Better PBL Contracts - An Analytical Approach

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ABSTRACT

Successful Performance Based Logistics (PBL) can reduce total ownership costs for government while maintaining or increasing capability. The chance of success depends heavily on the terms in the PBL contract. Performance targets, incentive models and measurement approach must be carefully selected in order to give the supplier both motivation and freedom to provide logistics functions that will enable high system performance.

When designing and negotiating such a contract it is imperative for all involved parties to have proper decision support. The consequences of different alternatives must be thoroughly analyzed in advance. A Monte Carlo simulation model of the logistics scenario can offer valuable insight to the how the outcome may change as different variables are altered and what results to expect with a statistical confidence level. Such information can be of great use when formulating PBL contract terms.

In this paper, some key success factors and a step wise approach for setting the terms of a PBL contract is presented. It is shown how a penalty function $y(x)$ can be defined, where x can be any measurable logistics parameter(s) that can measure the degree of contract fulfillment. An example is used where backorders, B, plays the role of the logistics parameter x, but the ideas presented can be applied to any other type of measurable parameter(s). It is furthermore shown that the design of $y(B)$ is dependent upon the time period T used for monitoring the backorders.

Keywords

Performance Based Logistics; PBL Contract Design; Monte Carlo; Simulation; Penalty; Cost Efficiency; Mission Readiness; OPUS10; SIMLOX

1. BACKGROUND

Performance Based Logistics (PBL) is often seen as an attractive solution these days, as it offers a potential to reduce Government ownership cost while maintaining or increasing capability. Applied correctly, and tailored to the specific scenario, that potential is substantial. But as many Program Managers and Logisticians have experienced, setting up a PBL-contract is a complex task. More importantly, if inadequately written, the outcome may be the opposite; increased costs and risks for government, contractor or both.

Success factor 1 - A common pitfall in PBL contract design is that the supplier scope is not clearly defined and that the distinction between supplier and customer responsibilities is imprecise. A weak definition of this basic foundation of the contract can be detrimental and cause discussions and disagreements about what is included and not. It can also lead to that the defined KPIs do not correspond to the actual interpretation of the contract scope.

Success factor 2 – Appropriate performance parameters (KPIs). The KPIs must be selected based on the nature and scope of the contract, and give the customer performance, affordability and control. On the other side, KPIs must give the contractor direction and incentive, but also maneuverability to build, adapt and manage the solution in the most cost effective way. To allow for the latter, a small number of well selected KPIs are preferable to many. It is a common mistake to try to compensate uncertainty with a long array of KPI's which are at best redundant and at worst conflicting and counterproductive.

Success factor 3 – Appropriate KPI target levels. It is crucial to understand the consequences of setting a certain target level in advance. For example, a target for average availability may seem acceptable if only considering a steady state situation, but can mean unacceptable sensitivity to changes or poor ability to handle peak loads. Meanwhile, a too high target typically escalates costs.

Success factor 4 – A clear and relevant incentive model. All involved should win when performance is on or above target and, the very driving force of PBL, the revenue for the contractor must drop significantly when performing below target. The approach can be either penalties or rewards.

Success factor 5 – Performance measurement approach and intervals. The way performance is measured and calculated, and how often it is measured can have a large impact on the outcome. Too long measuring intervals could for example mean that unsatisfactory performance over important periods can be averaged out by over-performing during the rest of the time. Too short intervals could mean that the contractor does not get enough time to adjust and correct deficiencies, hence the incentive to improve is lost.

Understanding the consequences of a PBL contract in advance, the potential benefits, risks and costs involved, is equally important to customer and contractor. Design, evaluation and ultimately the negotiation of the terms in the contract should be based on thorough analysis by both parties.

Thus far, it's easy. Everyone with some experience in PBL can probably agree with most of the statements above. The difficulty, as always, lies in "how?" This paper offers a step wise analytical approach, where Monte Carlo simulation is used to design an effective incentive model, to set the performance levels and suitable measurement intervals; all based on proper decision support, mission understanding and consequence analyses.

2. OVERVIEW

Performance based logistics represents a potentially cost effective method for system sustainment ref [3]. From the customer perspective PBL means a shift away from buying parts to instead buying performance from the supplier. PBL can be applied at system, subsystem or major assembly level. A key element in PBL is the ability to measure the system performance in a well-defined way, either directly, e.g. availability, or indirectly by measuring given logistic parameters, e.g. backorders. Monitoring and following up logistic parameters in the supply chain can on its own be a driver for supply chain performance improvements ref [2].

