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Development of a Calculation Model for the Life Cycle Cost and the Total Cost of Ownership Investigation of Container Cranes

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STATUARY DECLARATION

I declare that I have authored this thesis independently, that I have not used other than the declared sources / recources and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

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Date Signature

This work is dedicated to my beloved mother, Bibianne Soral, to whom I owe everything.

Danke

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I would like to thank the Hans Kuenz GmbH very much for this great opportunity and for providing a positive, active environment. I owe my sincerest thanks to everybody who helped me in reaching my goals for this thesis.

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Abstract

A buy decision based on purchase costs is, without a doubt, a common practice. Although following costs may exceed initial costs before the end of a product's lifetime, the purchase price seems to remain the most interesting part for the customer. A total cost approach considers all cost factors over a product's lifetime and provides the purchasing party a transparent view of the cost structure and, therefore, a proper basis for decision-making.

Since container cranes require a lot of maintenance activities during operation, a total cost calculation model seemed perfectly reasonable for crane manufacturing Kuenz. Specifically, the ideas behind a transparent cost structure were twofold. First, to offer the client an illustrative comparison of purchase and following costs and second, to create a tool for calculating full maintenance contracts.

Consequently, this thesis explains the approach and procedure in developing the aforementioned calculation model. The resulting Microsoft Excel model for the work, however, consists of a detailed maintenance cost calculation that can be adapted towards the main characteristics of a given Kuenz container crane. Finally, and based on this result, the model computes the Total Cost of Ownership of the crane.

Kurzfassung

Die Anschaffungskosten stellen ohne Zweifel, da offensichtlich und greifbar, das wichtigste Kriterium einer Kaufentscheidung für den Kunden dar. Dabei wird gerne vergessen, dass die Folgekosten den Kaufpreis im Laufe des Lebenszyklus des Produktes leicht übersteigen können. Hier kommen sogenannte Gesamtkostenbetrachtungen ins Spiel, die wie der Name verrät alle Kosten berücksichtigen und dadurch dem Käufer als Kaufentscheidungsinstrumente dienen.

Da Container Krane als besonders wartungsintensiv betrachtet werden können und ebendiese Kosten den Anschaffungspreis relativieren, stellt ein Kalkulationsmodell zur Berechnung der Gesamtkosten ein nützliches Werkzeug für Künz dar. Im speziellen ermöglicht das Model einen illustrativen Vergleich von Anschaffungs- und Folgekosten sowie die Basis für die Erstellung von Vollwartungsverträgen.

Die Diplomarbeit soll daher die Vorgangsweise bei der Entwicklung des angesprochenen Kalkulationsmodells auf Microsoft Excel Basis vorstellen, welches in erster Linie aus einer detaillierten Berechnung der Instandhaltungskosten besteht. Die Möglichkeit der Anpassung der Berechnung hinsichtlich eines bestimmten Kranes war dabei ebenso Ziel der Arbeit, wie die darauf aufbauende Total Cost of Ownership Betrachtung.

Table of Contents

1 Introduction

This chapter will give an overview of the company that initiated this thesis as well as the motivation and the basic idea behind the work. Furthermore, this section will introduce the objectives of the thesis and a guide for the following chapters.

1.1 The Hans Kuenz GmbH[1]

Figure 1-1 Kuenz Headquarter in Hard

Hans Kuenz founded the company, named after him, in the year 1932 in Vorarlberg, the westernmost state of Austria. As the company was gifted with innovative spirit since its birth, Hans Kuenz succeeded in building up a prosperous mechanical engineering firm. Starting out with tower cranes, the core business nowadays is the manufacturing of container cranes as well as the manufacturing of hydropower equipment. Additionally, Kuenz sets up customized cranes and tank house cranes.

Internationally, Kuenz has locations operating in Hard and Gross St. Florian (Austria) as well as in Kechnec (Slovakia) and in Raleigh (USA). Furthermore there exist formed partnerships with other companies worldwide.

As Hans Kuenz GmbH is still a family business, it never lost its entrepreneurial character. Specifically, their philosophy is based on pursuing fast communica-

[1] Compare www.kuenz.com (20/2/2010)

tion within the firm as well as quick reactions towards environmental opportunities.[2]

Container Cranes

The first container crane of Kuenz was manufactured in the year 1973.[3] Since then numerous successful installations were built, whether for intermodal operation Railway–River–Road or Railway–Road. Today, the portfolio of Rail Mounted Gantry Cranes (RMG) includes automated systems for intermodal operation and stacking. The biggest Kuenz project was the installation of 52 automated stacking cranes in the Hamburg Container Terminal “Altenwerden”.

