EINDHOVEN UNIVERSITY OF TECHNOLOGY

Influencing total costs of ownership in the tendering phase

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Influencing Total Costs of Ownership in the tendering phase

Influencing Total Costs of Ownership in the tendering phase

Concise summary of this best practice

Purchasing decisions of capital-intensive goods have a long-lasting impact on the company's profitability. As a result, potential buyers of capital goods want to know and understand the expected Total Cost of Ownership (TCO) during the tendering phase.
Vanderlande is a supplier of capital-intensive goods who is increasingly faced with TCO related challenges. Interestingly, many Vanderlande systems are designed to satisfy specific customer needs, so how can you estimate the (expected) TCO phase when the product design is not frozen? And how can Vanderlande create the highest added value, by influencing the TCO by making a smarter system design? Together with Eindhoven University of Technology, Vanderlande developed an intuitive tool that enables Vanderlande to calculate, evaluate and influence the TCO and the System Availability of a customer-specific design in the tendering phase. This research project shows that it is both smart and financially feasible to design for availability. This award-winning project is portrayed in this best practice. Moreover, recent applications of the tool during tenders demonstrate the added value of the tool.

Key terms

Total Cost of Ownership, System Availability, Tendering Phase, System Design

Relevant for

Suppliers and buyers of capital-intensive equipment

SLF Prize

Every year, the Service Logistics Forum (SLF) awards the best academic master thesis in the field of service logistics, with the SLF Prize. In 2010, Rutger Vlasblom has won the prize for his research. The jury praised the methods to analyze and construct the relationship between TCO and system availability. In their report, the jury highly valued the innovativeness and practical applicability of Vlasblom's research.

Introduction into Total Cost of Ownership

The purchasing process of capital-intensive goods is often a strategic, non-routine, uncertain and complex process, where decisions have a long-lasting financial impact. Many different business decision-making concepts have been investigated and applied to evaluate purchasing decisions. One of the concepts that became common practice in many businesses around the world is the concept Total Cost of Ownership (TCO).

Ellram and Siferd (1998) define TCO as "a purchasing tool and philosophy aimed at understanding the relevant cost of buying a particular good or service from a particular supplier". TCO reflects not only the initial purchase price of an asset, but also the less obvious long-term costs of the asset (such as maintenance, inspection, refurbishments, energy consumption and operating expenses) and net salvage value (negative or positive) of the asset at the end of its lifetime. Another interesting factor that can be included in a TCO study is the costs of system unavailability. Capital goods are often bought to facilitate a core process, making the system availability critical to the core process, and therefore valuable.

Calculating the Total Cost of Ownership of a certain capital-intensive asset is one thing, but how can one influence the Total Cost of Ownership? Several studies in the nineties have revealed that 70% to 85% of the TCO is determined by the design of the product. In other words, during the design phase of a product, the opportunities to reduce the TCO fade away quickly due to the inherent nature of design phase. Paradoxically, the designer (and vendor) of the asset determines the majority of the TCO during the design phase, whereas the future owner of the asset has relatively little influence (Barringer and Weber, 1996). This is visualized in Figure 1.