In this paper the degree of PBL contract fulfillment is proposed to be evaluated using a penalty function $y(x)$, where y is the share (%) of the maximum penalty amount and x can be *any* logistics parameter of interest to mission capability. The parameter x is measured as an average over a time period T.

In Section 5 it is shown that the time period T will influence the design of the penalty function $y(x)$. In the example used in this paper, the backorder measure B is used for designing the penalty function $Y(B)$, but the same approach can be used for any other logistics parameter. In fact $y(x)$ could be multidimensional, i.e. x being a vector of several types of logistics parameters.

In reference [1] it is shown that appropriate results collected from Monte Carlo simulations enable evaluation of alternative penalty (or reward) functions suggested in a PBL contract negotiation. In this paper guidelines are provided for *how* a penalty function $y(x)$ should be *designed* to meet the customer and supplier objectives in a satisfactory way for both parties. Rules for constructing $y(x)$ are described in Sections 5 and 6.

It is important to consider different operational scenarios and the potential effects of the penalty function on e.g. mission success, mission readiness, and operational effectiveness when designing the $y(x)$ function. Typically, the penalty increase in steps if performance drops below target. Each step in $y(x)$ should be simulated to demonstrate the capability impacts (positive and negative) of different outcomes. While requiring a thorough understanding of mission profiles, operational scenarios, and definitions of "success," this methodology allows both the customer and the supplier to make rational decisions and agree on a reward (or penalty) function commensurate with the relative impact of each $y(x)$ step on overall mission readiness and mission capability. Simulation of mission readiness and capability instead of availability provides a $y(x)$ function that aligns with operational realities and ensures cost effective capability to the warfighter.

The outline of the paper is as follows. In Section 3 a fictitious logistics scenario is described that is used throughout this paper to illustrate important points. Section 4 provides an initial analysis of the scenario using spares optimization and simulation, while Section 5 studies the inherent variation of backorders in more detail. Section 6 provides guidelines for an initial design of the penalty function $y(x)$ as a function of backorders ($x = B$).

In Section 6 the proposed penalty function $y(B)$ is evaluated on a validation simulation data set. Furthermore the consequence of modifying a design parameter of $y(B)$ is analysed. Section 7 discusses how sensitivity analysis can be performed on the logistic scenario.

3. SCENARIO

This paper studies the formulation of PBL contract terms between a customer and a supplier using backorders B as a performance metric. The PBL contract value C that should cover the supplier's Life Support Cost (LSC) expenses is:

$$C = 500 \text{ MUSD}.$$

The supplier responsibility is to provide both a cost efficient spares stock and a repair services solution so that the average system availability A is

$$A \geq 85\ \%,$$

which can be translated to a backorder requirement, see Section 3.

The PBL contract covers a 10 year period where the average backorders are measured and monitored on a time period T basis to ensure that the supplier fulfils the contract commitments.

The support organization is shown in Figure 1 and consists of three levels, an operating base, one collocated depot (DEPOT) and one contractor facility (CONTRACTOR). Both spares stock and repair solution can be optimized to consider cost and availability and the relative impacts on readiness.

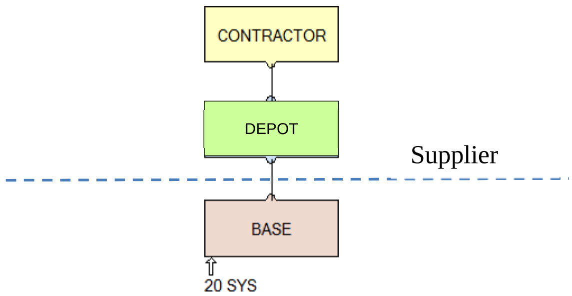


Figure 1. The Support organization.

The 20 technical systems at the BASE are utilized on average 25.2 hours per week or 15 % of the calendar time. Each system consists of 1000 items, out of which 400 are repairable and 600 discardable. The item repair time and lead time for reorders are both 6 months. The mean time between system failures (MTBF) is 20 hours.

4. INITIAL ANALYSIS, SPARES OPTIMIZATION AND SIMULATION

An initial analysis of the scenario using the logistics optimization tool OPUS10 [4] shows that the system operational requirement $A \geq 85\ \%$ can be met if the average number of backorders is $B = 3.14$, see Figure 2 and 3.

