

Chapter 6

Effect of Key Parameters on Design

This chapter discusses various problem formulation issues that were encountered and illustrates the effects of each of these issues on the design. Each section in this chapter has a table of results. In each case in these tables, sub-cases 1, 2 and 3 are the results obtained starting from the lower bound, upper bound and the middle of the design space respectively. The subsequent cases are started from the optimum point identified by the above process until the results converge. The bounds on the design variables are shown in Table 5.1. In all cases, the hull forms used for geometry manipulation (as explained in section 4.2) are basis ships 11 and 22. The objective function used is the required freight rate (2.62) subject to the constraints as explained in section 5.1. The optimization method used is Sequential Quadratic Programming.

The abbreviations used in the following tables of optimization results have been explained in section 5.1. They are mentioned here again for convenient reference.

- M: Method used in DOT
1. MMFD: Modified Method of Feasible Directions
 2. SLP: Sequential Linear Programming
 3. SQP: Sequential Quadratic Programming
- IT: Number of iterations
- TC: Termination Criteria
- A: Relative convergence criteria (0.001) met for 2 consecutive iterations
- B: Absolute convergence criteria (0.0001) met for 2 consecutive iterations
- C: Search vector is less than the specified tolerance (0.0001)
- AC: Constraints active at the optimum, in addition to the displacement-weight equality constraint:
- Fb: Freeboard Constraint (2.68)
- Troll: Rolling period constraint (2.70)
- GM: Constraint on metacentric height (2.67)
- L/D: Geometric constraint on the Loa /Depth ratio (2.65)

6.1 Port Waiting Time

Port waiting time or the time spent in port as described in 2.2.2, is identified by the user to allow for flexibility in trade routes and port conditions. Table 6.1 illustrates the significant effect that the port waiting time has on the design.

Table 6.1 Effect of port waiting time on design

Sub-case	Loa	B	D	T	Vk	C11	C22	Obj: RFR	IT	TC	AC
Case 6.1.1: Using Pwt = 15 Days.											
1	300	43	15.3	10.0	16.22	0.33	0.67	.001554	13	C	Troll
2	300	43	14.7	10.0	16.49	1.00	0.00	.001542	8	C	Troll, Fb
3	300	43	15.0	10.0	16.41	0.59	0.41	.001548	7	A,C	Troll
4	300	43	14.7	10.0	16.49	1.00	0.00	.001542	8	C	Troll,Fb
Case 6.1.2: Using Pwt = 2 Days.											
1	300	43	15.3	10.0	15.23	0.31	0.69	.001053	10	C	Troll
2	300	43	14.7	10.0	17.62	1.00	0.00	.001029	7	C	Troll, Fb
3	300	43	15.0	10.0	17.28	0.60	0.40	.001033	7	C	Troll
4	300	43	14.7	10.0	17.62	1.00	0.00	.001029	7	C	Troll,Fb

The results from cases 1 and 2 show that shortening the time spent by the ship in port has the effect of increasing the optimum speed of the ship. This is due to the fact that a shorter port waiting time results in a shorter round trip time and hence an increase in the number of round trips made by the ship annually.

6.2 Loading and Unloading Rate

The loading and unloading rate has a significant influence on the port turn around time and hence on the optimum speed. In Table 6.2; comparison of cases 6.2.1 and 6.2.3 shows that using a number of cranes calculated as an increasing function of the length of the ship to load and unload cargo (2.2.2), rather than using a single crane results in:

- a faster ship and hence more number of round trips annually,
- a larger ship leading to an increase in the cargo carrying capacity.

These factors make the design more profitable for the ship owner as can be seen from the lower amount of the required freight rate to breakeven.

