Creating and Applying Total Cost Model: A Case Study at Maritime Company for Last Time Buy Estimation

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Abstract. Kongsberg Maritime (KM) experiences growth in the number of reactive obsolescence events. Time constraints in the decision-making process limit options on how to resolve obsolescence. The total cost trajectory of labor and money consumed to resolve obsolescence is not sustainable for KM going forward.

Last time buy (LTB) is one of many tools in obsolescence management. LTB is attractive because it does not require reengineering, requalification, or redesign. Despite its benefits, LTB should only be used if the total cost of LTB outweighs other alternatives.

In this study a model was created to predict component obsolescence and quantifying the total cost of LTB. The research assumes obsolescence management less effective when dominated by LTBs. By proactively using this model, decision-makers can evaluate alternatives compared to LTB selecting the most cost-effective solution. Feedback from decision-makers confirms a need to have, and willingness to use, the model.

Introduction

Company. KM is a knowledge-based, technology company a subsidiary to Kongsberg Gruppen. KM develops in-house designs and delivers products that provide functions for positioning, navigation, automation, and cargo handling systems. These functions are for marine vessels and offshore platforms in merchant and petroleum industries worldwide. Owners of marine vessels and offshore platforms have profitability expectations from their installation over a 40-year or more life cycle.

Case. KM designs products with a typically shorter lifecycle than the installations where the products are used. The difference between product and installation lifecycle makes obsolescence risk as an inherent part of both. Adding to the risk of obsolescence is shortening market availability of the components. Original component manufacturers (suppliers) adapt their manufacturing cycles to consumer markets' never-ending desire for innovative technology. Market availability shorter than expected demand increase obsolescence risk to KM, and owners of instantiated KM products. Realizing obsolescence will happen, KM needs a way to handle obsolescence efficiently and effectively.

Problem. Obsolete is a status given to physical components that are no longer available for purchase. Suppliers offer LTB before obsoleting components as one alternative to resolve obsolescence. Review of past reactive obsolescence events at KM shows frequent use of LTB to sustain current products. A common denominator is lack of time until last order acceptance date. This prevents exploring the feasibility of alternatives to LTB. A working process to predict obsolescence on current products is missing. To the owner of the product portfolio, the total LTB expenditure is not affordable on the current outlook. The first author's participation in resolving actual reactive obsolescence events at KM since 2012 drives this research. Over time, the first author has been developing an idea of introducing a new process trigger to KM's working processes. By monitoring obsolescence risk, proactive mitigation activities can start before reactive events happen. The research in this paper attempts to create a re-usable model systematically used as input to obsolescence management decision-making.

Predicting total cost of LTB in obsolescence management. Bartels et al. (Bartels, Ermel, Sandborn, & Pecht, 2012) describe obsolescence management as investing in proactive activities to predict reactive events. Based on the business context of KM, the portfolio owner must target an acceptable, and affordable obsolescence risk level. To support the portfolio owner, the research introduces a total cost of LTB model to obsolescence management. The model is aimed at encouraging cross-discipline validation, and communication between the stakeholders. The goal of the model is to capture LTB cost elements enabling impact prediction on the product portfolio. A unified nomenclature safeguards transparency to all stakeholders when using the model to make obsolescence management decisions.

Research questions. To assess the model effectiveness, the following research questions are formulated:

- Which components are probable LTB candidates?
- How close to reality is the estimated total cost of LTB model?
- How will the total cost of LTB model results, including its preconditions, influence portfolio roadmap, and financial budgeting?

State of the art

All entities engaged in profit-seeking activities must be affordable to stay in business. United States general accounting office (GAO, 2003) review of the US Department of Defense weapons systems shows a 28% cost to develop and 72% cost to operate and maintain systems. The 2010 better buying power memorandum (Carter, 2010) mandates all acquisition professions to "r*estore affordability and productivity in defense spending.*"

INCOSE (INCOSE Staff, 2015) regards affordability as a contextual attribute determined by the relationship inside and outside the system of interest boundary. The 2011 INCOSE affordability working group defined affordability. "*Affordability is the balance of system performance, cost, and schedule constraints over the system life while satisfying mission needs in concert with strategic investment and organizational needs."*

Blanchard and Fabrycky (Blanchard & Fabrycky, 2014) claim "*many systems are planned, designed, produced, and operated with little initial concern for the affordability and total cost of the system over its intended life cycle.*" Blanchard and Fabrycky introduced a life-cycle costing breakdown structure offering a frame of reference to capture all life-cycle cost as a prerequisite when evaluating affordability.

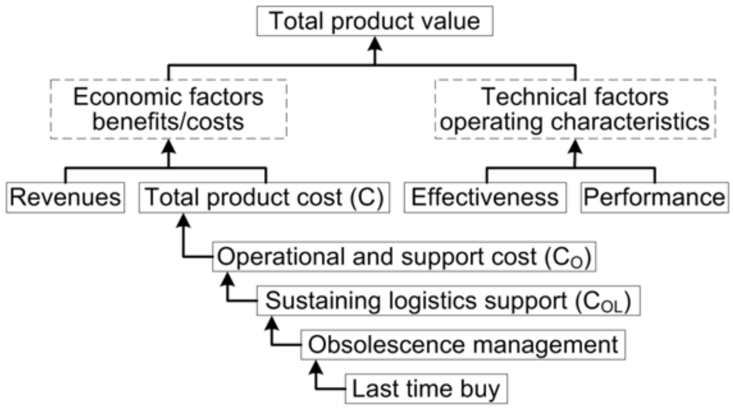

Figure 1 Economic and technical factors comprising total product value.

Last time buy (LTB) is one of many tools in obsolescence management. LTB is attractive because it does not require reengineering, requalification, or redesign (Bartels, Ermel, Sandborn, & Pecht, 2012). Figure 1, inspired by Blanchard and Fabrycky (Blanchard & Fabrycky, 2014) place the cost of obsolescence management and LTB in a total product cost context. Feng et al. (Feng, Singh, & Sandborn, 2007) introduced financial cost as a significant element when considering LTB. Jennings and Terpenny (Jennings & Terpenny, 2015) taxonomy of factors provides "*a comprehensive decision support tool capable of assisting lifetime buy quantity decisions over the product life cycle.*"

Product change notification (PCN) triggers the reactive obsolescence event, containing a time-limited LTB offering from a supplier. For product design owners time constraint may prevent evaluating the use of alternatives to LTB. When forecasting demand for the last order, the number of components to buy depends on the sourcing strategy. In a bridge-buy a limited number of components is purchased to cover the demand until a non-obsolete alternative replaces demand. In a life-time-buy, enough components are purchased to last until there is no longer a need of the obsolete component. Bartels et al. (Bartels, Ermel, Sandborn, & Pecht, 2012) obsolescence notification process in figure 2 show the pace of a product change notification.