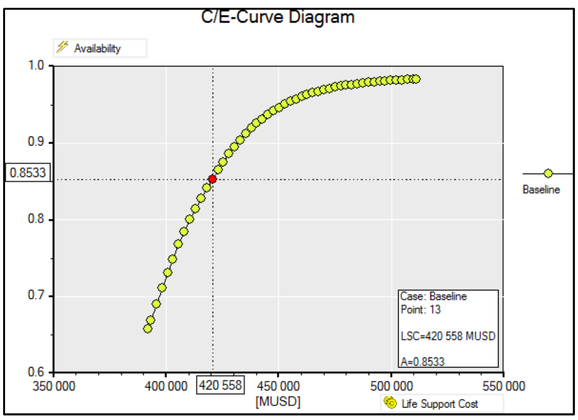


Figure 2. OPUS10 result: Cost efficient (CE) point 13.

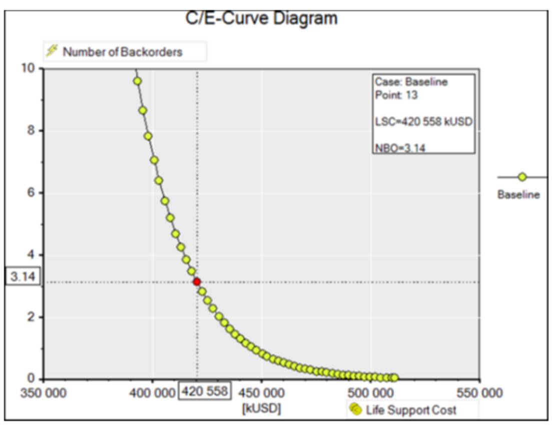
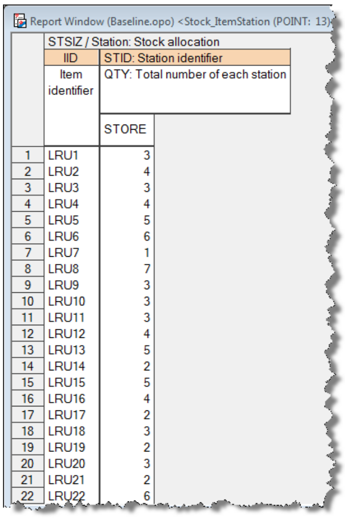


Figure 3. OPUS10 result: Corresponding backorder requirement (CE point 13), compare Figure 2.



Report Window (Baseline.opo) <Stock_ItemStation (POINT: 13)

	STSIZ / Station: Stock allocation	
	IID	STID: Station identifier
	Item identifier	QTY: Total number of each station
		STORE
1	LRU1	3
2	LRU2	4
3	LRU3	3
4	LRU4	4
5	LRU5	5
6	LRU6	6
7	LRU7	1
8	LRU8	7
9	LRU9	3
10	LRU10	3
11	LRU11	3
12	LRU12	4
13	LRU13	5
14	LRU14	2
15	LRU15	5
16	LRU16	4
17	LRU17	2
18	LRU18	3
19	LRU19	2
20	LRU20	3
21	LRU21	2
22	LRU22	6

Figure 4. OPUS10 result: Parts of the optimal spares stock corresponding to CE-point 13.

The optimal spares stock suggested by OPUS10 (CE-point 13) is used in the Monte Carlo based simulation tool SIMLOX [5] to verify the OPUS10 results, and provide additional information regarding the inherent variations in backorders. The simulations covers 11 years of operation out of which the backorder results for the first year are ignored to avoid the transient effects at the beginning of the simulation. The 11 year simulation is repeated 100 times using a different initial random seed in each replication. Hence the results presented in this paper are based upon backorder statistics from

$$10 \text{ years} \times 100 \text{ replications} = 1000 \text{ years of simulations}$$

In Figure 5, the backorder results from replication 1 are shown vs. time where the backorders are averaged for each 24 hour period. Figure 6 shows the same type of results from replication 12, where it is seen that the backorder variations are greater compared to replication 1. Averaging up all backorder results from the 100 replications for each 24 hour period the SIMLOX graph in Fig 7 is obtained. The total average number of backorders with respect to time and replications is $B = 3.09$ and is shown in Figure 8, this SIMLOX result is consistent with the result obtained from the OPUS10 analysis (Fig 3).

