IMAGIN Scenario Modeller

IMAGIN is an InterReg project looking at marine aggregate resources in the Irish Sea. The project has created and collated a considerable amount of information on the various parameters which influence aggregate extraction: from the existence of a potential resource through to the environmental, economic and political factors governing any decisions on whether extraction could or should take place. Whilst all information generated by or referenced by the project is readily available through the GIS interface, this only provides geographical context, or context specifically made available through the geographical context. The Scenario Modelling tool is one way in which we aim to make information more readily accessible, most particularly that information which will be of use to planners.

The task addressed by the tool is to simulate hypothetical dredging operations in the Irish Sea but this task is not geographically specific and the tool is intended to be generally applicable.

The IMAGIN Scenario Model is designed to simulate aggregate dredging operations. From input values of operational parameters describing ports, dredgers, the environment (e.g. tides, weather) and the deposit to be exploited it calculates operational costs, logistics and constraints. It is intended to allow planners to test hypotheses on potential resources and hence provide input to decisions which could result in sterilisation of resources. These requirements demand accurate prediction of the cost and efficiency of different operational scenarios and we are therefore looking at its potential as a tool to aid both the initial set-up of the dredging operation and the ongoing process of extracting the aggregate.

The costing and logistics of dredging operations are highly operation-specific but always represent an interaction between ports, dredgers, the environment and the deposit to be exploited. The underlying design of the IMAGIN model is to provide a "cyber platform" of linked tables simulating this interaction and then introduce logistics and parameter values particular to the operation to be evaluated. The IMAGIN model can thus become a powerful and comprehensive system that is tailored to calculate detailed values for specific operations.

The following description of the model functionality and related lists of parameters illustrates some of the possibilities of the model. For a particular operation, some of these options may be amended, others may be added and some suppressed as the platform is reconfigured to address the needs of the operation modelled. It is important to note that it is not just the value of parameters listed that can be amended but the manner in which they are applied and that new functionality can be added. The platform provides a framework for the model but the logic of each sector is amended to fit the logistics of the specific dredging operation.

The model is particularly useful when recalculating several interacting variables that change the scope of an operation. Examples include both initial set-up, through the interdependence of choice of equipment and available infrastructure, and stochastic variables, such as geological variability, which affects maintenance downtime through the different wear characteristics induced by different aggregate grades.

We are in the process of building realistic operation scenarios to demonstrate the modelling potential and would welcome input from or collaboration with operators, planners and other interested parties.

Summary of Model Functionality

A list of input parameters and a print layout of each screen is given in the appendices.

1. **Screen 1 - Deposit Data:** Data relating specifically to the deposit. These include its position, geological properties, value, reserves and operational constraints such as depth, distance to ports and tide windows. These data contribute to the computation of the timing and cost of the operation, calculated in the operations section (Screen 4).

2. **Screen 2 - Port Data:** Data relating specifically to various ports and the cost of operations from the ports. These include timing overheads for sailing and docking, constraints on unloading and other processes that add time to the operation, also costing and problems with port based capital costs. Costs are then applied as appropriate to the logic of the operation e.g. overheads per hour, fixed voyage costs, wages and overtime, bonuses, staged costs, etc. These data contribute to the computation of the timing and cost of the operation, calculated in the operations section (Screen 4).

3. **Screen 3 - Dredger Data:** Data relating specifically to various dredgers and the cost of operating the dredgers. These include the type of dredger and its hopper volume and related costs and service information from the CIRIA standard costs tables. Costs are then applied as appropriate to the logic of the operation e.g. overheads per hour, fixed voyage costs, wages and overtime, bonuses, staged costs, etc. These data contribute to the computation of the timing and cost of the operation, calculated in the operations section (Screen 4).

4. **Screen 4 - Operations Data and Model Application**: This is the most important section of the model. Several functions and performed:

    I. Model data input to the previous forms for Deposits, Ports and Dredgers is selected and displayed. These data are used in the model computations.

    II. Adjustments and constraints relating specifically to the operation and the cost of overcoming these are considered. These will be different for each operation and are finalised when the model is tailored to a particular operation, but might include:

        - Deposit needs screening at sea
        - Tide windows to be considered
        - Less than 100% of load usable
        - Bulking factor > 1
        - Problems of deep extraction
        - Economics of increasing cruising speed
        - Barge loading and unloading

    III. Data relating to each of these are input, together with related costs. These data are used in the model computations.