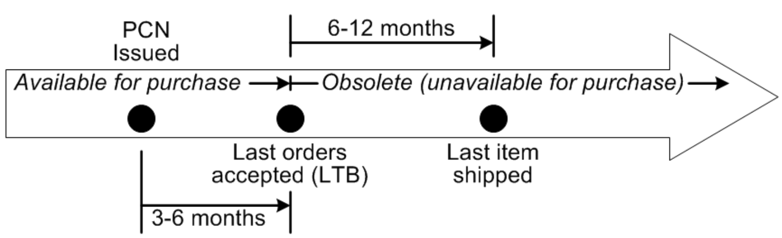

Figure 2 Obsolescence notification process.

Alelyani et al. (Alelyani, et al., 2019) performed literature review on obsolescence. They recommend applying a combination of proactive mitigation and reactive resolution strategies to manage obsolescence affordably. The capability to predict obsolescence is a proactive activity. To do this, KM buys components surveillance data estimating when LTB will happen. The service uses an algorithm developed by Sandborn (Sandborn, 2007) and his colleagues at the University of Maryland's center for advanced life cycle engineering.

Based on state of the art, it is concluded that predicting and estimating the total cost of LTB is valuable to KM. The main reason to have this capability is safeguarding enough time so that there are doable alternatives to LTB.

Research Methodology

This study uses action research (O'Brien, 1998) as research method. Riel (Riel, 2010-2017) defines action research as “a systematic, reflective study of one's actions, and the effects of these actions, in a workplace or organizational context”. Riel further considers the action research as an appropriate approach for doing research on a method applied in an industrial context.

Engebakken’s research (Engebakken, Muller, & Penotti, 2010) on model-based communication has been used as a guide in this research. This research creates a model with purpose targeted at a specific audience. For developing the model, it is important to consider the impact factors and their influence on model effectivenesss and resources. To create the model in this research, a cross-disciplinary team was selected, where all share their experiences from working together on previous reactive obsolescence events. Figure 3 shows the cross-disciplinary team participants and their properties.

	Title	Business unit	Area of work	Years at KM	Educational degree
1	Manager	Global supply chain	Process improvement	9,5	MBA
2	Senior principal engineer	Product management	Product life cycle data management	28	MSc
3	HW real-time platform manager	Technology	HW system architecture	28	MSc
4	Planner	Delivery projects	Operational purchasing	4	Upper secondary school
5	Category manager	Global supply chain	Strategic procurement	6,5	MBA
6	Life cycle manager	Product management	Obsolescence management	26	BSc

Figure 3 Cross-disciplinary team members with details.

At first a workshop was organized with the team shown in Figure 3. The participants completed a survey to establish a frame of reference. Figure 4 shows the results of the survey.

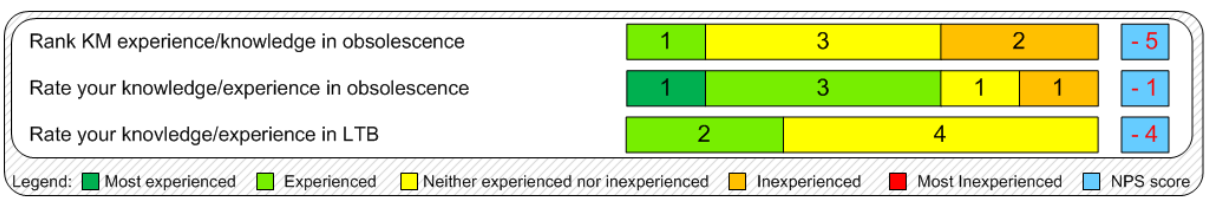

Figure 4 First workshop survey.

The team rates their knowledge/experience in obsolescence. There are differences between team members when looking at the distribution. When the team answers about their experience in LTB, the results are lower than that of obsolescence knowledge/experience. The team exhibits enthusiasm and expresses a strong need in KM for capabilities in obsolescence management and LTB.

Figure 5 illustrates the research approach used during this study. At second workshop, a draft version of the proposed model was introduced to the team. The model repository consists of a spreadsheet as the quantitative part, and a text document describes the model qualitatively. Data from previous LTB estimations and actual consumption data provides realistic model input. The team highlighted areas that needed further development. Feedback from the workshop was explored and factored in maturing the model further. In periods between workshops, the team and the first author had many clarifying discussions, which spawned valuable input. As work proceeded, and word spread, the first author encountered other stakeholders who enabled “feeling out” if the total cost of LTB model would be valuable.

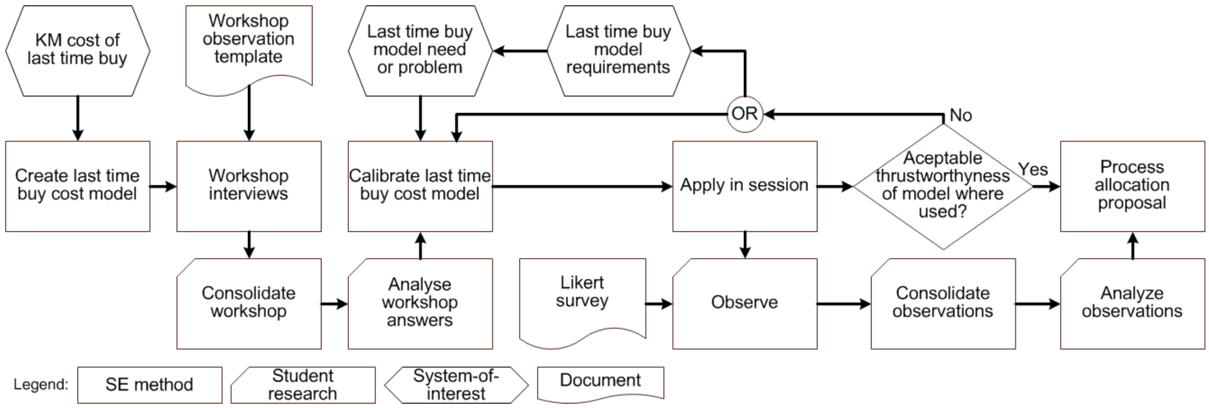

Figure 5 Research approach. Figure inspired by (Viken & Muller, 2018)