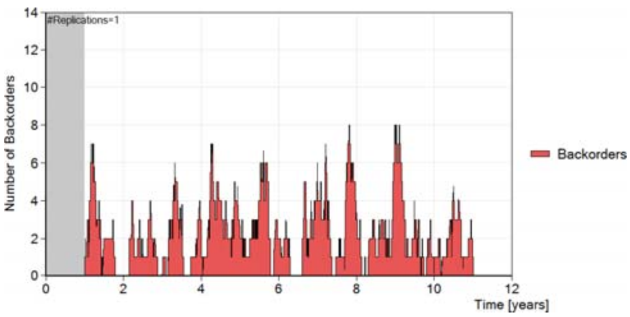


Figure 5. SIMLOX result, replication 1: backorders vs. time ($\mu = 2.2$, $\sigma = 1.8$).

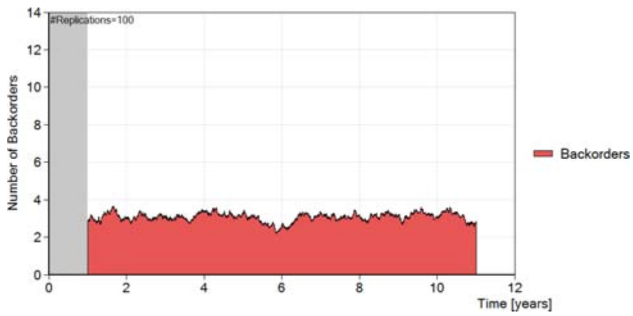


Figure 7. SIMLOX result: Backorders averaged over 100 replications.

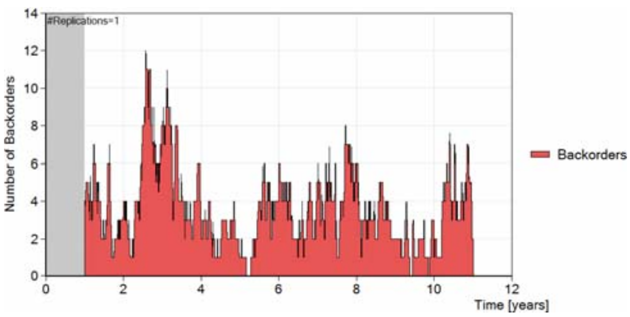


Figure 6. SIMLOX result, replication 12: backorders vs. time ($\mu = 3.6$, $\sigma = 2.1$).

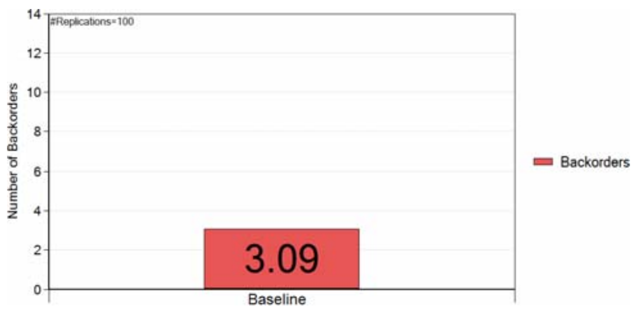


Figure 8. SIMLOX results: Backorders averaged over 100 replications and the simulation period (10 years).

5. BACKORDER VARIATIONS

From the previous section the SIMLOX Monte Carlo simulations indicate that the inherent backorders variations can be great over time. It is therefore important to consider this fact when designing the penalty function $y(B)$, see Section 5, but first the backorder variation dependence upon the measurement time period T should be considered.

The graphs in Figure 9 show the backorder probabilities

$P(k \leq B < k+1)$ evaluated for time periods *days*, *weeks*, *months*, *quarters* and *years*. The graphs indicate that the standard deviation σ of the backorders B decreases as the time period T is increased. For a daily time period T the backorder standard deviation is $\sigma = 2.1$ but for a yearly time period it is only $\sigma = 1.1$. The penalty function $y(B)$, which should take into account σ in the design, will therefore look different depending upon which time period T being used.

Once a suitable measurement time period T has been selected the design of the penalty function $y(B)$ can start. The time period T should be long enough so that the supplier has time to remedy defects in the support concept before the next measurement falls out. However, the time period T should not be too long since then the feedback loop to the supplier concerning defects in the support concept becomes too long. In this paper a monthly time period T is selected when designing $y(B)$.