Table 6.2 Effect of loading and unloading rate on design

Sub-case	Loa	B	D	T	Vk	C11	C22	Obj: RFR	IT	TC	AC	TEU_I	No. of Cranes
Case 6.2.1: Using 1 Crane													
1	256.2	43	14.7	10.0	17.02	1.00	0.00	.001514	17	A,C	Troll	4656	1
2	296.2	43	14.7	10.0	16.39	1.00	0.00	.001519	9	C	Troll,Fb	5355	1
3	231	43	15.1	10.0	15.76	0.58	0.42	.001529	7	A,C	Troll	4211	1
4	256.4	43	14.7	9.9	16.22	1.00	0.00	.001511	3	C	Troll	4655	1
Case 6.2.2: Using Number of Cranes(integer) calculated as a function of Loa													
1	300	43	15.2	10.0	17.07	0.44	0.56	.001035	26	C	Troll	5392	6
2	300	43	14.7	10.0	17.76	1.00	0.00	.001029	6	C	Troll,Fb	5356	6
3	300	43	15.0	10.0	17.33	0.63	0.47	.001032	10	C	Troll	5382	6
4	300	43	14.7	10.0	17.29	1.00	0.00	.001028	2	A,C	Troll,Fb	5356	6
Case 6.2.3: Using Number of Cranes(continuous) calculated as a function of Loa													
1	300	43	15.3	10.0	15.23	0.31	0.69	.001053	10	C	Troll	5399	5.967
2	300	43	14.7	10.0	17.62	1.00	0.00	.001029	7	C	Troll,Fb	5356	5.967
3	300	43	15.0	10.0	17.28	0.60	0.40	.001033	7	C	Troll	5383	5.967
4	300	43	14.7	10.0	17.62	1.00	0.00	.001029	7	C	Troll,Fb	5356	5.967

The number of cranes causes a discontinuity in the objective function from the fact that it is a discontinuous function of the length of the ship (Fig. 2.1). The gradient of the objective function, though discontinuous when using the integer expression (2.45) for the number of cranes, as seen from Figure 6.1, does not lead to local minima (Table 6.2). However, it is better to use the continuous expression (2.46) for the number of cranes to ensure that the gradient of the objective function is continuous. This has been followed throughout this work. Cases 6.2.2 and 6.2.3 in Table 6.2 show a small difference in the objective function at the optimum. This small difference is due to the flatness of the objective function in the vicinity of the optimum.

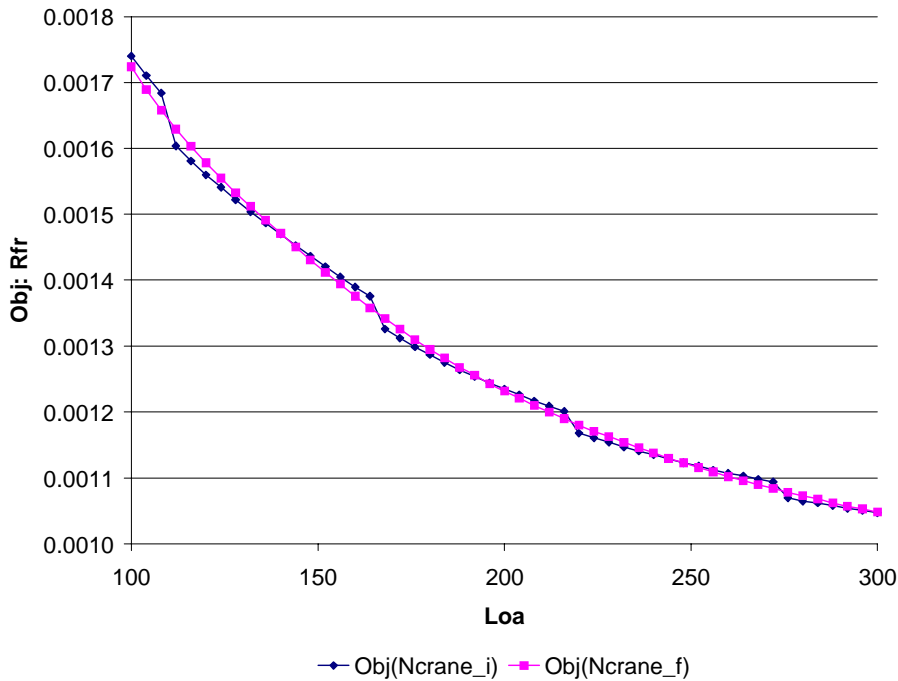


Figure 6.1: Effect of integer and continuous number of cranes on RFR

6.3 Number of Tiers on Deck

The number of tiers of containers a ship can accommodate on deck can be shown to be an increasing function of the beam (section 3.3). This needs to be accounted for in the design. Cases 6.3.1 and 6.3.2 in Table 6.3 illustrate the importance of this aspect on the design.

