the cost estimate at the date the final decision to proceed with the project was made.

The cost estimates which this paper presents underpin the opinion of those of us in DPC who believe that the idea of moving Dublin Port makes no sense. The estimates have been prepared by staff of and consultants to DPC who have succeeded in getting planning consents for major port projects from An Bord Pleanála in 2015² and again in 2020³ and who have constructed major works within Dublin Port of a similar nature to the works that would be required to construct DP2.0.

We accept that there are those who believe that the benefits of moving Dublin Port are worth the trouble and expense.

Similarly, in 1800, when experts of the day were asked for their opinions on solving the problems of Dublin Port at that time, solutions far more costly than ultimately proved necessary were proposed by eminent people. One of these was Thomas Hyde Page, a military engineer. In 1800, he suggested a series of works in Dublin Bay to solve the problems of Dublin Port at a cost, he estimated, of £1,784,885. Another expert, John Rennie, proposed works to a cost of £1,802,763.

The solution to the problems of Dublin Port was ultimately provided by the Ballast Board (the port authority of the time) at a far lower cost of £103,055 when the North Bull Wall was constructed between 1819 and 1824. The solutions proposed by Page and Rennie were seventeen times the cost of the solution delivered by the Ballast Board.

In our opinion, it is very likely that it would not be possible to secure the necessary planning and other consents to build a new port to which all of the cargo handling activities in Dublin Port could be moved. Given this, the question of cost is moot. Notwithstanding this, we have provided a detailed basis for our estimated costs to facilitate an initial cost benefit analysis (CBA) by anyone who thinks it worth doing even after having considered the planning hurdles and the likely magnitude of the costs.

And just as project costs have associated risks, so also any estimates of the benefits which the megaproject to make the lands of Dublin Port available for development have their own associated risks.

The analysis in this paper is confined to the cost side and we leave it to others to provide financial estimates for the benefit side of the CBA equation.

The starting point for our analysis of costs is the determination of the size of DP2.0 in terms of its throughput capacity.

Masterplan 2040 envisages Dublin Port being developed in its present location to provide capacity for up to 77 million gross tonnes by 2040. This is based on an average annual growth rate of 3.3% per annum over the 30 years from 2010. It is possible that this growth might not be achieved but historical trends suggest it could be. Moreover, we know that the long term historical trends we have seen in past decades cannot continue indefinitely and that port volume growth must slow down or even plateau at some point. It is even possible that a new trend of long term port volume reduction could emerge. The future is, inevitably, very uncertain.

Against this uncertain background, we have estimated what the capacity **DP2.0 Phase 1** would have to be as follows.

It seems reasonable to plan that the new port that would be available in 2040 to facilitate a relocation of existing cargo handling activities from Dublin Port would have to have a capacity at least equal to the level Masterplan 2040 seeks to provide by 2040.

If the rate of growth assumed in the Masterplan from 2010 to 2040 turns out to be less than 3.3% per annum, then the new port would have surplus capacity for some years after 2040. This would not necessarily be a bad thing; on the other hand, too little capacity would be a bad outcome.

DP2.0 would have a very long lifetime after 2040 and there is likely to continue to be some level of growth once the new port would open for business in 2040. DP2.0 must, therefore, be constructed in such a way as to be capable of being expanded as and when required.

	2010 '000 gross tonnes	Growth rate 30 years	2040 '000 gross tonnes	Growth rate 40 years	2080 '000 gross tonnes
Ro-Ro	16,403	4.1%	54,287	1.5%	98,478
Lo-Lo	6,317	3.0%	15,270	1.5%	27,700
Bulk liquid	4,009	0.0%	4,000	0.0%	4,000
Bulk solid	2,054	1.8%	3,500	0.0%	3,500
Break bulk	96	0.1%	100	0.0%	100
Total	28,879	3.3%	77,157	1.4%	133,778

² ABR Project, PL29N.PA0034, grant dated 8th July 2015

³ MP2 Project, PL29N.304888, grant dated 11th July 2020

To cater for this eventuality, we have assumed that the unitised modes of Ro-Ro and Lo-Lo continue to increase at a rate of 1.5% per annum for the 40 years from 2040 to 2080 and we have designed DP2.0 to be capable of being expanded to an ultimate capacity of 134 million gross tonnes. The additional port capacity required to cater for growth from 77 million gross tonnes to 134 million gross tonnes is **DP2.0 Phase 2**.