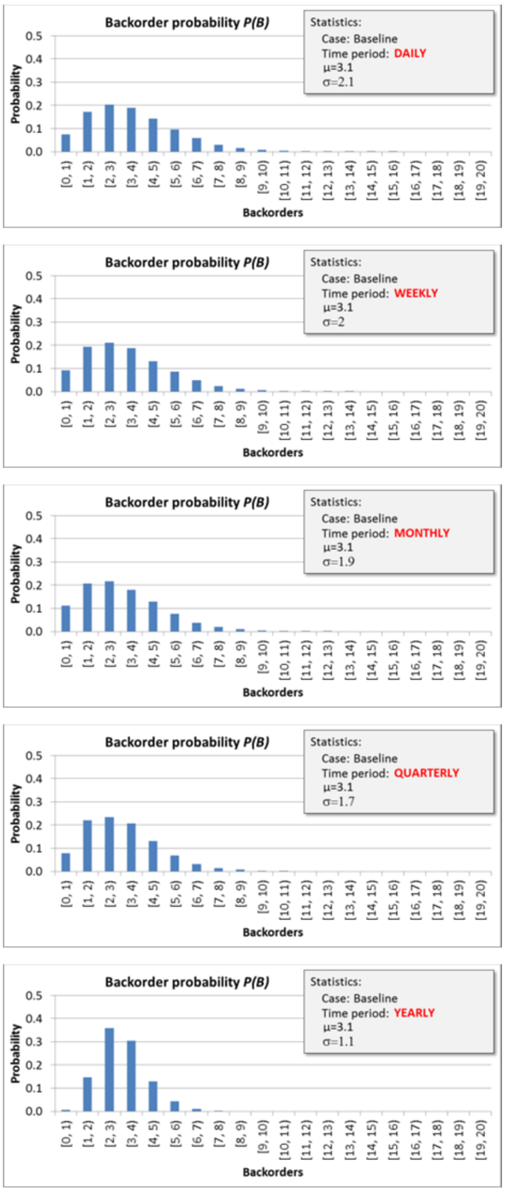


Figure 9. The backorder probability dependence upon the time period T.

6. PENALTY FUNCTION DESIGN

The penalty function $y(B)$ should not punish the inherent variations in backorders too much. By estimating the backorder probability $P(B)$ given a measurement time period T using Monte Carlo simulations as described in Section 4, the inherent variation in backorders is revealed. Two statistical measures of interest that can be obtained from the $P(B)$ estimate are the mean value μ and the standard deviation σ. An upper backorder threshold covering the most common backorder variations can then be written as

$$B_y = \mu + \alpha\sigma, \quad \alpha \in [1,2],$$

where α needs to be selected so that the probability $P(B \geq B_y)$ is small.

Using B_y as a threshold for the penalty function $y(B)$ the following step-wise exponential function is proposed

$$y(B) = \begin{cases} \min(y_{max},\ y_{min}(1+f_y)^{\left\lfloor\frac{B-B_y}{\Delta B}\right\rfloor}), & B \geq B_y \\ 0, & B < B_y. \end{cases}$$

The penalty function $y(B)$ contains the following constants:

y_{min}: Minimum penalty per time period T

y_{max}: Maximum penalty per time period T

f_y: Penalty increase fraction

B_y: Backorder penalty threshold

ΔB: Backorder step size

The function $y(B)$ is recommended to be designed iteratively by evaluating it on simulation results. This Section provides some rule of thumb guidelines for an initial design of $y(B)$

The constant y_{max} in the penalty function $y(B)$represents the maximum penalty for a backorder measurement time period T. If the PBL contract covers N time periods, the *total* maximum penalty becomes Ny_{max}, where y_{max} should be selected so that Ny_{max} becomes a significant fraction β of the total PBL contract value C, i.e.

$$y_{max} = \beta\frac{C}{N} \qquad \beta > 0$$

In this paper $\beta = 1$ is chosen. Note that the total cost for the supplier can then overshoot the total contract value C since

$$y_{max}N + LSC = C + LSC > C,$$

imposing a loss on the supplier.