IV. Operational details and costs are then calculated. Taking the above data for the deposit, port selected, dredger selected and specific operation constraints, the time and cost of each trip is calculated. This time calculation is then fitted into a tide cycle i.e. 12.5 hours, 25 hours, 37.5 hours, etc.

V. The trip is then optimised. It may be that by increasing the cruising speed, not filling the hopper to capacity or other operational adjustments it is possible to fit to a more favourable and/or economic tide cycle. See Screen 5.

VI. A start date and operation length is selected and then from pre-loaded, operations related tide tables the time of the first trip is selected. (It may be that the operation requires sailing on the high, low or mid-tide and tide heights and speeds change during the tide cycle. Tide tables reflecting the features of the tide cycle relevant to the operation are pre-loaded and used here).

VII. An operations schedule is produced, dependant on trip length and tide tables. This also indicates operations buffers before the next tide is missed e.g. maximum dredging overrun possible, maximum unloading overrun possible. See Screen 6.

VIII. A full cost benefit analysis for the operation is calculated, taking into account the value of the deposit landed and above data for the deposit, port selected, dredger selected and specific operation constraints. See Screen 7

IX. Consider different options. This is perhaps the most important feature of the operations planning capability of the model. By changing various parameters, including selecting a different ship or port and considering the adjustments and constraints listed above different scenarios are tested. Once different parameters have been selected, clicking the "Calculate Operational Data" button immediately re-calculates all the above computations, allowing the modelling of different situations to find the most favourable.

5. **Screen 5 – Calculate Optimum Load:** By increasing the cruising speed, not filling the hopper to capacity or other operational adjustments, this screen tests if it is possible to fit to a more favourable and/or economic tide cycle.

6. **Screen 6 – Calculate Operations Schedule**: Taking the start tide selected and the calculated trip times, calculate a sailing schedule. This includes operations buffers before the next tide is missed e.g. maximum time that can be spent dredging, latest docking time, latest unload time.

7. **Screen 7 – Cost/benefit Analysis:** A full cost benefit analysis for the operation is calculated. This takes into account the data and costs for the deposit, port selected, dredger selected and specific operation constraints together with the value of the deposit landed to calculate profit and loss and its constituents.

8. **Screen 8 –** Variance Reports: When an operation goes live the model calculations can be compared with reality and an analysis of loses or gains to the expected operation analysed. A model is only as good as its assumptions. If some of those assumptions turn out to be misplaced (e.g. grade of deposit, sailing times etc.) or are changed by uncontrollable factors (e.g. weather) the operation and its profitability will be amended. At the end of each trip this screen allows the actual values of parameters to be input and compared with those expected. By reworking the above calculations, gains and losses resulting from each can be calculated.

The following Appendices list the parameters deployed in our testing scenarios. Screen printouts are also included. Again, it is important to note that it is not just the value of parameters that can be amended but the manner in which they are applied and new parameters can be added. The model platform provides a framework for the model but the logic of each sector can be amended to fit the logistics of the dredging operation.

Appendix A - Screen 1: Deposit Data

Data relating specifically to the deposit. These include its position, geological properties, value, reserves and operational constraints such as depth, distance to ports and tide windows. These data contribute to the computation of the timing and cost of the operation, calculated in the operations section (Screen 4).

Parameter	Notes
Name	Deposit Reference
Latitude	
Longitude	
Distances to relevant ports	To calculate voyage times
Type	Sand, sandy gravel, etc
Description	Detailed description of geology
Bulking Factor (usually 1.0)	Reduces capacity of dredger hopper. Normal capacity/bulking factor = reduced capacity
Reserves	
Surface area	
Current Value	Used to compare with costs for calculate cost/benefit
Recent High Value	To test possible fluctuations in cost/benefit
Recent Low Value	To test possible fluctuations in cost/benefit
Maximum Depth	Depth of deposit may cause problems – to check against specific ship capabilities
Minimum Depth	
Start Overhead (minutes)	Are there specific overheads as a ship prepares to start extraction? Is so, subtract from available dredge time (or will this be ship specific?)
End Overhead	Reverse of above
Operational Window (minutes)	Is there a window outside which operations cannot take place e.g. either side of high or low tide? If so, this is maximum dredge time each tide
Notes	

Further fields include greater geological detail, particularly when aggregate grade changes costs of maintaining equipment.