Table 6.3: Effect of number of tiers on deck on design

Sub-case	Loa	B	D	T	Vk	C1	Obj: RFR	IT	TC	AC	TEU_I	TEUd_i
Case 6.3.1: Keeping Ntd constant at 5.5												
1	300	38.3	13.9	9.2	16.81	0.22	.001077	18	C	Troll,Fb	4171	2859
2	300	43.0	15.5	9.9	17.78	1.00	.001089	6	C	Troll	5039	3240
3	300	41.5	15.0	9.6	17.24	0.61	.001094	8	C	Troll	4770	3049
4	300	43.0	15.5	9.9	17.78	1.00	.001089	2	A,C	Troll	5039	3240
Case 6.3.2: Varying Ntd as a Function of Beam by interpolation (Table 3.2)												
1	300	43.0	15.3	10.0	15.23	0.31	.001053	10	C	Troll	5399	3534
2	300	43.0	14.7	10.0	17.62	1.00	.001029	7	C	Troll,Fb	5356	3534
3	300	43.0	15.0	10.0	17.28	0.60	.001033	7	C	Troll	5383	3534
4	300	43.0	14.7	10.0	17.62	1.00	.001029	7	C	Troll,Fb	5356	3534

When the number of tiers on deck is allowed to vary as a function of the beam, we can accommodate the maximum number of tiers (as per the equations mentioned in Table 3.2). This increase in the number of TEUs provides a further decrease in the objective function, as seen from the value of the objective function at the local optimum (Table 6.3).

6.4 Comparison of RFR and ROI as Objective Functions

In this section we examine the effect of using these two alternative measures of merit on the design.

Table 6.4 Comparison of RFR and ROI as Objective Functions

Sub-case	Loa	B	D	T	Vk	C11	C22	RFR	ROI	IT	TC	AC	TEU _i
Case 6.4.1: Objective Function: RFR in dollars/ metric ton / nautical mile													
1	300	43.0	15.3	10.0	15.23	0.31	0.69	.001053	75.98	10	C	Troll	5399
2	300	43.0	14.7	10.0	17.62	1.00	0.00	.001029	84.35	7	C	Troll,Fb	5356
3	300	43.0	15.0	10.0	17.28	0.60	0.40	.001033	82.83	7	C	Troll	5383
4	300	43.0	14.7	10.0	17.62	1.00	0.00	.001029	84.35	7	C	Troll,Fb	5356
Case 6.4.2: Objective Function: ROI expressed in percentage													
1	100	26.9	12.0	6.9	4.0	0.00	1.00	.006444	97.36	4	C	GM, L/D	767
2	300	43.0	15.2	10.5	23.94	1.00	0.00	.001200	93.12	4	A,C	Troll,Fb	5361
3	300	43.0	15.2	10.4	23.48	0.76	0.24	.001185	92.76	6	A,C	Troll,Fb	5380
4	300	43.0	15.2	10.5	23.94	1.00	0.00	.001200	93.12	4	A,C	Troll,Fb	5361

It is worth mentioning here that the return on investment values in Table 6.4 have been calculated (2.63) using a Chargerate of 0.0064 Dollars/ metric ton/ nautical mile, as mentioned in section 4.1. This results in a unrealistically high return on investment. Using a Chargerate of 0.0048 results in a 59.54 percent and 64.92 percent return on investment for sub-cases 4 in Cases 6.4.1 and 6.4.2 respectively.

From cases 6.4.1 and 6.4.2, it is seen that using the return on investment (2.63) as the objective function results in a faster ship and a small increase in the annual transportation capacity.