This study uses Likert scale surveys. Respondents score on a scale with five options to choose from, pivoting around neutral. A net promoter score (NPS) (Keiningham, Aksoy, Cooil, & Andreassen, 2008) is calculated based on the workshop results. NPS score is a summary of all respondent’s answers indicating group attitude. The group is likely to promote if NPS is positive. On a negative NPS, the group inclines to complain. A negative NPS gives cause to investigate why the group responded as they did. Based on analyzing observations recorded during the research, the first author was able to identify benefits, challenges, and blockers that either contributed to or prevented the use of the model.

Total cost of LTB model

Identifying components with high probability for LTB. This research has analyzed 3000 components used to manufacture 34 assemblies enabling the delivery and support of KM’s portfolio of products. On majority of the components, a reactive strategy is enough because the consequences of obsolescence are minor. The obsolescence notification process provides enough time to resolve obsolescence affordably. A minority of components are critical. A reactive obsolescence event on this minority group will result in major consequence caused by the limited time to resolve the event. Typical characteristics of a critical component is an active component from a single source supplier. If obsolete, there is no form, fit, and function replacement option. Redesign of a new component will require reengineering, and requalification.

Before 2018, KM monitored components for obsolescence reactively. In 2018, KM started to subscribe component surveillance data for predicting obsolete dates. The surveillance data categorizes components based on similar characteristics. Figure 6 contains actual and estimated obsolescence events on KM components. Events until 2019 are actual; events after 2019 are estimates. The legend recommends a level of pro-activeness based on component category. Out of all components, the critical group/components have the highest probability of LTB when the component transition to obsolete. Historically, the integrated circuits have caused major consequences for obsolescence events, so this category is critical. In 2024, 72 integrated circuits are estimated to be transitioning to obsolete.

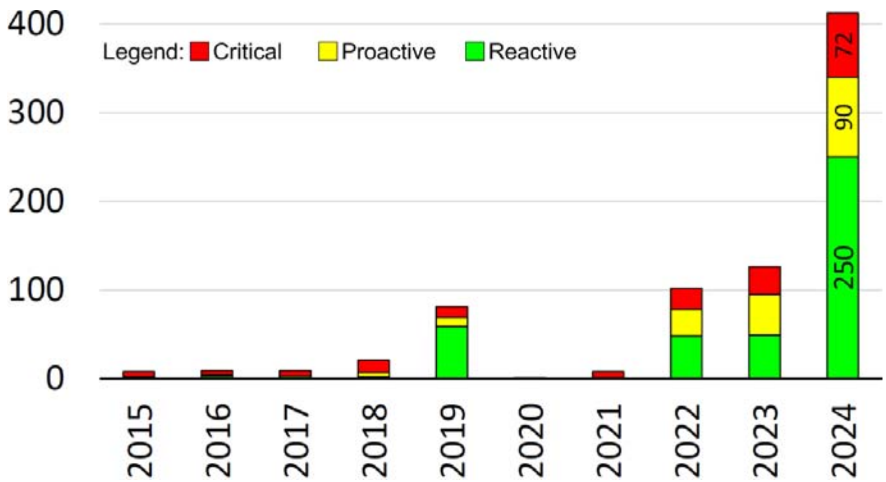

Figure 6 Obsolescence events for components in KM product portfolio.

Estimating total cost of LTB. Once a high probability LTB component is identified the total cost of LTB can be estimated. Figure 7 shows the model created in this study to estimate the total cost of LTB, which is based on different cost driving elements.

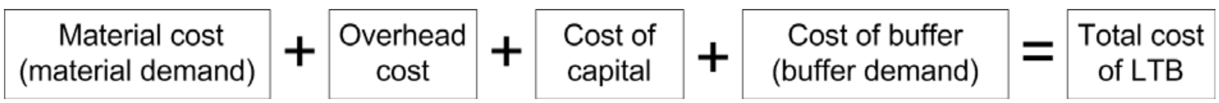

Figure 7 Total cost of LTB model inspired by Bartels et al. (Bartels, Ermel, Sandborn, & Pecht, 2012).

Demand forecast. The demand forecast is the total number to cover the need of all users in the product portfolio. The demand forecast is the sum of material demand and buffer demand.

Material cost. Material cost is the cost of component purchase. The model assumes payment regardless of who pays. The model does not consider financial models based on shared risk and opportunity between suppliers in the supply chain.

Overhead cost. Overhead cost is reoccurring cost related to storage, storage location, and handling of stocked LTB components in KM warehouses. This research assumes an overhead cost factor of 9% calculated based on the value of remaining LTB inventory at year-end.

Cost of capital. Cost of capital is the cost of the LTB compared against the company return of investment expectation on invested capital. LTB requires the purchase and stocking of components before they are needed. The capital used to purchase LTB cannot be used for other profit-generating activities. This research assumes a return rate factor of 10%, which is the discount rate used for NPV (net present value) calculations in the model. Cost of capital is calculated based on the value of remaining LTB inventory at year-end.

Cost of buffer. The decision on how many LTB components to purchase is conditional on the planned consumption matching the actual consumption. A deviation between planned and actual represents a risk factor where the consequences may be higher because LTB components are a finite resource. To a portfolio owner, the risk can be broken down to known and unknown risks. The known risks are manageable mostly inside the company boundary. An example is completing activities according to preconditions of the LTB purchase switching to a non-obsolete component on time. Unknown risks often originate in the business context outside the company boundary. An example of this is market trends resulting in changed material demand after surpassing last order acceptance date.