As this thesis is based on Life Cycle Cost (LCC) and Total Cost of Ownership (TCO) investigations of container cranes, these systems will be presented in detail in chapter 2.

Custom Cranes

As Kuenz has deep know-how in crane and gripper systems, there are hardly any limits in tailor-made crane solutions. Their own in-house engineering and manufacturing allow for the quick realization of each customer’s individual needs.

Tankhouse Cranes

The portfolio includes fully and semi-automatic tank house cranes for zinc and copper refineries, which are able to work in a harsh environment.

Hydropower Equipment

Kuenz delivers the full range of steel hydropower equipment including weir gates, stop logs, powerhouse cranes and trash rake cleaning systems.

1.2 Motivation

At first glance, a container crane seems rather unsophisticated compared to other systems within the engineering domain. However, the prediction of the overall running costs of such a system is definitely a challenge. Several moving parts cause wear and tear and hence a limited lifetime. This aspect is the most

[2] Conversation, Michael Geiger – Head of Sales, Kuenz (9/12/2009)

[3] Compare, STOISER (2008), p. 1

crucial in a running cost investigation and as a consequence in the identification of the total costs of a container crane.

Specifically, the lifetime of these components is difficult to determine because of many influential factors such as environment, operator skills, and so on.

As a container crane consists of many different parts, it is necessary to combine knowledge from different fields. An electrical specialist, for example, or in the best case the supplier, should assess electrical parts. But even a specialist in their own field has to make assumptions through the use of empirical values and calculations. Additionally, experience in the operation of existing crane systems is of high importance. That is especially the case for parts, which cannot be forecasted properly.

This leads to a diversified challenge: The necessity of integrating information from nearly all Kuenz departments, the suppliers as well as Kuenz clients and operators, in order to get the required data for this thesis.

The branch of container crane systems has just a marginal product diversification. Pricing and quality represent the main product characteristics. Moreover, customers attach great importance to service and the time of delivery.[4]

As Kuenz is situated in the high price segment of the market it is necessary to make the client understand the cost structure. Unfortunately, customers tend to compare cranes in terms of their purchase price instead of their overall costs.[5]

Consequently, a basic running cost calculation would be of high value for selling new cranes. Moreover, it would also be the basis for setting up full-maintenance contracts.

Kuenz offers tailor-made maintenance contracts as an additional incentive for cooperation. In reference to the difficulties mentioned before, however, the contracts were more likely predicted than calculated precisely in the past.[6]

In short, the total cost investigation of this thesis should be the basis for future full-maintenance contracts on the one hand and being helpful in selling new cranes on the other hand.

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[4] Compare STOISSER (2008), p. 64

[5] Conversation, Michael Geiger – Head of Sales, Kuenz (9/12/2009)

[6] Conversation, Wolfgang Fink – Head of Service, Kuenz (28/1/2010)

1.3 Objectives

Due to the fact that the maintenance costs are the most uncertain aspect of a total cost approach for a container crane, the idea behind this thesis is to significantly improve this issue. More precisely, the first and main target is to develop a calculation model implemented in Microsoft (MS) Excel, which ideally can also act as a pool for information from diversified sources. The more information and experience values contributing to this work, the more precise the maintenance costs will be at the end of the day.

The calculation model must also be adaptable towards the characteristics of a certain crane; whether the number of wheels, attached motor modules or the supplier of purchased components these different parts have to be considered. Needless to say that any given characteristic has to directly affect the outcome.

The second target of this thesis is a total cost approach, based on the prior explained investigation of the maintenance costs. Adding purchase and miscellaneous operation costs, and so forth, to the model will easily create the "Total Cost of Ownership" for the chosen crane. To sum up, the objectives of this thesis were the following:

- **Development of the following calculation model: Dataset and investigation of the maintenance costs (Life Cycle Cost - LCC)[7] of intermodal container cranes on a MS Excel basis with an investigation timeframe of 10 to 15 years.**
    - **Investigation of the necessary components**
    - **Analysis of the component's lifetime and costs**
    - **Adaptable calculation:**
        - **Input: Main characteristics of the crane**
        - **Output: Costs per year**
- **A Total Cost of Ownership (TCO) investigation based on the results of the LCC and integrated as a separate MS Excel sheet of the calculation model. The final result should hereby be the characteristic value of costs per twenty-foot equivalent unit (TEU).[8]**

[7] Compare LCC working definition, chapter 3.5.3.2

[8] TEU is the unit of the ISO shipping container; one TEU = one 20-foot ISO container, compare chapter 2.4

1.4 Guide Through

Chapter 1 “Introduction” is comprised of the presentation of company Kuenz as well as of the motivation and the objectives for this thesis.

