Chapter 5

A Discussion on Results of the Optimization Process

5.1 Results of the Optimization Process

The statement of the optimization problem has been discussed in section 4.1. The results discussed in this chapter [Table 5.2] are obtained in the design space bound by the values shown in Table 5.1.

Table 5.1 Bounds on the design variables

	Loa	B	D	T	Vk	C1	C2
Lower Bound	100	20	12	6	4	0	0
Upper Bound	300	43	25	11	35	1.0	1.0

Table 5.2 Results of optimization

M	Loa	B	D	T	Vk	C11	C22	Obj: RFR	IT	TC	AC
Basis Ships Used: 11 and 22											
Best optimum point identified by starting from the middle of design space.											
2	300	43	14.7	10.0	17.30	1.00	0.00	.001029	9	A	Fb,Troll
Restarting from the optimum point identified above.											
2	300	43	14.7	10.0	17.22	1.00	0.00	.001029	5	A	Fb,Troll

In the tables of optimization results, in this section and throughout this work, the following abbreviations are used:

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)

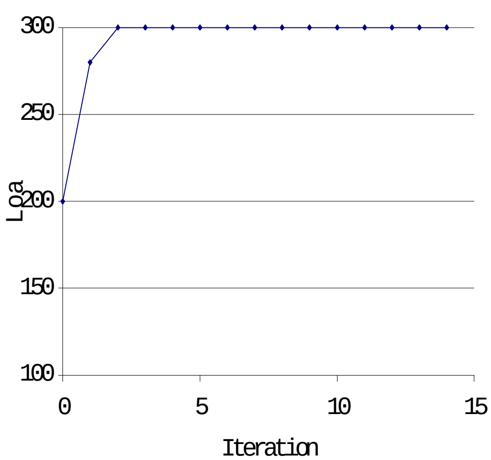
AC: Constraints active at the optimum, in addition to the displacement-weight equality constraint:
- Fb: Freeboard Constraint
- Troll: Rolling period constraint
- GM: Constraint on metacentric height
- L/D: Geometric constraint on the Loa/ Depth ratio

It is seen that the optimum ship tends to be the largest in terms of length and beam. An optimum speed has been identified as a trade-off between higher revenue implied by higher speeds and lower fuel costs implied by lower speeds. It is seen that the optimum ship tends to favor one particular hull in the above-mentioned combination of basis hulls. A more rigorous discussion on the basis hulls and on the use of the three techniques provided in DOT for optimization follows in chapter 7.

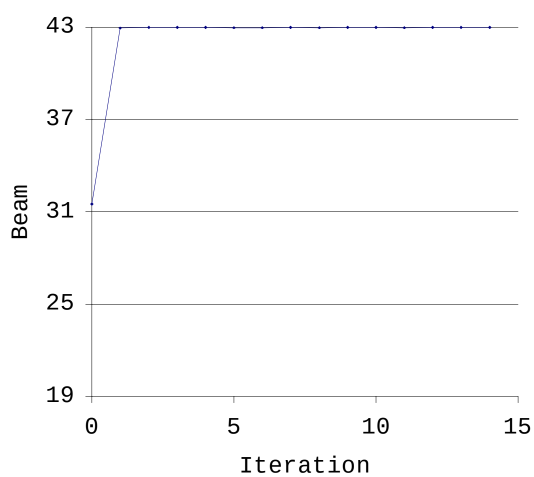
5.2 Iteration History

It is essential to have information regarding the behavior of the design variables, the objective and the constraint functions during the optimization process. This enables us to study the behavior of the model and the convergence of the design variables.

The iteration history provided below is obtained using the required freight rate (2.62) as the objective function subject to the constraints described in section 4.1 and using a weighted average of the hull forms: basis ships 11 and 22 to obtain the resultant hull form. The initial point identified is the middle of the design space subject to upper and lower bounds as shown in Table 5.1. Once an optimum point is identified with these conditions, the optimization process is restarted from this point until the results converge. In this case, the results converge to a local optimum in one restart. The results of the optimization process for the initial run and the second run starting from the optimum point identified in the first run are provided in Table 5.2.