Thinking about what volumes might be as long into the future as 2080 is necessary in order to determine the size of the breakwaters that should be built in Phase 1 – they need to be long enough to allow additional port capacity to be built in future years as and when required. The approach we have taken here is similar to the approach in other European ports including Rotterdam, Barcelona, Copenhagen and Bilbao.

Having determined the capacity of the new port, the next challenge is to decide where it might be constructed.

RPS Group has completed a *High Level Environmental Appraisal* on DPC's behalf for the DP2.0 project and, within this appraisal, RPS concluded that the two most suitable (or perhaps, more accurately, least unsuitable) locations are Arklow and Bremore. The *High Level Environmental Appraisal* was informed by *Hydraulic Model Studies* also carried out by RPS.

RPS has previously completed a number of environmental studies for DPC – most notably the environmental impact assessment reports and the studies of the impacts on Natura 2000 sites – included in the two successful applications for planning permissions to An Bord Pleanála. Given that DPC paid for the RPS study, the RPS study might be considered not to be independent. However, it has been prepared by experts with a proven track record whose analysis and judgement has been accepted in environmental impact assessments and appropriate assessments completed by An Bord Pleanála on two occasions.

The main challenge in selecting sites for DP2.0 is the need to avoid sites which are protected by EU environmental law. These sites are termed Natura 2000 sites and are of two types: Special Areas of Conservation (SACs) and Special Protection Areas for birds (SPAs).

EU environmental protection laws are sometimes cited by frustrated developers as being excessively burdensome. One developer, who suggested that the Tolka Estuary should be infilled at a cost of €200 million in a period of just 18 months so that houses for 65,000 people could be built, commented that *You have bird populations but there will have to be a compromise found at some time between birds and people*⁴.

The reality is that there are strong legal protections for the environment and any large infrastructure project has to have regard to these. In DPC's case, we not only have regard to these legal protections of the environment, we welcome them. If the protections in law were to be diminished or removed to facilitate development, it would require a change in EU law. There is no prospect of this happening. As recently as 2016, the European Commission completed a fitness check on the EU Birds and Habitats Directives and concluded that *...within the framework of broader EU biodiversity policy, they remain highly relevant and are fit for purpose*⁵.

Whereas there are SACs and SPAs all along the east coast, including some at sea, and whereas the selected sites at Arklow and Bremore avoid these to the greatest extent possible, a port project at either location would have to be assessed by An Bord Pleanála for its specific impact on nearby Natura 2000 sites in a process known as *Appropriate Assessment*. It is clear from our analysis that there would be such impacts because the huge footprint of DP2.0 at either Arklow or Bremore would alter coastal processes in such a way as to cause a loss or degradation of protected habitats in Natura 2000 sites.

The extent of the projected impacts is such that an application for planning permission for DP2.0 at either Arklow or Bremore would almost certainly have to invoke a provision of EU environmental law known as IROPI.

IROPI is an abbreviation for Imperative Reasons of Overriding Public Interest and the concept behind it is that where a proposed project would have negative impacts on a Natura 2000 site, it can only be granted planning permission if two conditions are satisfied.

Firstly, it must be shown that there is no alternative to the proposed project – in this case DP2.0 – and that it is in the public interest for it to proceed. Sustaining such an argument where there is a large and established working port in Dublin would be, to say the least, challenging.

Secondly, compensatory habitats which would at least offset the environmental loss which the project would cause would have to be created and the State would have to secure the agreement of the European Commission that the compensatory measures proposed to accomplish this were adequate.

No large IROPI project has ever been completed in Ireland. In 2014, Galway Harbour Company applied to An Bord Pleanála for planning permission for an IROPI project⁶. It is six years since the planning application was lodged and a decision has yet to be made.