Appendix B - Screen 2: Ports Data

Data relating specifically to the port and the cost of operations from the port. These include timings for sailing and docking; constraints on unloading and other processes that add time to the operation; costing and problems with port based capital costs. Costs are then applied as appropriate e.g. overheads per hour, fixed voyage costs, wages and overtime, bonuses, staged costs, etc. These data contribute to the computation of the timing and cost of the operation, calculated in the operations section (Screen 4).

Parameter	Notes
Port Name	
Latitude	Automatically calculate distance to deposit
Longitude	
Sailing Overhead (minutes)	Time taken from cast-off to get to cruising speed (there will be speed restrictions in port environs). Add to voyage time
Docking Overhead (minutes)	Time taken from reduced cruising speed to docking (as above)
Unloading overhead (minutes)	Time taken to set up unloading gear. Add to unloading time.
Unloading overhead (%)	Equipment restricts unloading efficiency. Increase ship specific unloading time proportionately
Cost of Unloading (per hour)	Specific costs related to unloading that can be quantified per hour
Equipment Hire	See note below
Labour costs	See note below
Overhead 1	See note below
Overhead 2	See note below
Overhead 3	See note below
Overhead 4	See note below
Overhead 5	See note below
Port Based Capital Equipment Costs	Similar to ship based capital costs, as allocated to the operation
Dep. and Interest	See note below
Maintenance and repairs	See note below
Service Life	Similar to ship based capital considerations, as allocated to the operation
Residual Value	Similar to ship based capital considerations, as allocated to the operation
Utilisation	Similar to ship based capital considerations, as allocated to the operation
M+R % of value	Similar to ship based capital considerations, as allocated to the operation
Insurance	See note below

Note: In this testing example a simple list of possible costs headings is given. In working models costs are applied as appropriate e.g. Overheads per hour, fixed voyage costs, wages and overtime, bonuses, staged costs, etc.

Appendix C - Screen 3: Dredger Data

Data relating specifically to the dredger and the cost of operating the dredger. These include the type of dredger and its hopper volume and related costs and service information from the CIRIA standard costs tables. Costs are then applied as appropriate e.g. overheads per hour, fixed voyage costs, wages and overtime, bonuses, staged costs, etc. These data contribute to the computation of the timing and cost of the operation, calculated in the operations section (Screen 4).

Parameter	Notes
Dredger Name	
Type	As per CIRIA classes – Selection sets table for Hopper Volume and Related Parameters and populates tables and parameters below
Hopper Volume and Related Parameters	Calculates and sets value and operational parameters below, based on values in CIRIA tables for hopper volume selected
Displacement	
Lightweight	
Power – Dredge Pumps	
Power – Jet Pumps	
Propulsion Power	
Value	
Depreciation and Interest	Fixed rate per week, used in calculation of cost/benefit
Maintenance and Repairs	Fixed rate per week, used in calculation of cost/benefit
M+R (% of Value)	
Insurance	
Overhead 1	Other dredger related overheads, either per hour or per voyage, used in the calculation of cost/benefit
Overhead 2	See note1 below
Overhead 3	See note1 below
Overhead 4	See note 1 below
Overhead 5	See note 1 below
Operational Cost 1	Total Cost per hour
Operational Cost 2	Fixed costs per voyage
Operational Cost 3	Costs applied in other ways
Operational Parameters	Used to calculate how long the operation takes, to both calculate costs and schedule voyages
Cruising Speed	Normal operational speed
Maximum Speed	Test not exceeded in “What if” scenarios
Loading Rate	Normal operations
Loading Degradation	Loading degradation close to capacity (negative exponential?) See Note 2
Unloading Rate	Normal operations
Unloading Degradation	Unloading degradation close to capacity (negative exponential?) See Note 2
Maximum Operating Depth	
Minimum Operating Depth	

Extraction Depth	May be linked to geology
Maximum Operating Time	Maximum voyage time possible
Restricted operations	Should be in deposits form
Notes	

Note 1: In this testing example a simple list of possible costs headings is given. In working models costs are applied as appropriate e.g. Overheads per hour, fixed voyage costs, wages and overtime, bonuses, staged costs, etc.