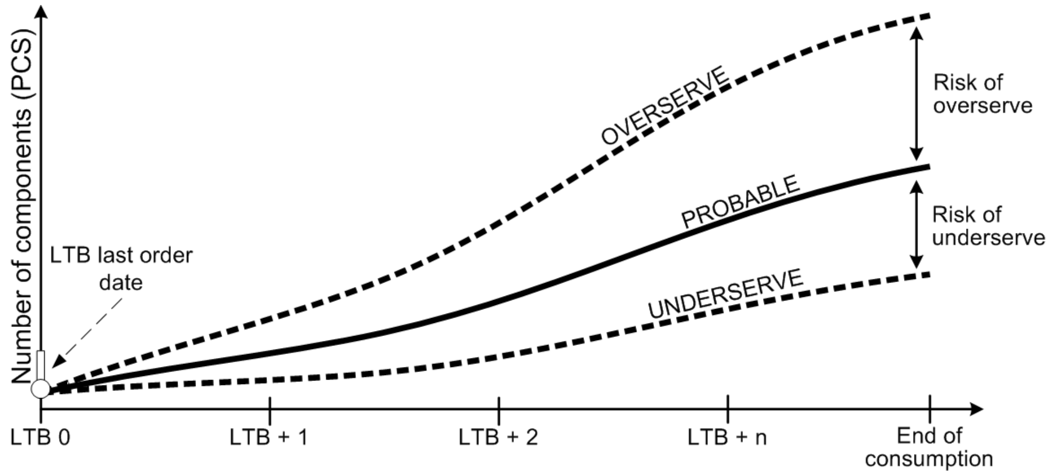

Figure 8 Buffer estimation strategy.

A buffer is added to mitigate the risk of deviation between planned and actual consumption. Buffer demand comes on top of how many LTB components the portfolio owner believe is needed. The downside of adding a buffer is that it will not be needed if there is no deviation between planned and actual consumption. As a buffer adds to the total cost of LTB, the company must have a strategy on how to size their LTB buffer aligned with the level of risk the company is willing to accept. To allow managing the buffer size, the buffer must be explicit in the total cost of LTB model. The input to sizing buffer must analyze the product portfolio based on diversity in where the products are sold and operationally used. Figure 8 shows the line of reasoning for buffer estimation.

Case Study: Last time buy estimation for MPC8245

Case introduction. Data from real-life events has been used to evaluate the created model quantitatively. The component used in the case study is the MPC8245. MPC8245 is a PowerPC™ MPC603e processor core built on Power Architecture™. As shown in figure 9, many different KM assemblies are using MP8245 over a long time.

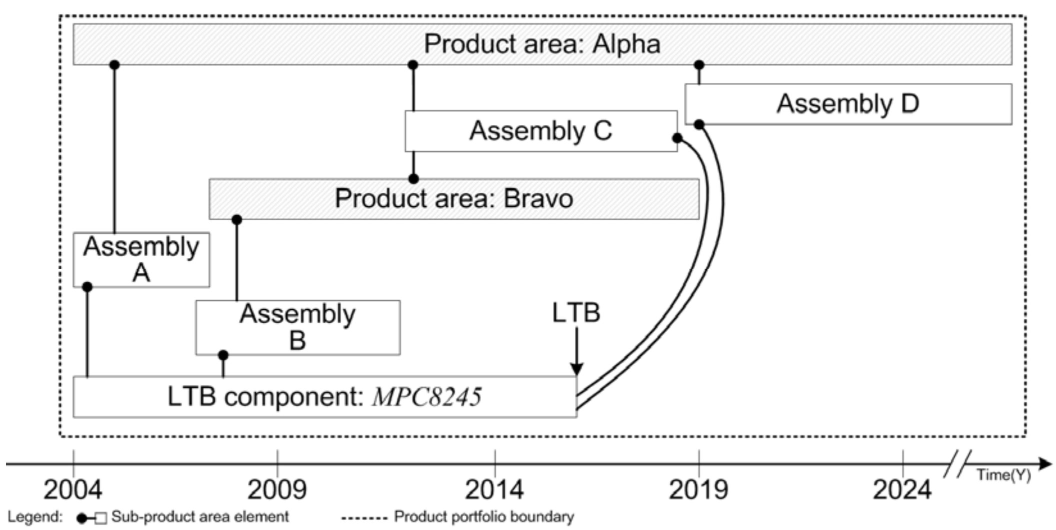

Figure 9 MPC8245 components usage in KM products.

The year 2015 started with a disruptive drop in crude oil prices. In 2015, MPC8245 consumption was at an all-time high due to KM's late-cyclic customer relationship. The fact that merchant and petroleum markets were on a trajectory towards a global recession, was not on anyone's mind when resolving MPC8245 LTB. The MPC8245 was the first major impact LTB processed in KM. A challenge when forecasting demand of MPC8245 was the duration in which high volume manufacturing would continue after LTB. To be able to issue a purchase order before the last order acceptance date, a small team was summoned working in blitz mode. In 2015, only the material cost was used to represent the cost of LTB.

Using the LTB model to estimate MPC8245 total cost. Table 1 shows two LTB estimations. For 2015 estimates use the demand forecast from 2015. Whereas for 2019 re-estimates use 2015 → 2019 actual consumption data and adjusted demand forecast for 2019 itself. Material demand, in 2019, is how many components KM have bought in 2015. Cost of buffer estimated where not explicit in 2015. When comparing 2015 and 2019 numbers, there appears to be an overserve in the material demand. According to first author, who was a part of the 2015 resolution team, the 7.9 thousand pieces (kPCS) overserve was expected to be consumed and not intended as buffer demand. Going forward with the analysis, the involuntary overserve is allocated as 5.5 million Norwegian kroner (MNOK) cost of buffer i.e. difference between 2015 estimates and 2019 re-estimates for material cost.

	Material demand kPCS	Material cost MNOK	Overhead cost MNOK	Cost of buffer MNOK	Cost of capital MNOK	Total cost of LTB MNOK
2015 estimates	21.5	15.1	2.7	0	2.2	20.2
2019 re-estimates	13.6	9.6	1.9	0	1.6	13.2

Table 1 MPC8245 total cost of LTB estimations.