Considering the baseline scenario described in Section 3 with a *monthly* backorder measurement period T, data from the third graph of Figure 9 gives that

$$B_y = \mu + \alpha\sigma = 3.1 + 1.9\alpha,$$

with $\alpha \in [1,2]$, B_y is within the range

$$B_y \in [5,7].$$

Selecting the mid-range value $B_y = 6$, we obtain

$$P(B \geq B_y) = 0.08,$$

which is a low probability indicating that the backorder threshold $B_y = 6$ is a candidate to be used in the penalty function $y(B)$, i.e. no penalty below this threshold and a step-wise exponential penalty increase if breaking above it.

Selecting the remaining penalty function constants as

$$y_{min} = 0.05c_{max}$$

$$f_y = 1.0$$

$$\Delta B = 0.5,$$

causes the penalty function $y(B)$ to rise from 0 % to 100 % of y_{max} over approximately one standard backorder deviation σ (see Figure 10). The minimal penalty y_{min} starts to falls out at the backorder threshold $B_y = 6$.

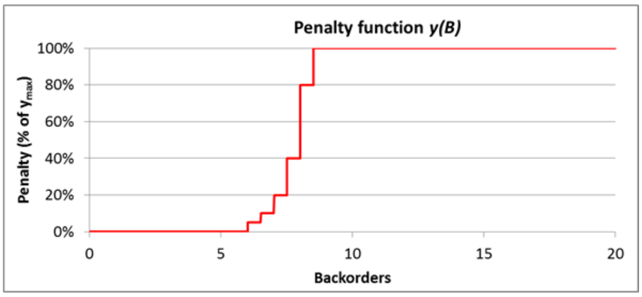


Figure 10. Penalty function $y(B)$.

7. VALIDATING THE PENALTY FUNCTION $y(B)$ USING SIMULATIONS

The penalty function $y(B)$ described in Section 6 is evaluated on backorder results obtained from a validation set of Monte Carlo simulations performed on the baseline scenario described in Section 3. Backorders are measured and averaged over a monthly time period T. Figure 11 shows the probabilities $P(y)$ for different penalty levels. Since the penalty function $y(B)$ is designed to only punish backorders B greater the inherent variations ($B > B_y$) we expect the average penalty to be low. From Figure 11 we conclude that the average penalty $\bar{y}$ is

$$\bar{y} = \mu = 0.028 y_{max},$$

with over 90 % of the time periods evaluated to a zero penalty. The total penalty $\bar{Y}$ over N time periods is

$$\bar{Y} = \bar{y}N = 0.028C.$$

In some rare occasions, a full penalty y_{max} falls out (1.2 % of the cases) which should not trigger a big change in the supplier concept. In general, one could wait for the confirmation of at least two consecutive monthly max penalty periods before investigating the hypothesis that there could be something wrong with the support concept.

From Figure 3 it is seen that the baseline Life Support Cost is $LSC = 421$ MUSD. Since the PBL contract value is $C = 500$ MUSD we can write LSC as

$$LSC = 0.84C.$$

The total supplier cost including penalties over the N time periods covered by the PBL contract then becomes

$$\bar{Y} + LSC = 0.87C,$$

i.e. a 13 % profit margin for the supplier.

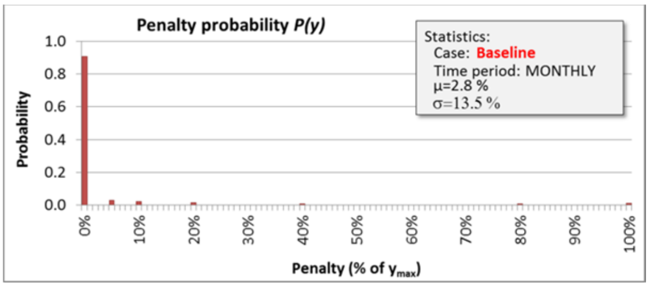


Figure 11. Penalty probability $P(y)$ for the baseline scenario.

If the supplier side of a PBL contract does not meet the operational requirements, it can be expected that the number of backorders B more often falls outside the expected backorder range. To illustrate this fact another Monte Carlo simulation is done on an *under stocked* scenario using a spares assortment corresponding to 5.75 backorders on average (Figure 12). The backorder variation for the under stocked scenario is shown in Figure 13, where the probability to exceed $B_y = 6$ is more significant

$$P(B \geq B_y) = 0.43$$

compared to the baseline scenario.