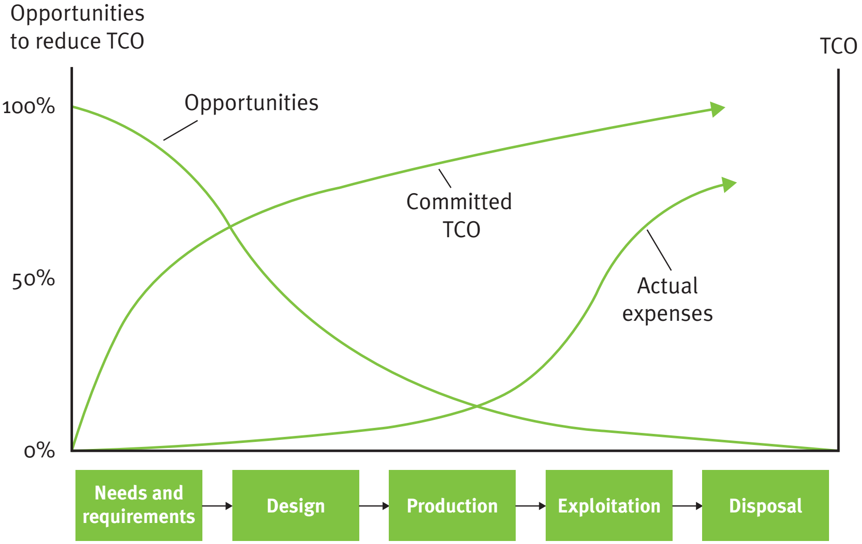


figure 1

A majority of the TCO is committed upon in the design phase, but paid during the exploitation phase.

Vanderlande Industries

Vanderlande designs and implements innovative, automated material handling solutions. It consists of 4 business units: Baggage Handling, Warehouse Automation, Parcel & Postal and Customer Services. The portfolio ranges from systems for small local sorting depots to the world's largest sorting and distribution facilities. Vanderlande provides turnkey solutions, so the company's disciplines range from system design and engineering, through supply chain management and manufacturing, to information and communication technology, system integration, project management and customer services. Vanderlande is a global player with a presence in all key regions of the world. It operates locally through customer centers in many countries handling all key business functions and maintaining direct contacts with her customers. It was established in 1949, and currently employs around 2.730 highly skilled workers worldwide.

Challenges in applying TCO at Vanderlande Industries

A typical manufacturer of capital goods is Vanderlande Industries. Vanderlande offers automated material handling systems for the handling of goods in e.g. e-fulfillment distribution centers, express parcel sortation facilities or baggage handling at airports (see also the textbox on Vanderlande).

Customers of Vanderlande require high availability for their systems, and because their primary processes depend on these systems, the downtime costs are often high. To ensure that systems at customer sites operate smoothly, Vanderlande offers different kinds of maintenance and support packages, including Performance-Based Contracts and Service Level Agreements. Previous research at Vanderlande, executed in close collaboration with the Eindhoven University of Technology, showed that maintenance and downtime costs together accounted for almost 70% of the TCO of major baggage handling systems, where the acquisition costs accounted for 30% (Öner et al., 2007). It's no surprise that potential customers are increasingly interested in Vanderlande's TCO calculations before buying a product.

Pricing Manager Radj Bachoe explains: *"In the tender phase, Vanderlande needs to provide the customers with a solution that adds value. To do so, we analyze the underlying business processes of the potential customer, to design a custom-specific system that satisfies the customer requirements. And at the same time, we need to be able to provide detailed costs estimations on the expected TCO of that customer-specific system. This makes the tendering projects very complex. To fully satisfy our customer requests, we want to be able to influence the TCO by creating the smartest design. Therefore we have to bring our TCO knowledge to a higher level."*

Modeling Total Costs of Ownership in the tendering phase

This initiated the graduation project of Rutger Vlasblom, a Master of Science student at Eindhoven University of Technology. Vlasblom developed an intuitive, excel-based tool that enables Vanderlande to calculate, evaluate and influence the TCO and the system availability of a customer-specific design in the tendering phase. A simplified visualization of the tool is shown in Figure 2.