Figure 10 shows the estimated total cost of LTB caused by a deviation between planned and actual consumption for MPC8245. It is a fact that 21.5 kPCS of MPC8245 were purchased and stocked at a cost of ≈16 MNOK ① in 2015. As indicated in ② the LTB inventory consumption from the warehouse is lower than planned. Slow-moving inventory results in higher overhead cost and capital tied in the warehouse. 2016 onwards ③ the dominating cost elements adding to the total cost of LTB are overhead cost and cost of capital. Re-estimates from 2019 shows the extend the use of MPC8245 from 2027 until 2031. The involuntary dead-stock buffer ④ of ≈ 6 MNOK can either be sold or scrapped based on the market need of the component. Calculations performed in this study comparing 2015 estimates with 2019 re-estimates indicate a total cost of LTB of ≈ 36 MNOK.

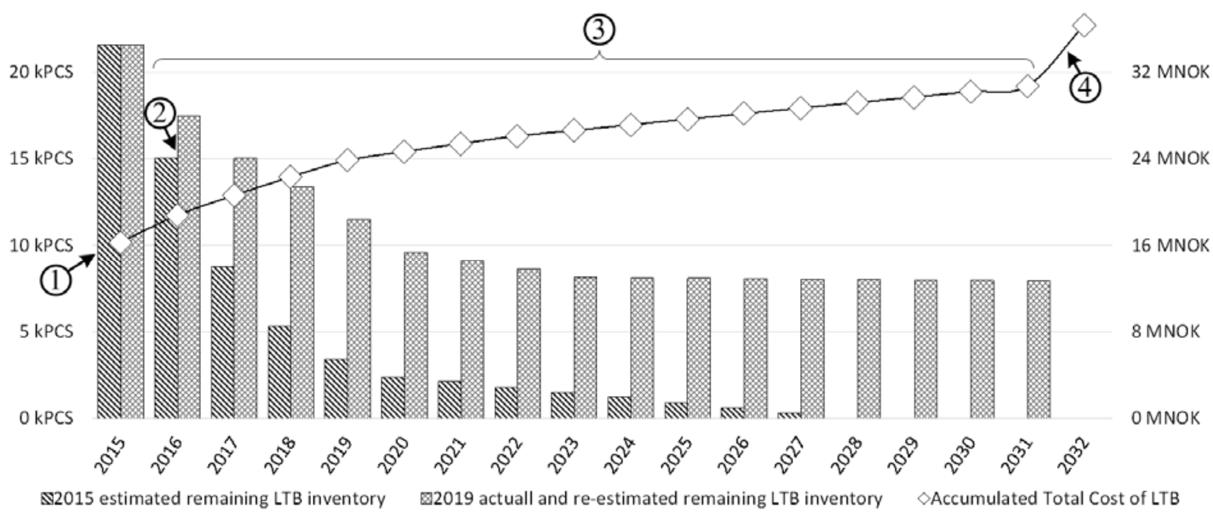

Figure 10 Total cost of MPC8245 LTB, based on 2015 to 2019 actual data, and 2019 onwards planed data.

Evaluation / research findings

In this section, we discuss the benefits, challenges, and blockers based on the research findings. Concerns regrading the implementation of the total cost of LTB model in KM's working processes is also discussed here.

Subscribing to component surveillance data introduces new capabilities at KM. Out of 3000 components, minority group cause high consequences when the component transitions to obsolete. The ability to predict obsolescence events, provides KM the option to mitigate proactively and manage product obsolescence. Thorough investigation of past reactive obsolescence events at KM, made it possible to suggest that there are components where LTB is the only realistic alternative due to the criticality of the component. If at all LTB is to be avoided altogether, the current product must be replaced by a new product. The investigations also reveal LTB purchases are constrained by time excludes using alternatives to LTB even if these are easy. In summary, it is possible to predict probable LTB components with a high degree of certainty.

To evaluate the total cost of LTB model, the model is broken down to its model element below:

Demand forecast. There is a 7.9 kPCS difference between 2015 estimated and 2019 re-estimates material demand. Feng et al. (Feng, Singh, & Sandborn, 2007) study of Motorola indicates a 30% variation on either side of mean in their demand forecast. 2019 re-estimates based on actual consumption and adjusted demand forecast indicate a 36% overserve from 2015 estimates.

Feng et al. (Feng, Singh, & Sandborn, 2007) apply life of type evaluation (LOTE) to optimize buffer demand to minimize lifecycle cost from LTB. In the simulation, Feng et al. (Feng, Singh, & Sandborn, 2007) look at data from Motorola, who has traditionally applied a buffer factor of 39% for life-time buy and 23% for bridge buy. The LOTE simulation recommends a buffer factor of 7%. Feng et al. (Feng, Singh, & Sandborn, 2007) conclude that organizations are inclined to overserve when estimating buffer due to fear of underserving need of the LTB component. The 36% overserve of MPC8245 is in line with Feng et al. (Feng, Singh, & Sandborn, 2007). The overserve at KM is involuntary and unplanned. The 2015 estimations were unable to predict markets disrupting, resulting in the overserve.

Material cost. The workshop team has discussed at length, whether to include the material cost in the total cost of LTB estimation model. Material cost does not initially impact negative on the company financial balance sheet. The net working capital used to purchase LTB components is reposted as warehouse inventory which does not change financial balance. The company's freedom of capital investment is constrained when capital is tied in LTB inventory. Alternatives to LTB may negatively impact the company financial balance sheet. When comparing alternatives on how to resolve an obsolescence event, all alternatives must be compared based on equal terms. The research advocates, including the cost of material in the LTB estimation model because there are negative financial impacts associated with purchasing LTB.

Overhead cost. Jennings and Terpenny (Jennings & Terpenny, 2015) use an overhead cost factor of 20%. Feng et al. (Feng, Singh, & Sandborn, 2007) indicate an overhead cost factor of 5%. KM's LTB strategy is adding as little cost as possible to the component while in storage awaiting assembly manufacturing. This way, LTB components occupy little space and can be easily handled, supporting a low overhead cost factor. On the other hand, LTB components may require distributed warehouses, special handling, and facilities with special environmental conditions supporting a higher overhead cost factor. The research advocates an overhead cost factor on LTB components at KM would be closer to 5% than 20%.