4 Irish Times, 17th August 2019

5 https://ec.europa.eu/environment/nature/legislation/fitness_check/index_en.htm

6 Galway Harbour Extension, An Bord Pleanála reference PL61.PA0033

Natura 2000 sites



Having selected the two locations of Arklow and Bremore, the layout and orientation of a workable port with the required capacity was determined for each location.

The main factors considered in doing this were the need to have a safe access channel which could be maintained over time and the need to protect and shelter ships at berth from wave action. These are the most basic requirements for any port. In the case of Arklow, there is deep water close to Arklow Head and the port could be built with sufficient adjacent depth of water to obviate the need to create a long entrance channel.

Each design yielded a very large harbour protruding far into the Irish Sea and the impacts of such a large construction on the coastal areas north and south of each harbour were then assessed in terms of their environmental impacts.

The above issues were considered iteratively to arrive at the final layouts of the new port that would be built at either Arklow or at Bremore. In both cases, the port would constitute an enormous coastal excrescence.

Because Dublin Port is nestled into Dublin Bay and along the banks of the Liffey, it can be difficult to appreciate its scale. For example, the distance from the Tom Clarke Bridge to the end of the easternmost berth in Dublin Port is almost three kilometres. It is a further two kilometres from this point to the entrance to the port at the Poolbeg Lighthouse. Dublin Port is concave; DP2.0 would be convex. DP2.0 would extend 3.2 kilometres into the Irish Sea if built at Arklow and 4.5 kilometres if constructed at Bremore.

The huge size of DP2.0, at either Arklow or Bremore, is because the channel inside the breakwaters has to be long enough to allow ships to slow down once they have entered the shelter of the harbour. This distance, combined with the impact of the new harbour on coastal processes and the extent of the land that needs to be made by infill, dictates how far the outer breakwaters need to project from the coast.

DP2.0 at Bremore projects farther into the sea than at Arklow because the surrounding waters at Bremore are relatively shallow. Because of this, the entrance channel needs to be farther out to sea so as to reduce the risk of the movement of sands blocking the channel during major storm events. This is a known and recurring feature at existing ports on the east coast.

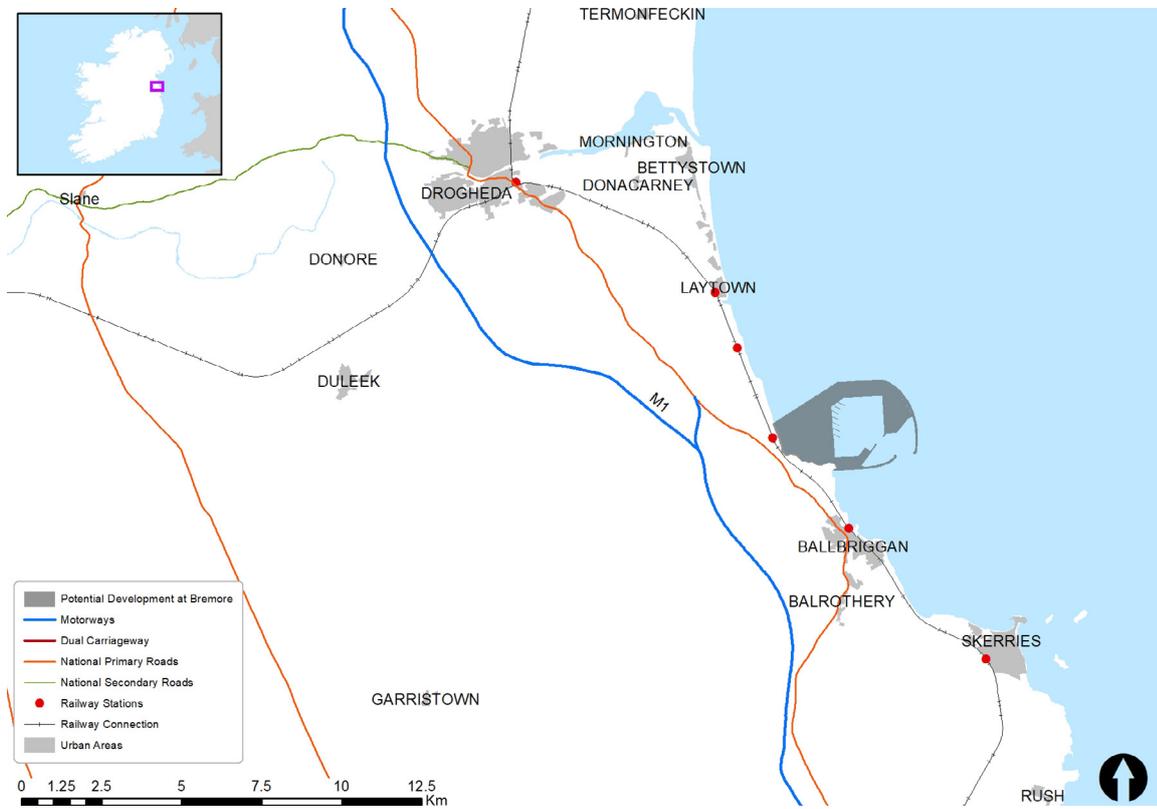
By comparison, DP2.0 at Arklow would lie in much deeper water and this problem would not arise.