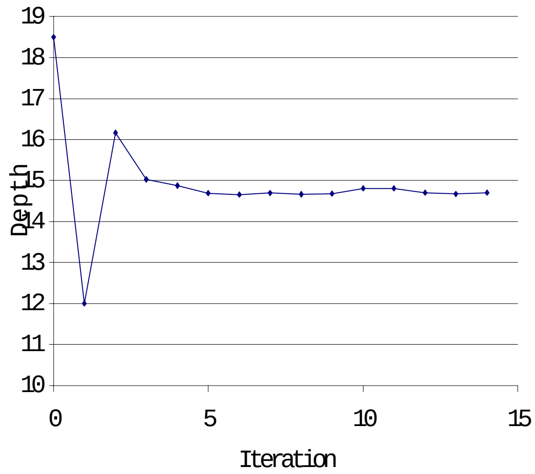


a) Iteration History: Length, overall

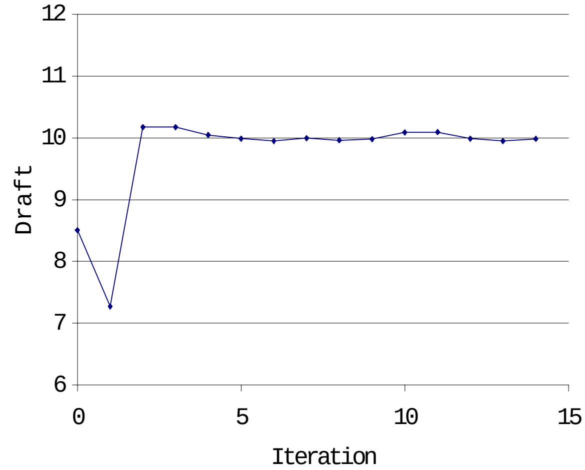


b) Iteration History: Beam

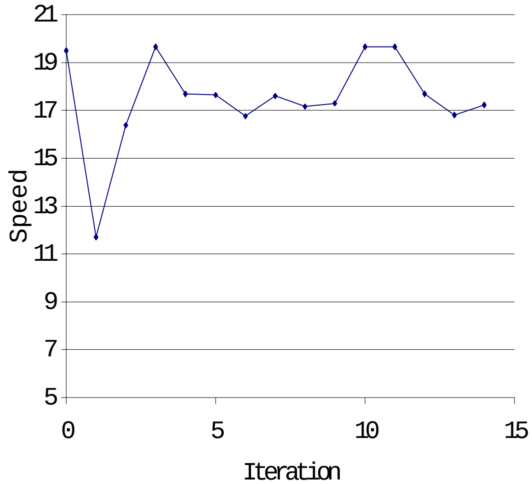
Figure 5.1: Iteration History



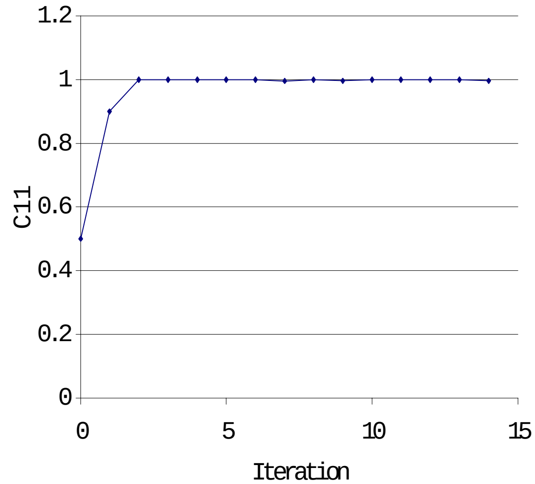
c) Iteration History: Depth



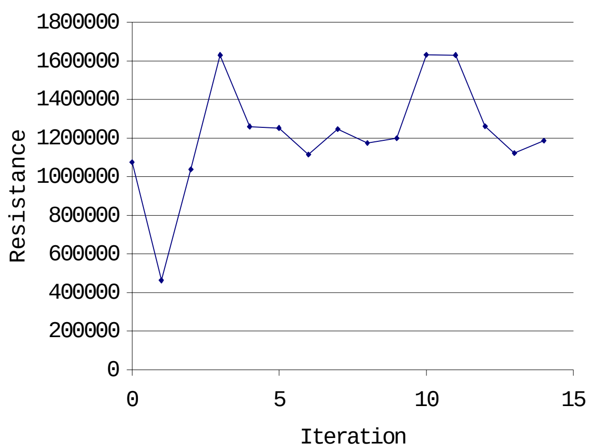
d) Iteration History: Draft