The emphasis of the following chapter 2 “Container Cranes” is to lead carefully to the necessary technical knowledge for understanding the practical part of this work. In respect to the complexity and variety of different components in the domain of container cranes, however, please be reminded that the chapter offers a general overview.

The chapter 3 “Cost Accounting” introduces, besides the term cost and the process of cost accounting, especially the terms Life Cycle Cost (LCC) and Total Cost of Ownership (TCO). The idea and definition of these concepts is vital for understanding the structure and composition of the calculation model.

Since the thesis is based on the practical work at company Kuenz, the main part refers to the development of the calculation model. Specifically, chapter 4 “The Way to the Calculation Model” explains chronologically and detailed the process of developing the model, while chapter 5 “Calculation Model” provides an overview of the finished model. The aim for chapter 4 was to describe as precisely as possible the steps towards the calculation model. Please consider in regard to chapter 5, therefore, that if you have the wish for more detailed information you can always refer (back) to the corresponding section of the previous chapter.

Chapter 6 “Summary” will finally give a brief statement of the work by presenting the results, while chapter 7 “Outlook” finally presents the prospects for the calculation model.

2 Container Cranes

As already mentioned in chapter 1.1, container cranes represent the core business of Kuenz and the point of interest in this work. Consequently, this chapter provides a brief overview of container handling gantry cranes and their functionality as well as a list of the terms used in this context.

2.1 Introduction[9]

A container handling gantry crane is the heart-piece of a container terminal usually located, for example, at a rail-attached goods station that is accessible by trucks. Furthermore, there are terminals integrated in a freight port. Thus, container cranes can be seen as a kind of an interface in between different modes of transportation with the purpose of loading and unloading containers.

Due to different types of transportation being involved, terminals often have to deal with delays and therefore must have enough space to buffer the freight. For example, it makes no economic sense to release a container freight ship carrying only a couple of containers.

[9] Conversation, Michael Geiger – Head of Sales, Kuenz (9/12/2009)