Based on the layouts identified for Arklow and for Bremore, conceptual schemes for each site were designed to a sufficient level of detail to allow bills of quantities to be produced. These bills of quantities were then costed.

The project to build Phase 1 of DP2.0 at either Arklow or Bremore would be enormous by any standard and would be of the same magnitude as the Maasvlakte 2 expansion of the Port of Rotterdam in 2012.

	Arklow Phase 1	Bremore Phase 1
Total port area (land plus water)	893 hectares	963 hectares
Land area (including land made by marine infill)	340 hectares	416 hectares
Area of land made by marine infill	186 hectares	416 hectares
Length of external breakwaters	9,150 metres	9,200 metres
Length of berths (including Ro-Ro berths on jetties)	5,675 metres	5,675 metres
Land area for port operations	311 hectares	309 hectares
Road system (including connection to national road network)	12.8 kilometres	17.8 kilometres
Rail system (including connection to national rail network)	11.4 kilometres	9.7 kilometres
Bulk fill materials	29m cubic metres	45m cubic metres
Dredging quantities	5m cubic metres	23m cubic metres
Access channel	Not required	4.1km
River diversion	Not required	1.8km ⁷
Overall cost estimate at 2020 prices	€7.6 to €8.9 billion	€7.7 to €8.9 billion

Location and scale of DP2.0 at Arklow or Bremore



“Because Dublin Port is nestled into Dublin Bay and along the banks of the Liffey, it can be difficult to appreciate its size.

In addition, the project to build DP2.0 at Bremore would have similarities with the 2013 project to expand the port of Barcelona. In Barcelona, the Llobregat river had to be diverted by two kilometres. In Bremore, the Delvin would have to be diverted by almost the same distance.

Finally, in both locations there would have to be a considerable development to provide road and rail access to national networks.

However, it is important to emphasise that in addition to these connections, there would likely be a requirement for major investment to increase the capacity of either the M1 or the M11 motorways in order to cater for a large volume of port-related HGV traffic. Our costings take no account of this.

The overall cost estimates for the project to build DP2.0 and to free up the lands at Dublin Port for development comprise four elements:

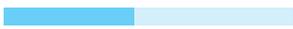
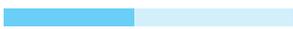
- The cost to construct DP2.0
- The cost of replicating in Arklow or Bremore all of the buildings and equipment which allow Dublin Port to function

- Three categories of land costs:
 - The costs to acquire lands at the site where DP2.0 would be built
 - The cost to buy out the property rights and compensate for the loss of the operating assets of leaseholders in Dublin Port
 - The cost of remediating the lands of Dublin Port to bring them to the point where they could be developed
- The capitalised costs of long-term continuing environmental mitigating measures at either location.