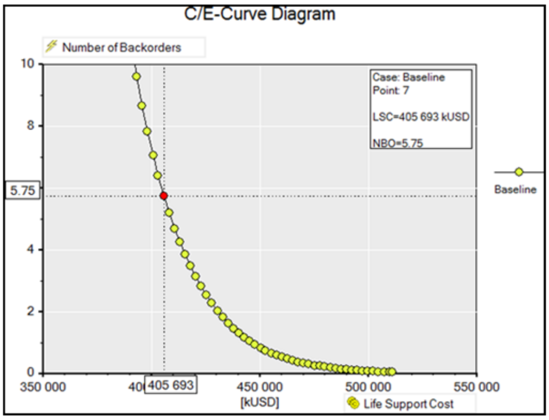


Figure 12. Selecting CE-point 7, $B = 5.75$, an understocked scenario not meeting the operational requirements.

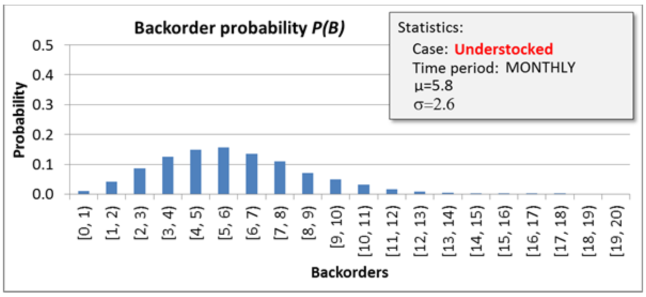


Figure 13. Backorder probability $P(B)$ for the under stocked scenario of Figure 12.

Figure 14 shows the penalty probability for the under stocked scenario when using the penalty function $y(B)$ described in Section 5. The average penalty $\bar{y}$ is

$$\bar{y} = \mu = 0.22y_{max},$$

with almost 15 % of the time periods evaluating to a maximum penalty y_{max}. The total penalty $\bar{Y}$ over N time periods is

$$\bar{Y} = \bar{y}N = 0.22C.$$

The LSC cost in the under stocked scenario is 406 MUSD (Figure 12), or in terms of the PBL contract value C

$$LSC = 0.81C.$$

The total supplier cost including penalties over the N time periods covered by the PBL contract then becomes

$$\bar{Y} + LSC = 1.03C,$$

i.e. a 3 % supplier loss.

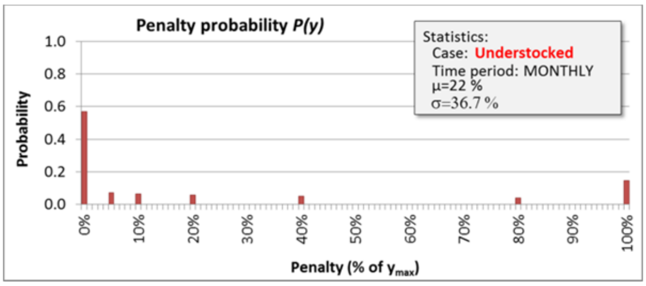


Figure 14. Penalty probability $P(y)$ for the under stocked scenario.

To get a more complete overview of the consequeces using the penalty function $y(B)$ the analysis done in the baseline and understocked scenario is repeated for all the cost effective assortments of Figure 12. The result of this analysis is seen in Figure 15 which also displays the upper and lower 90 % percentiles. The minimum is obtained at CE-point 15 close to the baseline stock (CE-point 13). For understocked scenarios the suplier cost $\bar{\bar{Y}} + LSC$ increases rapidly to well exceed the contract value C imposing a net loss on the supplier.

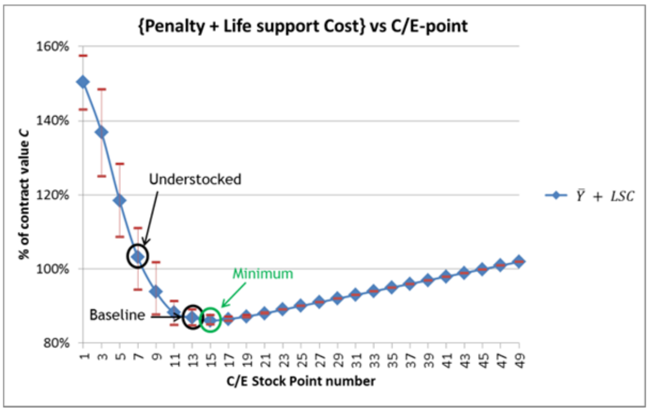


Figure 15. Supplier cost evaluated for the cost effective points of Figure 12.