Cost of buffer. The involuntary buffer shown in the case study adds to the total cost of LTB. The case study assumes liquidating overserve buffer at the end of the consumption period because KM no longer needs the component. In the case, the deviation between planned and actual consumption happened early in the consumption period. A yearly review and decision to liquidate accrued over-serve buffer would reduce the total cost contribution from overhead cost and cost of capital because of fewer stocked LTB components.

Cost of capital. Jennings and Terpenny (Jennings & Terpenny, 2015) and Feng et al. (Feng, Singh, & Sandborn, 2007) both use a discount rate of 10% when calculating the cost of capital, which co-incides with 10% used in this research. The research supports a 10% discount rate as reasonable at the start of the LTB consumption period. As pointed out by Jennings and Terpenny (Jennings & Terpenny, 2015) cost of capital use compound interest in NPV calculation. Due to this, the cost of capital will become dominant to the total cost of LTB if stocking expensive components for a long time.

Managing obsolescence will always cost. The principle behind the cost of capital is the assumption of full freedom of choice in selecting the most profitable investment opportunity. Yes, investing capital in LTB comes at the cost of capital; however, saying no to LTB does not free up capital to invest in something else. If faced with the loss of delivery capability due to an unplanned obsolete product KM has no other alternative than resolving the reactive obsolescence event.

Total cost of LTB. Feng et al. (Feng, Singh, & Sandborn, 2007) focus on penalty cost as a contri-bution to the total cost of LTB. Types of penalties are LTB price higher than the regular purchase price, or the cost of unavailability. The data analyzed in this research has not discovered a predictable price increase as components get closer to LTB; however, there are indications of this happening. Attempts were made to forecast LTB price proactively, but how much and when this happens has not been possible to establish. It was explored to find examples of underserving, resulting in penalty happening at KM.

Jennings and Terpenny (Jennings & Terpenny, 2015) and Feng et al. (Feng, Singh, & Sandborn, 2007) concur that when evaluating the attractiveness of LTB, all costs must be considered. As the study of Motorola indicates, the fear of underserving is the dominant factor considered when evaluating LTB. Jennings and Terpenny (Jennings & Terpenny, 2015) recommends a redesign frequency of five years to limit LTB buy length. Jennings and Terpenny (Jennings & Terpenny, 2015) also points out that the company executing the LTB must use planned obsolescence to plan how future products will shape sales for current products. Transition planning as an integral part of the product roadmap process will mitigate obsolescence risk.

In summary, if reality defined as comparing MPC8245 total cost of LTB estimation to the works of Jennings and Terpenny (Jennings & Terpenny, 2015) and Feng et al. (Feng, Singh, & Sandborn, 2007) the proposed model is close to reality. The study of the MPC8245 is limited to analyzing the use of one type of component. The component context is influential to any deviation between planned and actual consumption of the component. The MPC8245 LTB happened in a period of disruption in merchant and petroleum markets.

After model creation, calibration, and use the workshop team concluded their work. At this stage, the model repository contains the collective knowledge of the team. Before dissolving the workshop team, a Likert survey asks team members to evaluate the model in its current form. Figure 11 shows the results of the survey.

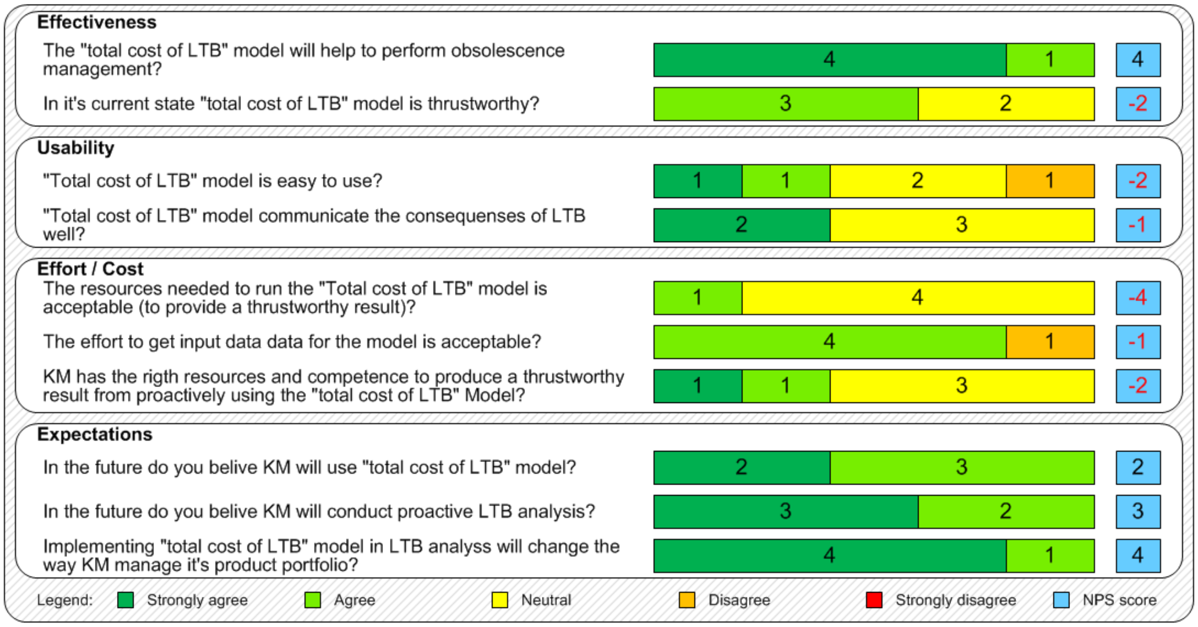

Figure 11 Workshop survey on proposed LTB model.

None of the workshop participants had the decision-making power. The first author interviewed a senior manager (SM) with 25 years' experience at KM to get his point of view on the proposed model. The decision on the future of this model will be up to the SM based on the cost to use the model versus the benefits of use. SM reflected on some of the threats and opportunities at KM based on the current conditions. The response from the SM is used to elaborate the workshop team response.

Effectiveness. In the results of the survey, the workshop team maintains its expectation from the initial survey. There is a strong belief that the model will be useful to KM; however, the workshop team is divided in their answers when asked to score the trustworthiness of the model.