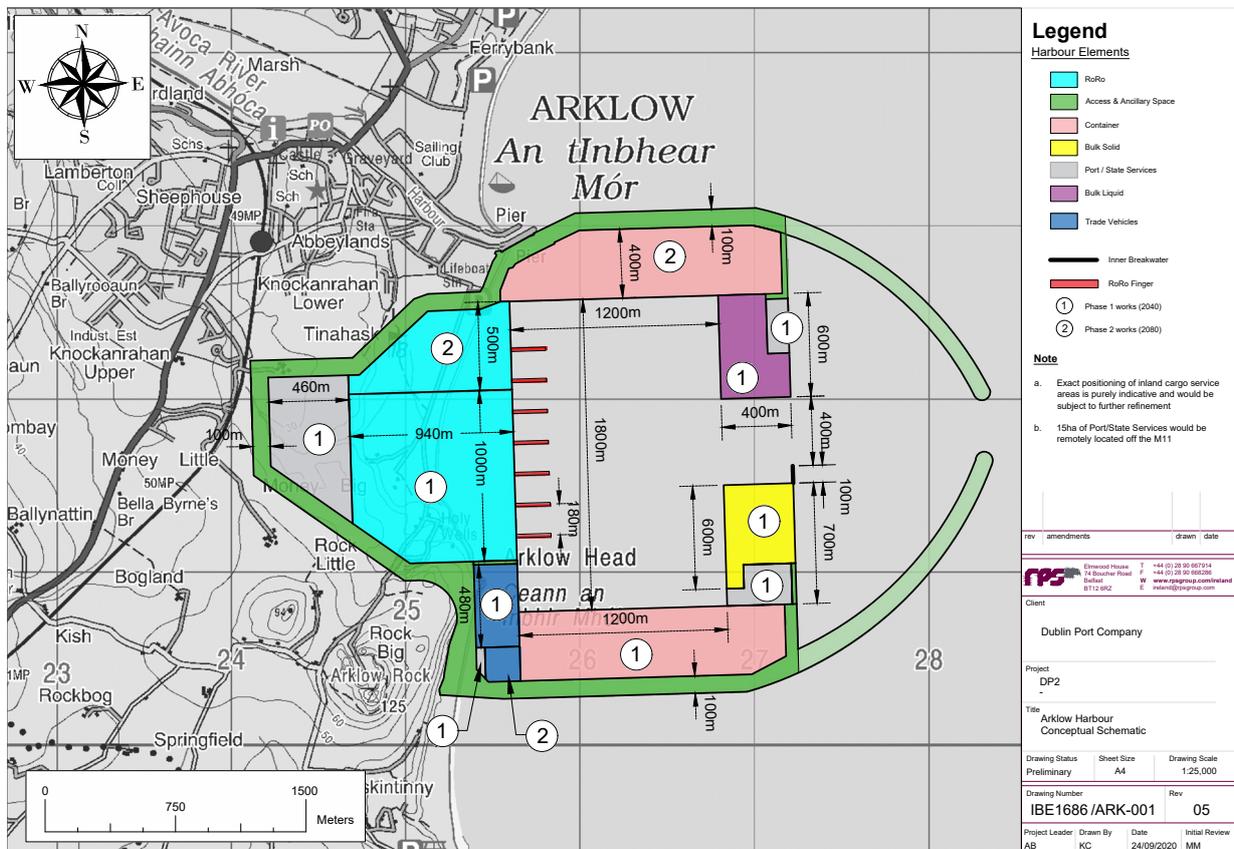
The costs to relocate an existing port business can be very substantial as evidenced by the project to construct the Waste to Energy plant on the Poolbeg Peninsula where a new molasses storage and distribution facility had to be constructed at a cost of €31m on a 0.7 hectare site to clear the site for the Covanta plant.

Moreover, property rights in Ireland are strongly protected in law and there would be substantial costs to acquire land for DP2.0 and to buy out the property rights of leaseholders in Dublin Port.

Because of the inherent uncertainties in estimating quantities and in applying estimated pricing rates to these quantities, (long in advance of detailed designs being prepared) contingency allowances were added to each of the four elements at a lower level and at a higher level.