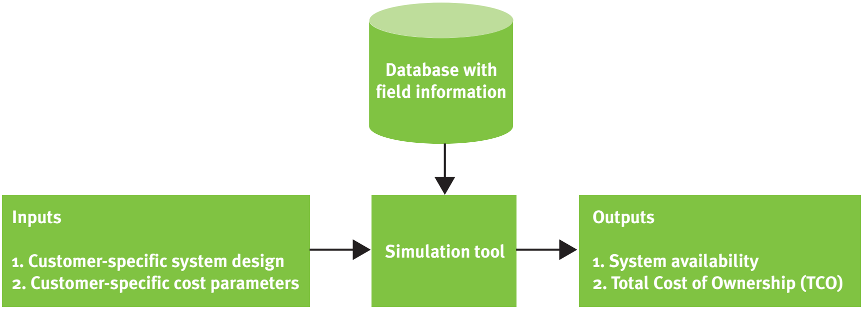


figure 2

An overview of the calculation tool, using two inputs and providing two outputs

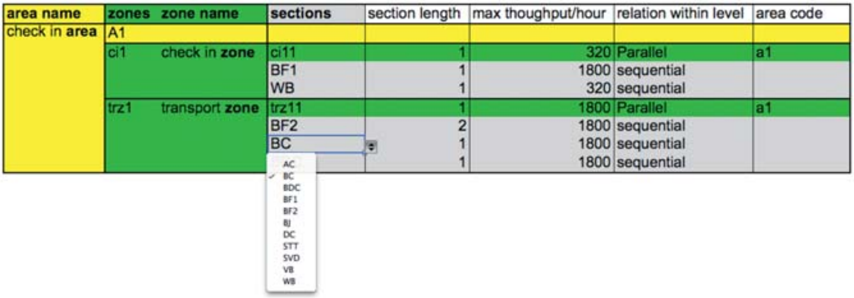
In the following pages, this research will be described and discussed.

The customer specific inputs

The first part of the input-screen is dedicated to the design of many different system designs[1]. To build a flexible input-screen, Vlasblom took the actual design-practices of Vanderlande as starting point. Vanderlande uses many fixed modules (modularity) to create customer-specific demands. Modularity is an engineering technique that builds larger systems by combining smaller subsystems. The use of modularity has numerous advantages, such as increased design speed, decreased design costs, reduced complexity and improved economies of scale in procurement and production. Group Leader of System Simulations, Ivo van Lith, explains: *"On top level, our system consists of areas. The different areas consist of zones, and zones consist of different sections. The sections are the building blocks, or modules, from which the entire product is built up. Sections can be straight conveyor belts, curved belts, elevators or scanning devices, etc."*

Based on these modules, basically any Vanderlande system can be modeled in the developed tool. The input-screen allows the user to freely add areas, zones and sections to model a certain system design (see Figure 3). All sections, known in the tool's database, can be found in a drop-down list. This drop-down list avoids that the user makes typing errors and it avoids the use of unknown sections. By defining the relationships between the different sections, these sections can be positioned in series or parallel. The two remaining design parameters, section length and maximum designed throughput, should also be entered here.

[1] Although Vlasblom's tool was developed for baggage handling systems, the calculation method is generically applicable in the other businesses, as long as all parameters of the required sections are known in the database with field information.



area name	zones	zone name	sections	section length	max thoughput/hour	relation within level	area code
check in area	A1						
	ci1	check in zone	ci11	1	320	Parallel	a1
			BF1	1	1800	sequential	
			WB	1	320	sequential	
	trz1	transport zone	trz11	1	1800	Parallel	a1
			BF2	2	1800	sequential	
			BC	1	1800	sequential	
				1	1800	sequential	

figure 3

A screenshot of the tool.

The second part of the input-screen is dedicated for the customer-specific operational parameters and cost factors. This input is necessary for the different maintenance related calculations in the tool. For many customers, Vanderlande executes inspections and maintenance to maintain the reliability and performance of the system. During these inspections, components may be replaced preventively when damage is observed. Components that fail in-between inspections are replaced via a corrective maintenance action. This may cause long, unexpected downtimes. Therefore, preventive maintenance has (at least) two advantages: it can be executed during planned downtime (e.g. at night) and secondly it can be prepared, which should diminish downtime for diagnostics and logistics. The disadvantage of preventive maintenance is that you might replace your components too early, which slightly increases parts consumption. All these optimizations are taken into account in the TCO model.

Operational parameters

- Expected lifetime (in years)
- Operating hours (per day, per week, per year)
- Number of peak hours per day
- Expected throughput in peak hours
- Expected throughput in remaining hours
- Expected operational availability

Cost factors

- Corrective maintenance labor hour cost rates (per hour)
- Preventive maintenance labor hour cost rates (per hour)
- Spare part costs (per section)
- Costs per baggage-item not loaded (per occurrence)

Database with field-based information

The tool uses a database of field information to establish future performance estimations on historic performance data. To create this database, there are two important questions.