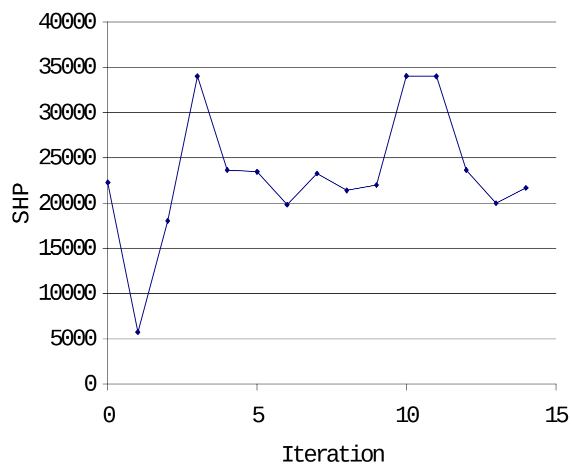
e) Iteration History: Speed



f) Iteration History: Blending Coefficient

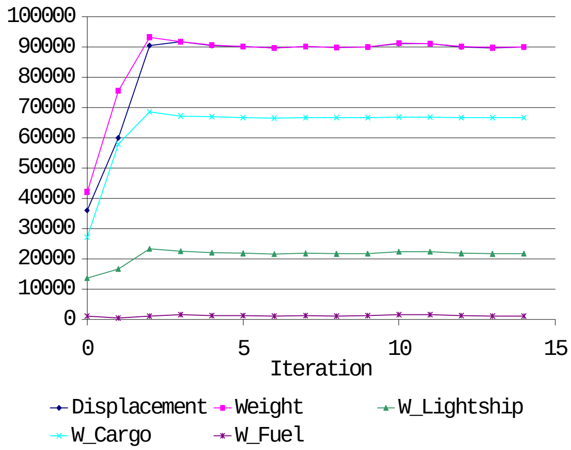


g) Iteration History: Resistance

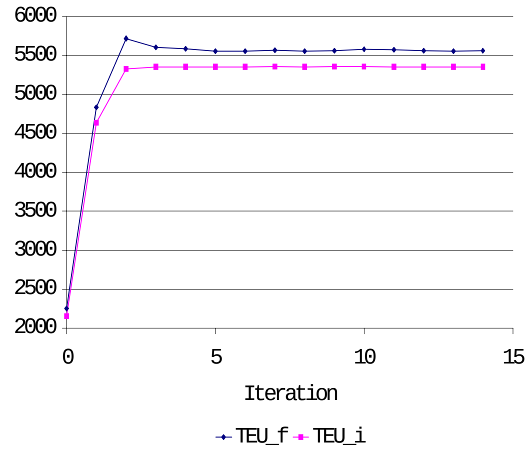


h) Iteration History: SHP

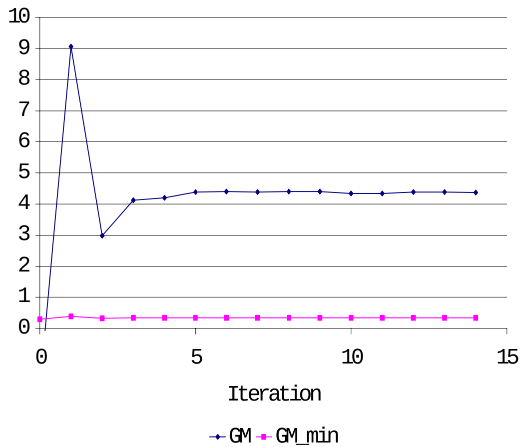
Figure 5.1: Iteration History (continued)