Cost category	Lower contingency levels	Higher contingency levels
New port infrastructure	25% 	45% 
Buildings and equipment	25% 	45% 
Land Acquisition	25% 	45% 
Remediation of existing port land	25% 	50% 
On-going liabilities (capitalised)	25% 	45% 

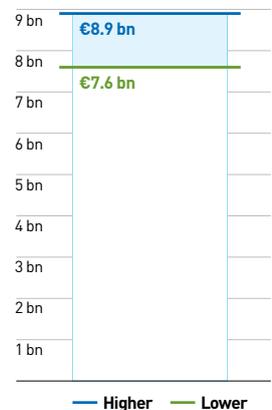
DP2.0 at Arklow



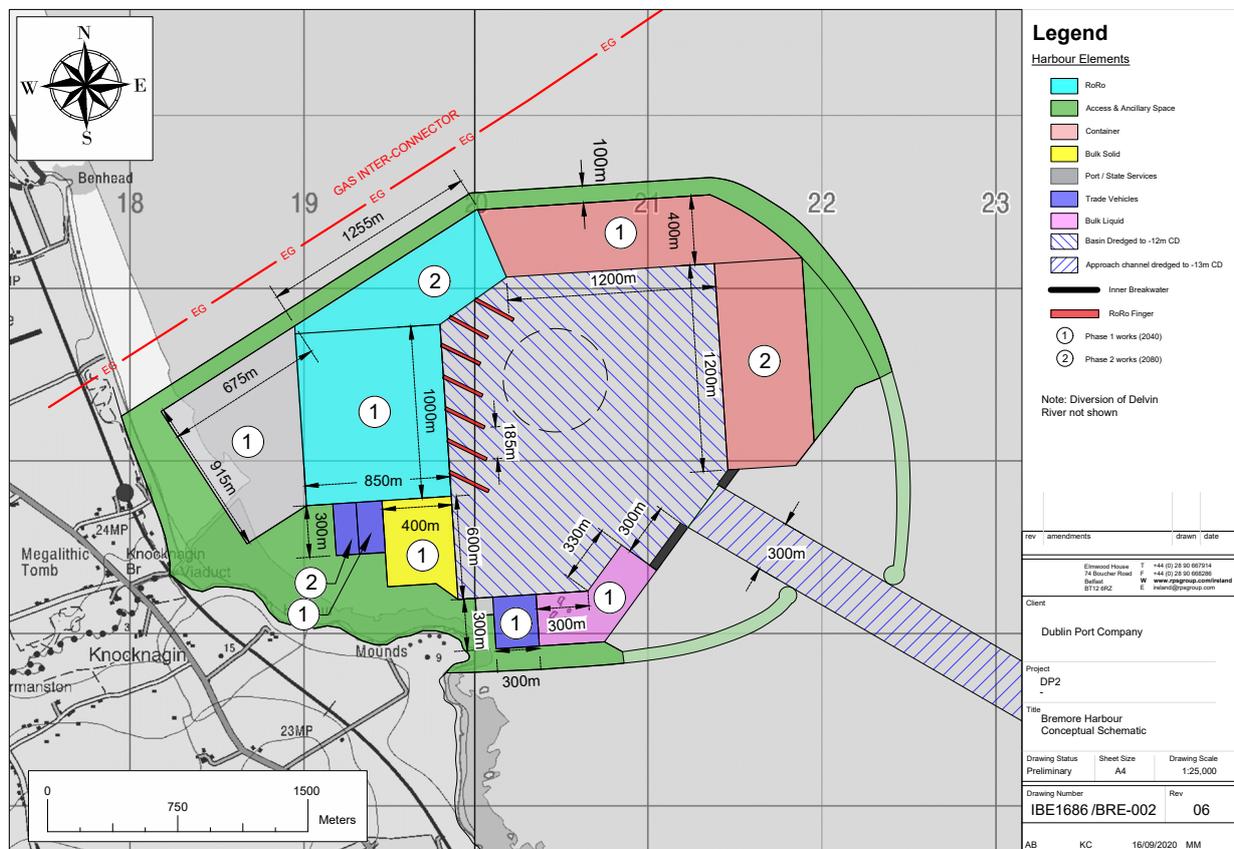
Based on the above, the cost to make the lands at Dublin Port available for development by building DP2.0 Phase 1 at Arklow was estimated to be between €7.6 billion and €8.9 billion at 2020 cost levels.