1. Which information needs to be stored in the database?
2. How can reliable and generic information be obtained?

To answer the first question, Vlasblom quantified the underlying relationships for the TCO and system availability calculations. After extensive research (and with a number of creative solutions) he identified the required information to solve these calculations. In the table below, a simplified overview of the required parameters is given. For each section, a library with the specific field information is stored in Excel.

Reliability characteristics per section	Maintenance characteristics per section
• Mean Time Between Failures (MTBF) with preventive maintenance • Mean Time Between Failures (MTBF) without preventive maintenance	• Mean Time To Repair (MTTR) • Number of yearly inspections • Mean Diagnostic Delay Time (MDDT) • Mean Logistics Delay Time (MLDT) • Number of spare parts on stock • Expected usage of spare parts

For the second question, not all required information for this research was available at hand. For his research, Vlasblom manually determined all parameters for 15 often-used sections, relying on field information from a large reference site. Interestingly, the developed model incorporates the measured effect of inspections on the failure rate of sections. Keep in mind that it is not straightforward to find reliable and generic data of performance, since the deterioration rate of components is continuously influenced by both usage and maintenance. (Nowadays, few years after Vlasblom's research, this is continuously monitored in the field, since Vanderlande has installed so-called Business Process Intelligence systems at customer sites, to gather and analyze all kinds of relevant data. This is a big improvement as opposed to conventional maintenance modeling practices. Especially when it comes to a different deterioration behavior of the systems in different environments, there is plenty room for improvement. The tool is designed with this future wealth of data in mind.)

Calculating output 1: System availability

Due to the complex structure of Vanderlande systems, availability calculations are not straightforward. For example, a belt may be broken, but the system may continue to operate. Or, a system can also be down due to a stuck baggage-item, meaning that the system is technically available, but operationally unavailable.

Therefore, the tool calculates the expected technical availability (All calculations, assumptions and explanations can be found in Vlasblom's thesis). Availability will be expressed in a percentage of time that the system is available in the long run. The technical availability is calculated via four automated steps:

- In the first step, the **availability on section level** is calculated. This takes all MTBF-, MTTR-, MDDT- and MLDT estimations into account, as well as the throughput restrictions and the usage estimations.
- In the second step, the **availability on zone level** is determined using basic probability formulas. Herein, it is assumed that all sections are sequentially placed. That means; if one section fails, the zone is down.
- In the third step, the **availability on area level** is determined, based on the parallel or serial structure of the area. This uses the zone characteristics as inputs.
- In the fourth step, the **availability of the system** is calculated, by repeating step 3 for the system, using the area characteristics as inputs.

Obviously, Vlasblom did not have to start from scratch. Vanderlande has obtained extended knowledge on calculation availability in complex systems and the developed tool integrates approximately 20 years of experience. The main challenge was to develop the methodology to design a reliable, flexible and automated calculation tool.

Calculating output 2: Total Cost of Ownership

Extensive research led to a series of equations to calculate the expected TCO. Vlasblom focused on four cost buckets, namely equipment cost, maintenance costs, spare parts costs and downtime costs. Below, the most important characteristics of these equations will be given per cost bucket.

The first cost bucket is **design and equipment costs** of the goods sold. These costs are based on the current pricing methods to calculate a sales price as offered to the customer. For each section, surcharges are added for the accompanying mechanical, electrical, installation, system and production engineering costs.

The second cost bucket concerns **maintenance costs**. This bucket includes the costs charged for all preventive and corrective actions that are required to extend the operational life and reliability of the system. The major difficulty lays in the estimation of the required efforts, since these efforts are dependent on one another: the more preventive actions, the less corrective actions are required. As described previously, Vlasblom has been able to measure the impact of inspections on the amount of corrective maintenance. This tool provides a major improvement in this perspective.

The third cost bucket contains the **spare parts costs**. Spare parts costs are only a small portion of the TCO, but the spare parts decisions have a strong influence on the system availability. Proper spare parts management should balance the downtime waiting for parts with associated costs. Therefore, the model accounts for (i) initial spare parts investments, (ii) inventory holding costs, (iii) costs of consumption and (iv) costs for emergency shipments.