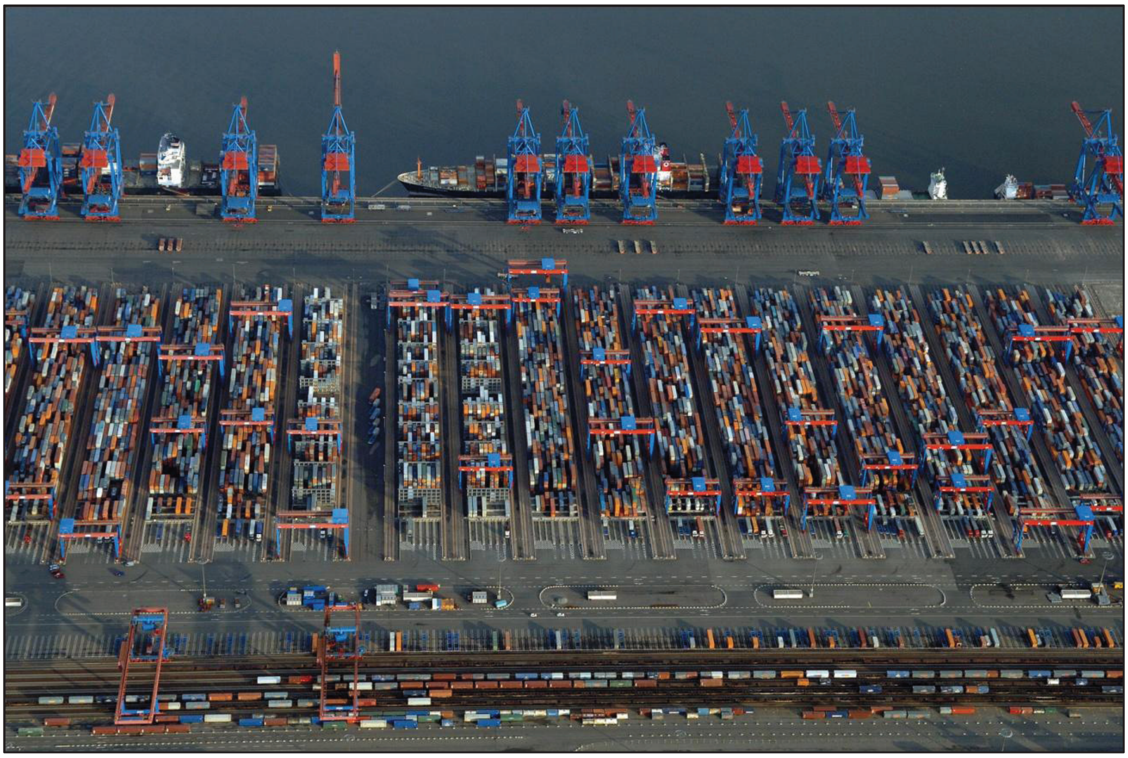

Figure 2-1 Hamburg Altenwerder Container Terminal[10]

Figure 2-1 demonstrates the previously described different modes of transportation as well as stacked containers acting as the buffer in between them.

2.1.1 Intermodal Freight Transport

In reference to chapter 1.1, Kuenz manufactures RMGs for intermodal operation, transferring containers between Railway–Road–River modes.[11] Jones, research assistant for the National Center for Intermodal Transportation, defines intermodal transportation as „the shipment of cargo and the movement of people involving more than one mode of transportation during a single, seamless journey“.[12]

Consequently, intermodal transport itself is not necessarily limited to the transportation of cargo. However, the term intermodal indicates simply the fact that different forms of carrier are involved in transportation.[13]

[10] Kuenz: Sales Media Archive
[11] Compare www.kuenz.com (9/2/2010)
[12] Compare JONES (2004), p. 8
[13] Compare www.merriam-webster.com (20/2/2010)

2.1.2 Basic Movements

Because of different modes of transportation it is necessary that the cranes offer the possibility to place the lifted container in a different location. The gantry system has to offer, therefore, at least a vertical and two horizontal movements of the container. However, an additional rotation movement may be also required for two reasons.

First, terminals, dealing with freight trucks, require an additional rotation movement in order to place the container in the right orientation. The door-side of the container should be thereby oriented against the driving direction of the lorry. Otherwise it would not be possible to have access to the enclosed freight due to the cab of the truck.[14]

Second, the rotation of a container may also make sense at a rail-attached terminal. In order to have non-accessible shipping containers, the two containers should be oriented door-side towards each other on each wagon. This measure increases the security of the goods inside the container, as it hinders thieves from breaking in.[15]

In fact, almost every container crane installed by Kuenz has an implemented rotating mechanism.[16]

2.2 Types of Container Cranes

Container handling gantry cranes can be differentiated in terms of their steel structure as well as in terms of their technical characteristics; both highly dependent on the crane’s purpose.

Basically, a container crane is a moveable gantry crane system, classified as Figure 2-2 illustrates. Accordingly, whether the crane is running on fixed rails or on rubber tires, we distinguish between a Rail Mounted Gantry Crane (RMG) and a Rubber Tired Gantry Crane (RTG).[17]

[14] Conversation, Joerg Hauser – Head of Operation, Rhenus Teminal Basel (12/2/2010)
[15] Conversation, Michael Geiger – Head of Sales, Kuenz (17/2/2010)
[16] Conversation, Gebhard Schmelzenbach – Project Manager, Kuenz (8/2/2010)
[17] Conversation, Michael Geiger – Head of Sales, Kuenz (9/12/2009)