Arklow (€ millions)	Phase 1	Phase 2	Total
New port infrastructure	3,551	758	4,309
Buildings and equipment	926	98	1,024
Land Acquisition	866	-	866
Remediation of existing port land	703	-	703
On-going liabilities (capitalised)	73	-	73
Total (excluding contingency)	6,119	856	6,975
Contingency Lower Range	1,530	214	1,744
Total cost (low)	7,649	1,070	8,719
Contingency Upper Range	2,789	385	3,174
Total cost (high)	8,908	1,241	10,149
Total cost (average of high and low)	8,279	1,155	9,434

Estimated cost to make the lands at Dublin Port available for development by building DP2.0 Phase 1 at Arklow (at 2020 cost levels).



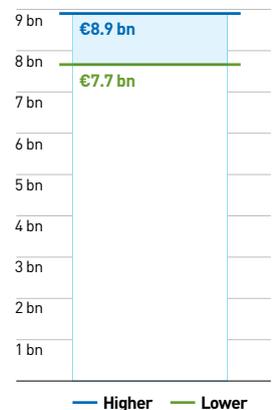
DP2.0 at Bremore



The cost range based on building DP2.0 Phase 1 at Bremore was estimated to be between €7.7 billion and €8.9 billion at 2020 cost levels.

Bremore (€ millions)	Phase 1	Phase 2	Total
New port infrastructure	3,668	903	4,571
Buildings and equipment	926	98	1,024
Land Acquisition	686	-	686
Remediation of existing port land	703	-	703
On-going liabilities (capitalised)	147	-	147
Total (excluding contingency)	6,130	1,001	7,131
Contingency Lower Range	1,533	250	1,783
Total cost (low)	7,663	1,251	8,914
Contingency Upper Range	2,794	450	3,244
Total cost (high)	8,924	1,451	10,375
Total cost (average of high and low)	8,293	1,351	9,644

Estimated cost to make the lands at Dublin Port available for development by building DP2.0 Phase 1 at Bremore (at 2020 cost levels).



Detailed cost estimation and the application of contingency sums can give the illusion of high side cost certainty. Having completed a detailed analysis under several hundred cost headings and having applied high levels of contingencies, how could the cost of building DP2.0 Phase 1 at Arklow or Bremore combined with the cost of bringing the vacated lands of Dublin Port to the point where they could be developed possibly exceed €8.3 billion?

One answer we know of is construction cost inflation and the experience of many other megaprojects suggests that, if the DP2.0 project were to go ahead, other issues would emerge which would lead to cost escalations which we cannot meaningfully identify or estimate today.

The cost of land used in our analysis has assumed an acquisition price for existing long leaseholds at Dublin Port based on the current guide price for the Irish Glass Bottle Site of €4.2m per acre less site remediation costs. The reality is that existing leaseholds would need to be acquired at the open market value current at the time of acquisition, whether through CPO or by negotiation. Land prices in Ireland can increase rapidly, particularly where the State is a purchaser in need because a large project has to be delivered. The cost of replacing the molasses facility on the Poolbeg Peninsula referred to above is a salutary precedent.

The Phase 1 cost estimate of €8.3 billion for each of the Arklow and Bremore options is equivalent to a cost, at 2020 prices, of €12.9m per acre of land made available for development at Dublin Port. If this were to be developed for housing at the rate envisaged in the Poolbeg Peninsula SDZ planning scheme of up to 238 units per hectare, the land cost per housing unit would be €134,000, again at 2020 prices.

This assumes, of course, that planning permission for the new port could be secured and that the cost of the megaproject to build this new port did not escalate beyond the estimate we have made today 10 years before construction might commence and 20 years before it would be completed.