The fourth and final cost bucket includes the **downtime costs**. As discussed previously, for these capital-intensive machines, the downtime costs can account for a majority of the TCO. For airports, downtime costs occur when a baggage-item cannot be loaded into an airplane. Unfortunately, it has proven to be very difficult to quantify the relationship between system availability and the expected number of delayed bags, because a large number of (unknown) factors influence this relationship. During this research, it was found that there is an exponential relationship between operational utilization and delayed baggage-items. Now, the tool can estimate the expected number of delayed bags, relating throughput, designed capacity and technical availability. The tool multiplies the expected number of delayed baggage-items with an average costs parameter per delayed item, calculating the total amount of expected downtime costs.

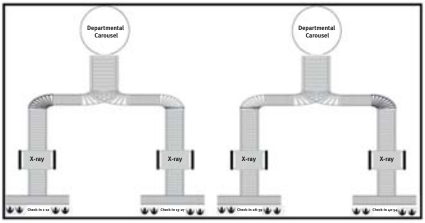
The summation of these four cost buckets determines the expected TCO[2]. Notice that the inclusion of downtime costs in the TCO implies that the effect of downtime comes back both in the system availability and the TCO.

[2] Since a system is likely to operate for 15 to 40 years, the model accounts for inflation to discount future money flows. When properly applied, a TCO analysis also takes the economic concept of the Net Present Value into account (the sum of the present and future value of cash-flows).

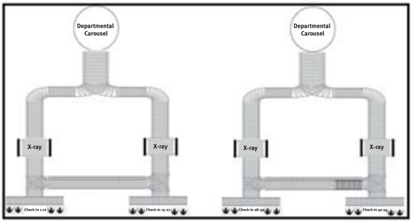
Case study: comparing alternative designs

Vlasblom applied his model to a regular system design. One of these case studies analyses different levels of redundancy. Redundancy is the parallel placement of duplicates of critical components in a system with the intention to increase the system's reliability. Vanderlande's system engineers often advise certain customers to apply redundancy. This is especially interesting at zones of the system wherein the system availability is vulnerable to damage.

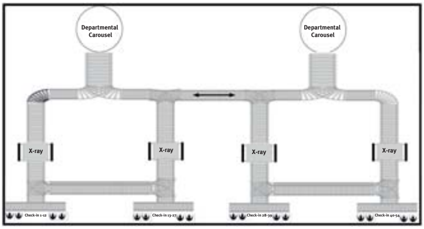
In the case study, four possible designs with an increasing level of redundancy are analyzed. The first design is the most basic one with two zones consisting of four check-in docks, four scanners and two exit-conveyors. The structure of this design is very often used in airports. In the second design, redundancy is created after the check-in islands and before the scanners. In the third design, an additional conveyor is placed after the screening area, linking the two zones. These two zones are now redundant. In the fourth design, an extra exit-conveyor is added to the design. Observe that this also increases the total capacity of the system.



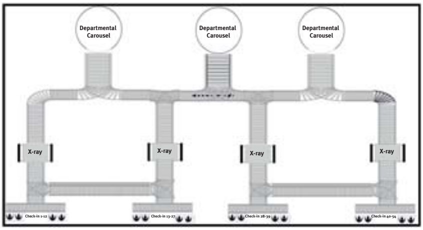
Design 1: Basic design



Design 2: Plus redundant conveyors belts



Design 3: Plus redundant check-in zones



Design 4: Plus additional exit conveyor

These four designs were entered into the tool, to assess the impact on TCO and availability (see Table 1). From this case study, the following conclusions are drawn:

- Investments in system redundancy can lead to 5% TCO reduction. Clearly, design for availability can pay off, but not all redundancy investments necessarily lead to lower life-cycle costs.
- Designs 2 and 3 do not add much value: the amount of delayed bags decreases slightly, but in both cases the TCO estimations are 2% higher. Apparently, the improved delivery performance of bags is too small, and the downtime costs reduction does not outweigh additional equipment investments.
- Design 4 turns out to be a smart long-term investment. Although the initial investment increases by 21%, the total cost of ownership decreases by a stunning 4,7%. The combination of increased availability and 50% added capacity enables a drop of 31% in the expected number of lost bags. This is due to an exponential relationship between operational utilization and expected delayed baggage-items.