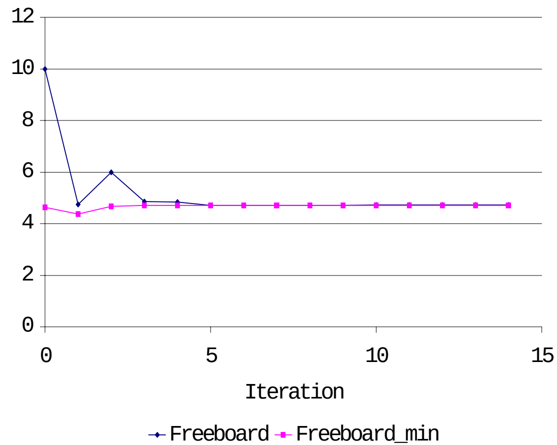
i) Iteration History: Weights



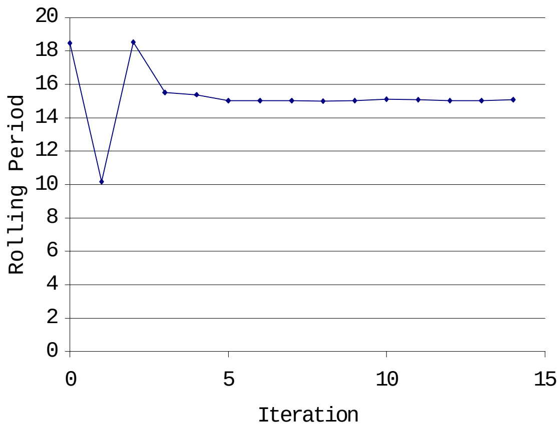
j) Iteration History: TEUs



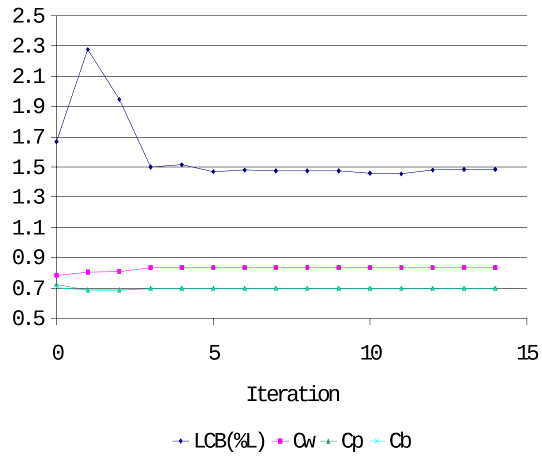
k) Iteration History: Metacentric Height



l) Iteration History: Freeboard



m) Iteration History: Rolling Period



n) Iteration History: Hydrostatics

Figure 5.1: Iteration History (concluded)

The iteration data shows that the length, overall and the beam converge quickly, within two iterations. The depth and the draft take more iterations to converge. The speed fluctuates quite a bit before converging to the optimum. The blending coefficient favors the basis ship 11 (as c11 =1.0) and converges in three iterations.

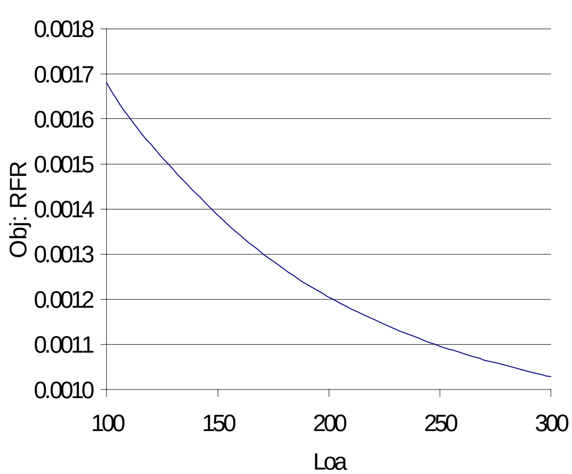
The optimum point identified in the first run turns out to be the local optimum in the given design space, as verified by the results of the second run starting from the optimum point identified in the initial run.

The fast convergence of displacement and weight shows that the optimizer enforces the displacement-weight equality constraint fairly quickly, in three iterations. Iteration history of the metacentric height shows that the optimum ship is very stable.