Note 2: Loading and unloading degradation are examples of the flexibility in the way values can be applied in the model as these two values are likely to be negatively exponential. Values could also be applied as the results of formulas that could be real-time interpretations of other input values.

Appendix D - Screen 4: Operations Data and Model Application

This is the most important section of the model. Several functions and performed:

I. Model data input to the previous forms for Deposits, Ports and Dredgers is selected and displayed. These data are used in the model computations.

II. Adjustments and constraints relating specifically to the operation and the cost of surmounting these are considered. These will be different for each operation and are finalised when the model is tailored to an operation, but might include:

- Deposit needs screening at sea
- Tide windows to be considered
- Less than 100% of load usable
- Bulking factor > 1
- Problems of deep extraction
- Economics of increasing cruising speed
- Barge loading and unloading

III. Data relating to each of these are input, together with related costs. These data are used in the model computations.

IV. Operational details and costs are then calculated. Taking the above data for the deposit, port selected, dredger selected and specific operation constraints, the time and cost of each trip is calculated. This time calculation is then fitted into a tide cycle i.e. 12.5 hours, 25 hours, 37.5 hours, etc.

V. The trip is then optimised. It may be that by increasing the cruising speed, not filling the hopper to capacity or other operational adjustments it is possible to fit to a more favourable and/or economic tide cycle. See Screen 5.

VI. A start data and operation length is selected and then from pre-loaded, operations related tide tables the time of the first trip is selected. (It may be that the operation requires sailing on the high, low or mid-tide, tide tables reflecting this and relevant to the operation are pre-loaded and used here).

VII. An operations schedule is produced, dependant on trip length and tide tables. This indicates operations buffers before the next tide is missed e.g. time spent dredging, latest unload time. See Screen 6.

VIII. A full cost benefit analysis for the operation is calculated, taking into account the value of the deposit landed and above data for the deposit, port selected, dredger selected and specific operation constraints. See Screen 7

IX. Consider different options. This is perhaps the most important feature of the operations planning capability of the model. By changing various parameters, including selecting a different ship or port and considering the adjustments and constraints listed above, by clicking the “Calculate Operational Data” button all the above computations are re-calculated, allowing the modelling of different scenarios to find the most favourable.

Parameter	Notes
Deposit	Select previously input deposit name from the dropdown box, sets related parameters from previously input values
Type	
Reserves	
Longitude	
Latitude	
Bulking Factor	
Description	
Port	Select previously input port name from the dropdown box, sets related parameters from previously input values
Docking Overhead	
Sailing Overhead	
Unload Overhead minutes	
Unload Overhead %	
Port considerations	
Dredger	Select previously input dredger name from the dropdown box, sets related parameters from previously input values
Load rate	
Unload rate	
Maximum Operation time	
Hopper Volume	
Normal Cruising Speed	
Total Operational Costs per hour	
Total Fixed Operational Costs	
Operation Specific Information	
Distance	Distance from port to deposit (distance to port limits, excluding distance covered by sailing and docking overhead)
Voyage Overhead (minutes)	The voyage time is calculated as the length of the voyage x the cruising speed, plus docking and sailing overheads. The Voyage Overhead is any additional time required.
Tide Overhead (minutes)	Similar to the Voyage Overhead, this represents any overhead incurred because of missed tides. This can be linked to tide tables.
Useable % of load	Proportionately reduce load value
Screening overhead	Added to the dredging time if screening required
Optimum Load	It may be that a combination of the voyage distance, loading time and load degradation, costs and tides mean that it is more economic to return to port without filling the hopper to capacity. This feature of the model performs calculations (increase speed, more manpower, etc) to determine the optimum load, which replaces the hopper capacity. See screen 5
Overhead 1	See Note 1
Overhead 2	See Note 1
Overhead 3	See Note 1
Overhead 4	See Note 1