These timing estimates of 10 years and 20 years have been arrived at by considering three sets of challenges:

- Planning policy would have to be amended at a range of levels from national to local to support the proposed development of DP2.0
- Once planning policies had been aligned, there would be a lengthy consent process due not only to the scale of the project but also to the near certainty of it having to rely on an IROPI argument
- Construction of what would be a huge marine construction project unprecedented in scale in Ireland

Importantly, so great is the environmental challenge of building DP2.0 at either Arklow or Bremore, there is a clear and obvious risk that, after ten years of effort, planning permission to proceed with the project to build DP2.0 at either location could be denied.

Based on DPC's experience of developing Masterplan 2040, having it recognised at multiple policy levels (including: Project Ireland 2040; Regional Spatial and Economic Strategies; Dublin City Development Plan) and taking large port projects through consent processes and into construction, we have prepared project schedules for developing DP2.0. If a decision in principle was taken during 2020 that DP2.0 should be built at Bremore, we estimate that the new port could be available for operation in mid-2041 as summarised below. A development of DP2.0 at Arklow would be no quicker.

Task	Duration in months	Start date	Finish date
Gaining policy support	70	Jan-2021	Jan-2027
Securing planning permission	70	Jul-2024	Jun-2030
Getting other consents	24	Jun-2030	Jun-2032
Mobilisation	6	Jan-2033	Jun-2033
Northern breakwater	68	Jul-2033	Mar-2039
Southern breakwater	17	Nov-2033	Apr-2035
Internal breakwater	34	Aug-2034	Jun-2037
Quay walls	45	Dec-2035	Sep-2039
Yards	48	Jun-2036	Jul-2040
Contingency	12	Jul-2040	Jun-2041

Large infrastructure projects everywhere have a lengthy gestation period and given the scale of what would be involved to vacate the lands at Dublin Port to make them available for development, the estimate of 70 months to get all necessary policies aligned is not unreasonable.

However, once there might be a Government decision in principle to undertake the project, work on preparing planning applications could commence and, in our project plan, we have suggested that this could start in mid-2024. Gaining planning and other consents would itself be a large and expensive undertaking particularly where the consent would depend on the making and acceptance of an IROPI case.

Only after consents had been secured could detailed design work, incorporating the requirements of environmental conditions in planning permissions, be completed and works tendered and procured. We have suggested that this could be done in about two years to allow site mobilisation in the first half of 2033.

Thereafter, the construction times and sequencing are based on recent experience of actual large marine civil works in Dublin Port and using benchmarks from large international marine projects.

Behind the 20 year programme shown there is a host of challenges to secure contractual agreements with all of the stakeholders who would be displaced from Dublin Port.

When the jewel of redeveloping 260 hectares of Dublin Port lands is so dazzling, it can be difficult to appreciate and accept the magnitude of the challenge to make this happen. However, if this vision were to be realised

then all of the challenges we have described above would have to be taken on in what would be the largest megaproject ever undertaken in the State. Given the worldwide experience of megaprojects, it is likely to the point of near certainty that the project to develop a new port for Dublin at either Arklow or Bremore in order to make the lands of Dublin Port available for development would take far longer and be more costly than we have estimated in this paper. And only at that point could work commence to build out the new vision for the lands of Dublin Port.

Undermining all of this, of course, is what we believe to be a high probability that it would not even be possible to secure planning permission for DP2.0.

All of the analysis behind this paper is available to be critiqued by anyone who believes it worthwhile to move to the next stage of completing a cost benefit analysis of the megaproject to redevelop the lands at Dublin Port. It is clear to us in Dublin Port Company that this would be an unnecessary and wasted effort.

However, there still remains the challenge of providing additional port capacity to cater for growth after 2040 by which stage Dublin Port is planned to be operating at full capacity. One option to provide this additional capacity is to build a new port at either Arklow or Bremore smaller than the DP2.0 port considered in this paper. We have termed this project DP1.5 and have carried out a similar detailed analysis to test its feasibility.