From the SM's point of view, the cost of LTB comes on top of investing in alternatives to LTB. Looking at the financial reports at KM, LTB does not appear as problematic because reporting mechanisms do not capture the total cost of LTB. The SM welcomes a total cost model integrated with financial reporting structures going forward.

Effort/cost. Effort/cost is the area of the survey where respondents complain most through their NPS score. Obtaining data to use the model, and operators with the skills to use the model are pointed out. At the time of the survey, the model is only able to calculate based on one component. The choice to focus the model on only one component is not to overload the model during creation. If implementing the model, it needs to be able to estimate the total cost of multiple LTB events in multiple assemblies.

The SM's vision is introducing a technology refreshment program resulting in less LTB as a last resort. To the SM, the capability to predict and estimate LTB impact is instrumental in timing the technology insertion. The SM expresses a strong desire to use incremental technology refreshment to extend the life of current products.

Expectations. The workshop team confirms their expectation by promoting total cost of LTB estimation implemented in KM working processes.

The SM presents some view on his expectations to obsolescence management going forward. Today's "Fire-fighting" to resolve obsolescence on current products constrains resources we need to develop future products. In addition to obsolescence, new product capabilities are requested often in such a way that KM realistically cannot say no to do it. The 2015 oil crisis resulted in staff dismissals with a subsequent hiring freeze. Too few resources make it hard to handle day-to-day obsolescence on current products while at the same time developing future products. In the future, KM must start to research technologies for future products earlier; introducing the new product before obsolescence becomes a major problem.

The SM expresses an interest in the total cost of LTB model because the consequences of obsolescence are high. The SM questions the accuracy of the results from the model; however, the order of magnitude gives a good indication. The SM points out that regardless of the model result, predicting what will happen short and long term and its consequences is instrumental in making timely decisions. The SM believes KM will become more active through a better understanding of future LTB consequences. As for the model, it must be able to abstract without omitting relevant details suited to its target audience to be effective. Implementing proactive obsolescence management activities means deciding under uncertainty. The total cost of LTB model helps decision-makers make informed decisions. There is a willingness to invest in proactive obsolescence data collection and analysis to support decision-making.

Conclusions

Obsolescence is a risk factor in the evolutionary management of products. The risk exposure is not limited to product design owner but affects all stakeholders through a shared value chain. Obsolescence will happen, and more often than before. Without being aware companies work assuming a never-ending availability of components. The company of interest in this study has been KM, which is a design owner, and product supplier to merchant and petroleum markets. KM unique business properties influence the willingness to invest in proactive obsolescence management. Other companies, in other markets, or different value chain roles may perceive obsolescence risk differently.

Which components KM is using are probable LTB candidates? Identifying which components are probable LTB candidates depends on the type of component and use in products design. Understanding the relationship between component, assembly, and the product is instrumental in understanding the consequence if obsolete. This research shows it is possible to group critical components through similar features where one of these features is a high probability of LTB. For future research, we recommend developing an understanding of dependency between different types of product elements.

How close to reality is the estimated total cost of LTB model? The model created in this study quantifies a total cost of LTB based on input from the model operator. Lacking a unified definition of reality, all recipients exposed to the model so far have interpreted the result based on his or her reality perception. A remaining challenge is adjusting the model calculation mechanism so that its contribution adds value to the way of working. Stakeholders responsible for accounting and reporting can provide valuable input on how to tune the calculation mechanism in later iterations of the model. For future research, one shall explore the total product value models.

The case in this study is limited to the MPC8245 LTB happened in a period of business disruption. More cases are needed to assess the model usefulness on different components and in different business conditions. More exploration will help establish the model boundary of trustworthiness towards its target audience.

How will the total cost of LTB model results, including its preconditions, influence portfolio roadmap and financial budgeting in KM? The model created through this research introduced a new capability to KM challenging the existing way of working. Full implementation requires integrating the model into accounting and reporting structures, adding value to the way of working. The SM's concern to the model in its current form relates to the context of use. The current model introduced in financial budgeting now can disturb financial reporting to shareholders and markets in an unwanted way.

The concerns of the SM have not prevented the workshop team from starting to use the model. Their experience from creating the model is starting to show in the way of work. KM is now recurrently monitoring LTB components mitigating deviation between planned and actual consumption. KM is entering supplier partnerships with manufacturers of critical components that KM uses. Source information predicting obsolescence gives KM more time to resolve obsolescence events.

Feedback from KM organization to this research indicate KM will change obsolescence management to a more proactive way of working going forward. The process of roadmapping will benefit from knowing the inherent obsolescence risk of the product portfolio. Obsolescence risk now appears as a blip on the KM radar. KM needs to safeguard enough time to evaluate and select cost-effective solutions when obsolescence on critical components. The knowledge of the total cost of executing an LTB will change behavior away from the reactive obsolescence culture today.

Future research

Many companies have reporting structures optimized to the fiscal year cycle. Blanchard and Fabrycky (Blanchard & Fabrycky, 2014) introduce the term total product cost. The purpose is placing cost elements based on the product life cycle from idea to disposal. Obsolescence in products happen many times across many years and will increase as the technologies in the product design age. Many refer to obsolescence as a form of technical debt. It is something that will consume resources in the future. Understanding how accrued and avoided obsolescence cost impact total product cost is an area suggested for future research. Figure 12 shows a total product cost breakdown structure.