Overhead 5	See Note 1
Operational Cost 1	Total Overhead per hour
Operation Cost 2	Total Fixed Costs
Trip Calculations	These values are computed for the trip from the above parameters
Dredging Time	Time to load capacity or optimum load
Sailing Time	Return trip, excluding overheads
Unloading time	
Total Overhead	Sum of all trip (time) overheads
Trip Load	Hopper capacity or optimum load
Trip Time	Total time from cast off to completion of unloading
Number 12.5 hour tidal cycles per trip	
Operation Summary	
Operation length	In days
Start Date	
Select start tide	From pre-loaded tide tables geared to the operation
Maximum Number of trips possible	During the operation length (usually restricted by tides)
Total Operation Time	
Total Load Landed	
Total Operation Cost	
Total Value Landed	
Profit / Loss	
Non-quantifiable considerations	E.g. weather, strikes, natural disaster, etc. Tailored to each operation
Display Operating Schedule	For each voyage of the operation (See screen 6)
Adjustments to Calculations	
Bulking Factor > 1	Reduces hopper capacity proportionately
Amend cruising speed	Possibly economic when fitting in with tide cycle is tight. Increased fuel consumption and other costs? Check against max speed
Deposit needs screening	Introduces screening overhead
Voyage overhead	The voyage time is calculated as the length of the voyage x the cruising speed, plus docking and sailing overheads. The Voyage Overhead is any additional time required.
Tidal windows	Turn off if operations are not planned round tides
Barge loading	Adjust loading and unloading times accordingly
Deep extraction	Loading degradation because of suction loss

Note 1: In this testing example a simple list of possible costs headings is given. In working models costs are applied as appropriate e.g. Overheads per hour, fixed voyage costs, wages and overtime, bonuses, staged costs, etc.

Appendix E - Screen 5: Calculate Optimum Load

It may be that a combination of the voyage distance, loading time and load degradation, costs and tides mean that it is more economic to return to port without filling the hopper to capacity. This feature of the model performs calculations (increase speed, more manpower, etc) to determine the optimum load, which replaces the hopper capacity.

Parameter	Notes
Dredger	
Load rate	
Load degradation	
Unload rate	
Unload degradation	
Maximum Operation time	
Hopper Volume	
Normal Cruising Speed	
Total Operational Costs per hour	
Total Fixed Operational Costs	
Port	
Docking Overhead	
Sailing Overhead	
Unload Overhead minutes	
Unload Overhead %	
Deposit	
Bulking factor	
Distance	
Voyage Overhead (minutes)	
Tide Overhead (minutes)	
Useable % of load	
Screening overhead	
Cost 1	
Cost 2	
Cost 3	
Cost 4	
Cost 5	
Operational Cost 1	
Operation Cost 2	
Trip Time	Total time from cast off to completion of unloading
Tide Tables	
Number 12.5 hour tidal cycles per trip	

Appendix F - Screen 6: Calculate Operations Schedule

Taking the start tide selected and the calculated trip times, calculate a sailing schedule. This includes operations buffers before the next tide is missed e.g. maximum time that can be spent dredging, latest docking time, latest unload time.

Parameter	Notes
Sailing Time	Dependant on tide tables
Outward Voyage Time	
Arrival Time	
Dredging Time	
Dredge Buffer	How long the dredging can overrun without impacting on favourable return tide
Inward Voyage Time	
Latest Docking Time	The time at which the tide turns to be unfavourable
Scheduled end	
Sailing Buffer	How long unloading can overrun without impacting on the next sailing time
	Unused dredging buffer can be added to the sailing buffer

Appendix G - Screen 7: Cost/benefit Analysis

A full cost benefit analysis for the operation is calculated. This takes into account the data and costs for the deposit, port selected, dredger selected and specific operation constraints together with the value of the deposit landed to calculate profit and loss and its constituents.

Parameter	Notes
Dredger Costs	List of all dredger costs (see dredger form) multiplied by operational values to give total dredger costs for the operation
Port Costs	List of all Port costs (see Port form) multiplied by operational values to give total Port costs for the operation
Specific Operation Costs	List of all specific operation costs (see operations form) multiplied by operational values to give total specific costs for the operation
Amount of Aggregate Landed	
Value per tonne	
Value of Aggregate Landed	
Total Operation Costs	
Profit or Loss	

Appendix H - Screen 8: Variance Reports

When “What if” scenarios have been completed and an operation planned the schedule predicted by the model values is then transferred to a “Live Operations” file. Real operational values are subsequently input and the variations with those of the model calculated, together with the benefit or loss accruing. A model is only as good as its assumptions. If some of those assumptions turn out to be misplaced (e.g. grade of deposit, sailing times etc.) or are changed by uncontrollable factors (e.g. weather) the operation and its profitability will be amended. At the end of each trip this screen allows the actual values of parameters to be input and compared with those expected. By reworking the above calculations, gains and losses resulting from each can be calculated.