Table 1: percentage changes of the designs with respect to design 1

	Design 1 (standardized)	Design 2 (delta)	Design 3 (delta)	Design 4 (delta)
Equipment investment	100 %	2.7 %	6.0 %	20.8 %
Designed capacity	100 %	0.0 %	0.0 %	50.0 %
Expected delayed bags	100 %	-0.1 %	-0.5 %	-30.6 %
Output 1: Technical system availability	100 %	0.1 %	0.2 %	0.4 %
Output 2: Total Cost of Ownership	100 %	2.0 %	2.1 %	-4.7 %

In the other case studies, Vlasblom came to the following additional managerial insights:

- Reducing spare part stock levels can lead to a substantial higher TCO, because the logistics delay time has a strong influence on the availability.
- Replacement of long conveyors by multiple shorter conveyors leads to a higher TCO, because the additional component costs are not sufficiently compensated by decreasing cost buckets.
- The time to repair averages (MTTR) are already fairly small, and calculations show that investments in reducing the MTTR will probably not pay off.

Impact on the business

In 2013, four years after the finalization of the research, it is clear that this research has had a considerable impact on the business of Vanderlande. The thesis project and the accompanying Excel tool are still highly appreciated within the company. This is mainly for three reasons:

1. In the past three years, the tool (and the knowledge gained from the research) was used in at least four major tender projects, to predict the expected system behavior quantitatively. According to the pricing manager Radj Bachoe, quantitative knowledge is pivotal during tenders. It clarifies discussions and it lowers risks for both the vendor and the buyer. Moreover, it enables the execution of scenarios analyses, which is a major qualifier and unique selling point during tendering phases. Scenario analyses examples include the expected spare part usage, or expected availability under potential circumstances, or downtime estimations. In conclusion, the tool is highly appreciated, and it has become a part of the Pricing department toolkit. Vanderlande is currently looking for a way to further integrate the Excel tool into the IT systems.
2. During the master thesis project, all company knowledge about availability and TCO was conveniently recorded into the master thesis report, including both the knowledge and ways of working on all relevant TCO and maintenance concepts. The master thesis report has become an important reference to Vanderlande employees.
3. During his research, Vlasblom worked together with the departments R&D, System Engineering, Pricing and Service Development, to combine specific knowledge between the involved departments. As a result, this project has delivered an internal boast to mutual understanding and cross-departmental collaboration.

Conclusion

During this research, Vanderlande enhanced the understanding of the total cost of ownership of their systems. This intuitive tool enables Vanderlande to calculate and evaluate the TCO and the expected availability of a customer-specific design in the tendering phase. This research shows that it is both smart and financially feasible to design for availability and TCO. More importantly, recent applications of the tool during tenders demonstrate the added value of the tool.

In the end, the tool makes Vanderlande more comfortable with providing the recommendations towards their customers. Customers will certainly appreciate sophisticated and reliable analyses to compare different product designs.

References and resources

- Barringer, H.P., Weber, D.P., (1996) 'Life Cycle Cost Tutorial', Fifth International conference of process plant reliability.
- Blanchard, B.S., Fabrycky, W.J., (1998) '*Systems engineering and Analysis',* New Jersey, USA , Prentice Hall.
- Elram, L.M., and Siferd S.P., (1998) '*Total Cost of Ownership: A Key Concept In Strategic Cost Management Decisions*', Journal of Business Logistics Vol. 19 No. 1
- Öner, K.B., Franssen, R., Kiesmüller, G.P., and Van Houtum, G.J., (2007) *'Life cycle costs measurement of complex systems manufactured by an engineer-to-order company*, In: Qui, R.G., Russell, D.W., Sullivan, W.G., Ahmad, M. (eds.), The 17th International Conference on Flexible Automation and Intelligent Manufacturing, Philadelphia, pp. 589-596
- Van Weele, A.J., (2005) '*Purchasing and Supply Chain Management*', Thomson, 4th Edition
- Vlasblom, R., (2009) *'Steering LCC in the early design phase'* (Master thesis project), Eindhoven University of Technology

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