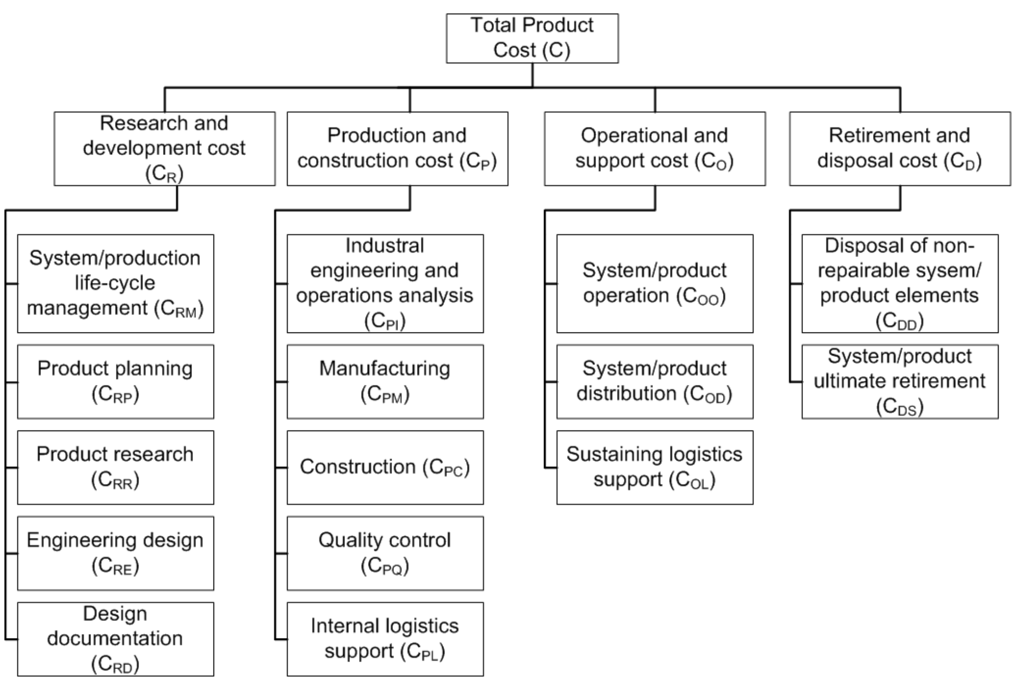

Figure 12 Partial life cycle costing breakdown structure by (Blanchard & Fabrycky, 2014).

Through the research, it has become apparent that there is a relationship between all elements in a product. Tom Herald's (Herald, 2007) work on high-level technology categories explores relationships within a product baseline. Figure 13 shows an example of how component type and technology categories can be related to the product baseline. Exploring the impact of software evolution on obsolescence risk is an area suggested for future research.

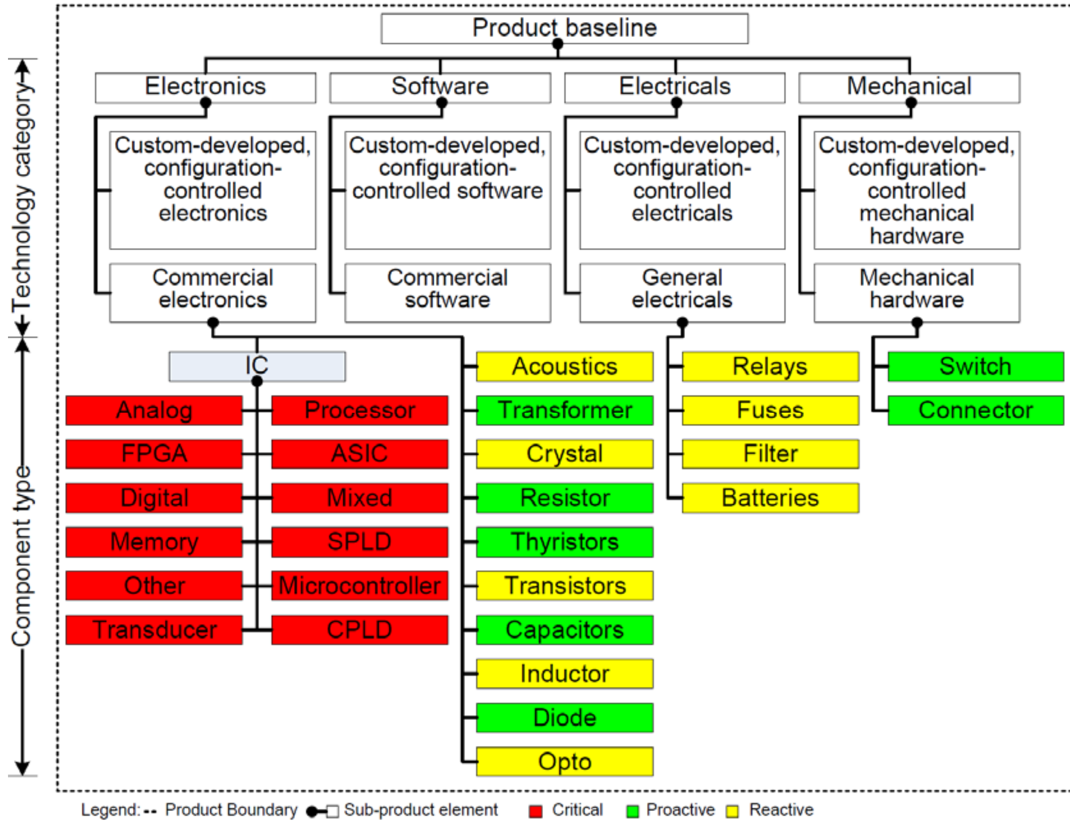

Figure 13 Technology categories and component types inspired by (Herald, 2007).

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Biography

Lasse Andre Sletaker, is a principal engineer at Kongsberg Maritime in Kongsberg, Norway. He has 19 years' experience as a products and services supplier to merchant marine and offshore petroleum industries worldwide. He is currently holds the position as Life Cycle Manager, accountable for the enabling of Life Cycle Management in Kongsberg Maritime. He has as a Bachelor in mechatronics engineer from the University of South-Eastern Norway. He completed his Master's degree in Systems Engineering in spring 2019 at the University of South-Eastern Norway. This paper is the result of the research done for his Master's degree in Systems Engineering from the University of South-Eastern Norway in 2018. He is currently employed as a Systems Engineer.

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Gerrit Muller, originally from the Netherlands, received his Master's degree in physics from the University of Amsterdam in 1979. He worked from 1980 until 1997 at Philips Medical Systems as system architect, followed by two years at ASML as manager systems engineering, returning to Philips (Research) in 1999. Since 2003, he has worked as senior research fellow at the Embedded Systems Institute in Eindhoven, focusing on developing system architecture methods and the education of new system architects, receiving his doctorate in 2004. In January 2008, he became full professor of systems engineering at University of Southeast Norway in Kongsberg, Norway. He continues to work as senior research fellow at the Embedded Systems Innovations by TNO in Eindhoven in a part-time position.

All information (System Architecture articles, course material, curriculum vitae) can be found at: Gaudí systems architecting http://www.gaudisite.nl/

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