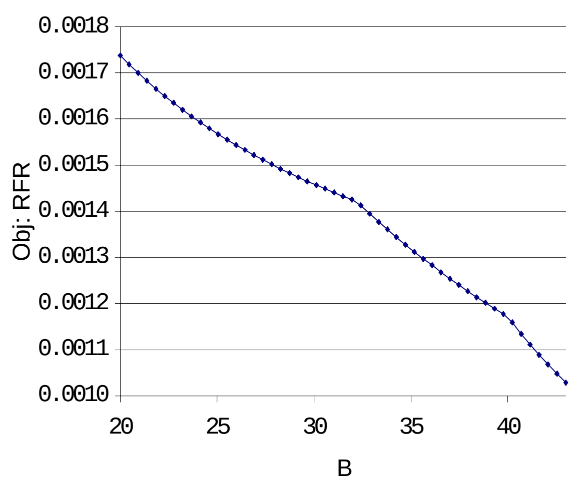
5.3 Sensitivity Analysis

The objective of the sensitivity analysis is to study the effect of each design variable on the objective function independently. The objective function is calculated as a function of a single design variable between its bounds (Table 5.1) while all other design variables are fixed at the optimum (Table 5.2). The resulting figure shows the effect of this design variable on the objective function, in other words, the sensitivity of the objective function to this design variable.

It is seen that the objective function is sensitive to the length and the beam. The optimum length and the beam are on the upper bound. The objective function is also sensitive to the depth and the draft. An optimum speed is identified in the design space. The blending coefficient, however, has negligible effect on the objective function as seen from the flat nature of the latter in this dimension.