Note that once all simulations of interest are done, no new simulations are needed to evaluate other candidate types of penalty functions $y(B)$. In the graph of Figure 16 the supplier cost is evaluated using a backorder penalty threshold $B_y = 4, 5, 6, 7$ and 8, where $B_y = 6$ corresponds to the baseline scenario. Overstocking is encouraged in the case of $B_y = 4$ because otherwise the supplier risks losing money although meeting the system availability requirements. Understocking is encouraged in the case of $B_y = 4$ because the supplier can in fact increase the profit by understocking a bit (minimum cost is obtained at point 11, compared to point 13 for baseline scenario). An appropriate value of B_y should be somewhere in the range $B_y \in [5,7]$.

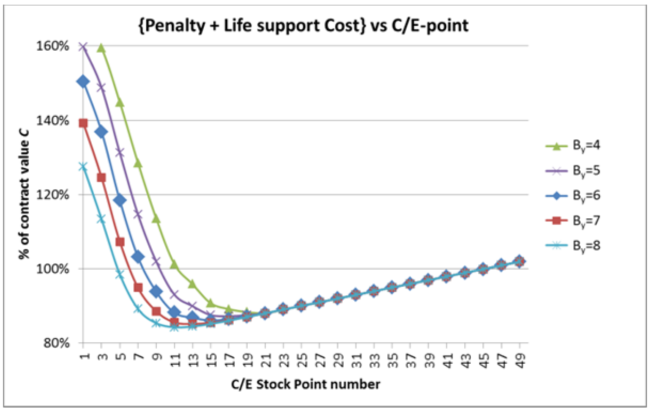


Figure 1. Supplier cost when using backorder penalty thresholds $B_y = 4, 5, 6, 7$ and 8.

8. ASSESSING RISKS

Assessing the risks before agreeing to PBL contract terms is important. From the supplier perspective it can be of interest to do a sensitivity analysis with respect parameters that involve some degree of uncertainty. To examplify, the supplier wants to analyse what an increase in repair times would mean in lost profit.

In Figure 17 the result of simulating the a scenario with 20 % increase in repair times but still using the stock suggested for the baseline scenario (CE-point 13 of Figure 3). The 13 % profit for the baseline scenario has now instead turned into a 2 % loss measured in terms of the contract value C.

The supplier can plan for various actions to take in this situation, e.g. try to reduce repair times or increase the spares levels. A spares optimization tool can be of great benefit in this decision process.

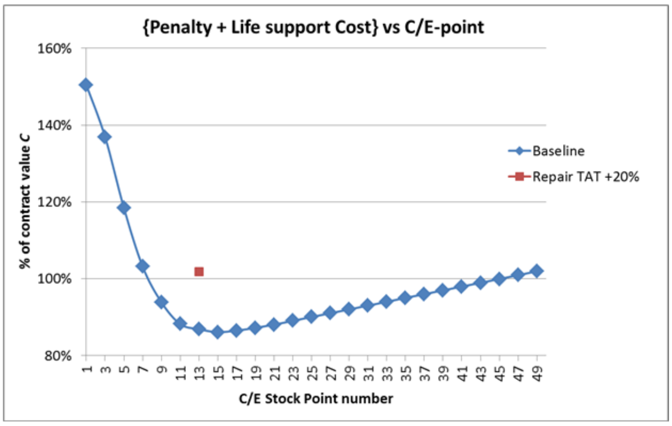


Figure 17. The impact of a 20 % repair time increase.

9. SUMMARY

The way that performance targets, incentive models and measurement approach are specified has a great impact on the chance of success, and should give both the customer and the supplier possibilities to achieve their goals. Setting the terms of a PBL contract without proper decision support means significant risks.

The methodology described in this paper has been used in several business cases with great success. Examples of customers where this methodology has been used are Saab Dynamics, BAE Systems Hägglunds and the Swedish/Norwegian NH90 program. Systecon's software OPUS10 and SIMLOX has in these projects proven to be well suited for supporting this kind of analysis.

The presented approach makes it possible for both customer and supplier to evaluate the PBL contract and assess the risks for not meeting the contract objectives. The suggested simulation approach is also highly suitable for the supplier when designing and optimizing the logistic support solution to fulfil the customer requirements at an acceptable cost and with an acceptable margin.

10. REFERENCES

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