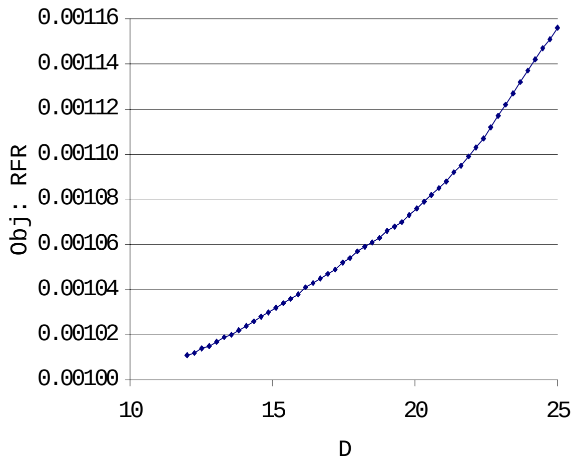


a) Sensitivity Analysis: Length, overall

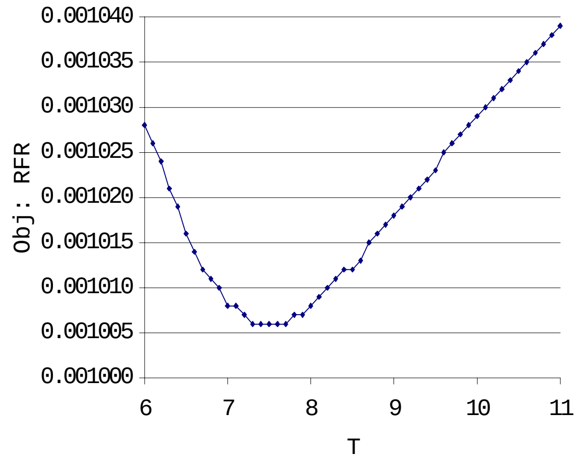


b) Sensitivity Analysis: Beam

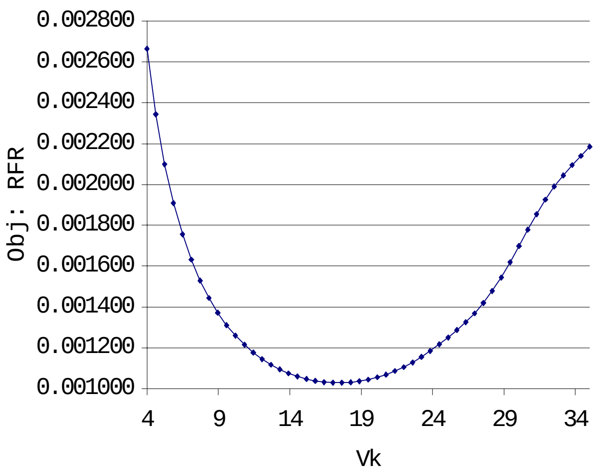
Figure 5.2: Sensitivity Analysis



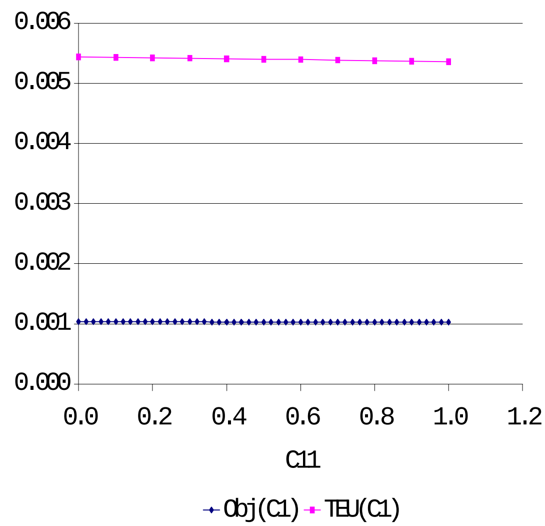
c) Sensitivity Analysis: Depth



d) Sensitivity Analysis: Draft



e) Sensitivity Analysis: Speed



f) Sensitivity Analysis: Blending Coefficient

Figure 5.2: Sensitivity Analysis (concluded)

5.4 Breakdown of Weights and Costs

Once the optimization process is complete, it is desirable to have information pertaining to the breakdowns of the weights and the costs for the optimum ship. The charts in this section show the breakdowns of the weights and the costs for the optimum ship identified in section 5.1. Note that the cargo handling cost is not included in the calculation of the annual operating cost, as we presently do not have a reasonable representation of this parameter in our model.

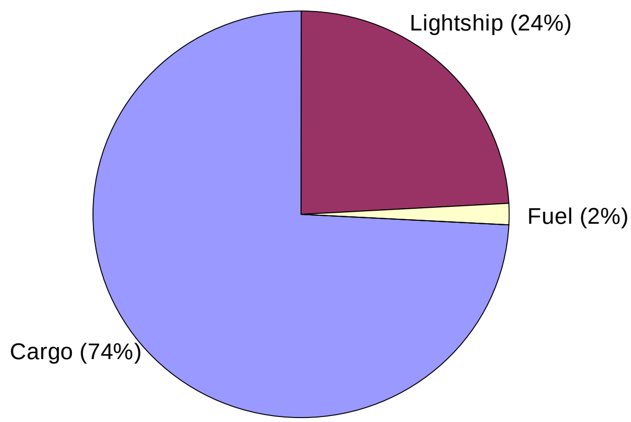


Figure 5.3 Weight Breakdown

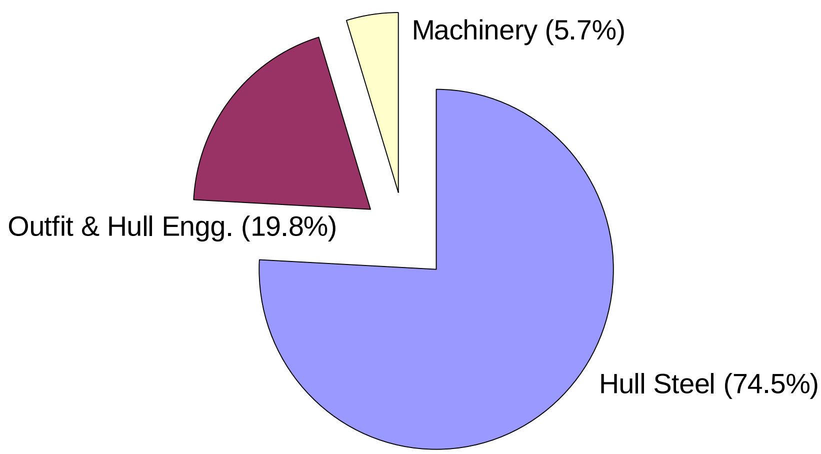


Figure 5.4 Lightship Weight Breakdown

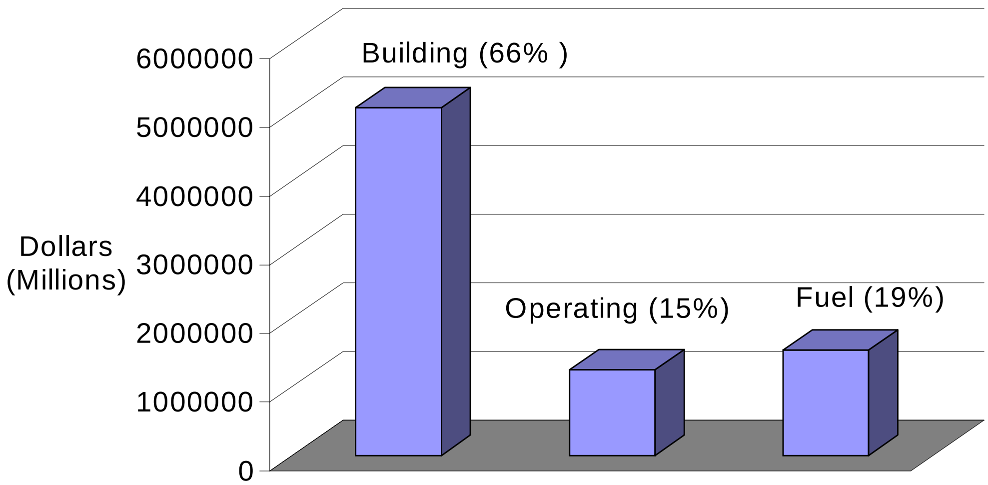


Figure 5.5 Breakdown of Annual Costs

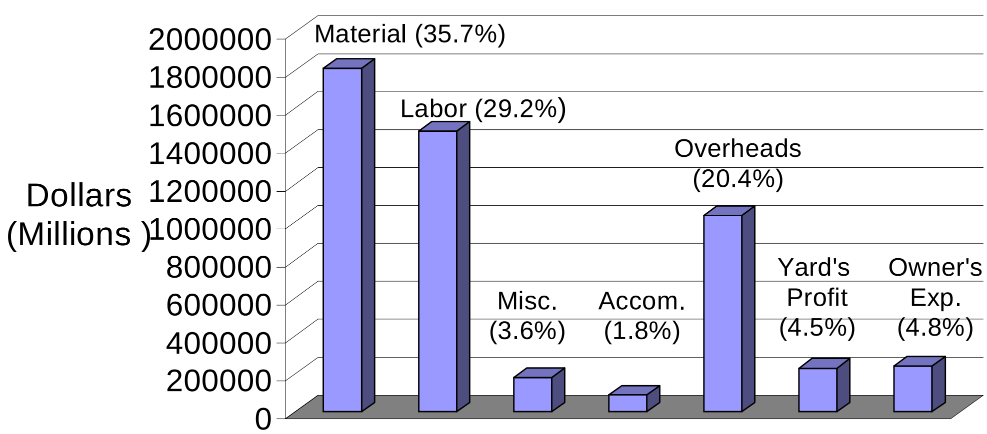


Figure 5.6 Breakdown of Annual Building Costs

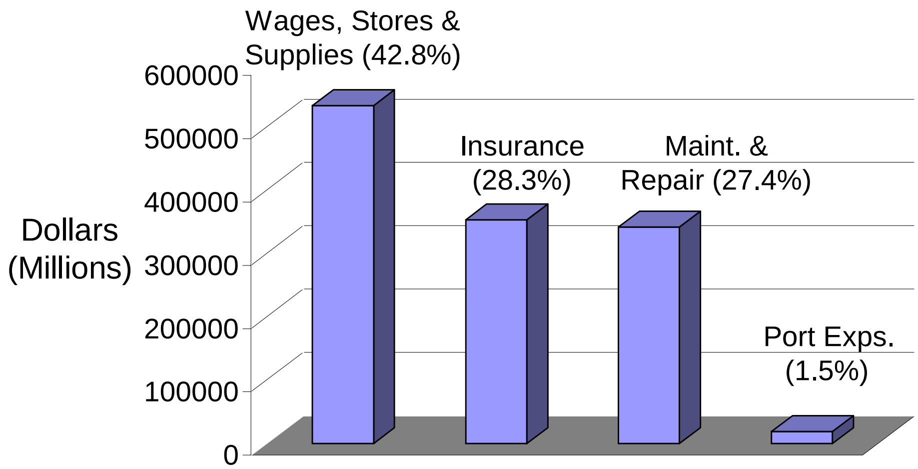


Figure 5.7 Breakdown of Annual Operating Costs