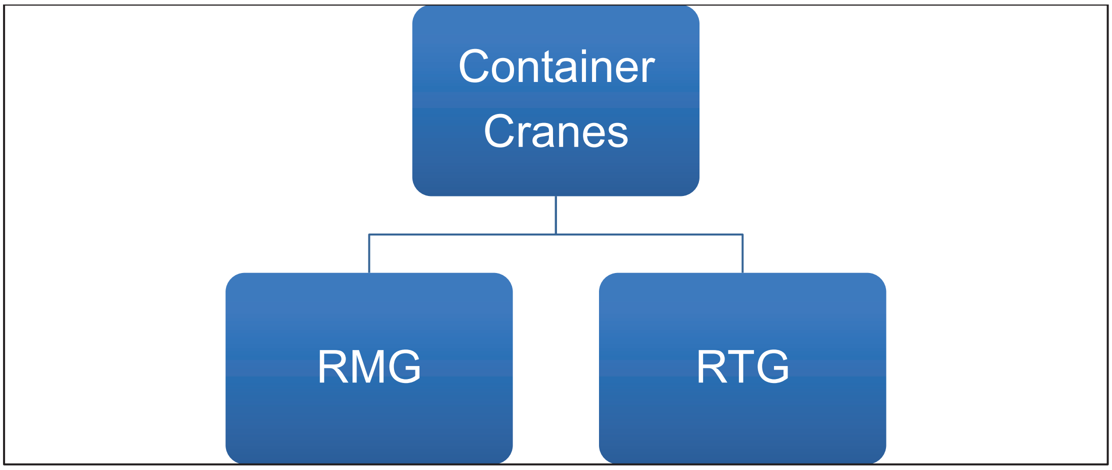

Figure 2-2 Classification of Container Cranes

2.2.1 Rubber Tired Gantry Crane (RTG)

The main advantage of the RTG is certainly its high flexibility and independence due to the tires. However, this results in a slower driving speed in comparison to a rail-mounted system. Another disadvantage in comparison to the RMG is the higher maintenance efforts required for tires, gearing, and steering.[18]

2.2.2 Rail Mounted Gantry Crane (RMG)

RMGs are high performance container cranes, operating on a defined rail path at floor-level.[19] Referring to the previous chapter 2.2.1, the advantages are faster driving speeds and less maintenance effort. However, an RMG requires high capital costs, due to the installation of the rails. Nevertheless, the environmental-friendly operation derived from shore power and the decrease in maintenance effort leads to high suitability for automated operation.[20]
In fact, all container cranes manufactured by Kuenz are RMG installations.[21]

2.2.3 Alternatives

Although, container cranes are the most efficient system to realize intermodal container transportation,[22] the following alternatives exist:[23] [24]

[18] Compare STOISER (2008), p. 66
[19] Compare www.cranesforsale.org (25/10/2010)
[20] Compare Kalmar Industries: Brochure (25/2/2010), p. 7
[21] Conversation, Wolfgang Fink – Head of Service, Kuenz (3/2/2010)
[22] Compare Kalmar Industries: Brochure (25/2/2010), p. 11
[23] Conversation, Michael Geiger – Head of Sales, Kuenz (9/12/2009)
[24] Compare Kalmar Industries: Brochure (25/2/2010), pp. 2-4

- Reach Stacker
- Heavy Lift Trucks
- Straddle Carrier

2.3 Components of an Rail Mounted Gantry Crane (RMG)

This chapter will provide a rough overview of the main assemblies of a container crane. Basically, Kuenz classifies the RMG in the following way:[25]

- Crane Gantry
- Crane Trolley
- Spreader

2.3.1 Crane Gantry

The gantry of the crane is a solid metal construction, which moves on wheels and follows a defined rail-path. Moreover, the gantry itself carries the E-housing as well as rails on the top of which the trolley runs orthogonally in the direction of the movement of the gantry.[26]

2.3.1.1 Metal Gantry Construction

The dimensions of the gantry plus the length of the rails basically define the cuboids workspace of the crane. Hence, the dimensions of the gantry also limit the number of containers, which are usually buffered in between two different modes of transportation.[27]

In general, Kuenz manufactures two different kinds of gantries: an over-spanned construction and a gantry without over-span.[28] Figure 2-3 shows the gantry of the Cargo Center Graz (CCG) Terminal as an example of a gantry without over-span. In comparison, an over-spanned gantry can be seen in Figure 2-4.

[25] Conversation, Wolfgang Fink – Head of Service, Kuenz (3/2/2010)
[26] Conversation, Wolfgang Fink – Head of Service, Kuenz (3/2/2010)
[27] Compare chapter 2.1
[28] Conversation, Wolfgang Fink – Head of Service, Kuenz (3/2/2010)

Figure 2-3 CCG Terminal[29]

2.3.1.2 The E-housing

The E-housing is based on the top of the gantry, which contains the majority of the required electrical components.[30] Figure 2-4 shows the E-housing as the white cuboids on the top of the blue gantry.

[29] Kuenz: Sales Media Archive

[30] Conversation, Wolfgang Fink – Head of Service, Kuenz (19/2/2010)

Figure 2-4 Kuenz RMG with an Attached Claw Fastener Instead of a Spreader[31]

Figure 2-4 also indicates the dedicated rail-path of the gantry on the ground and the right-angle oriented pathway of the trolley on top of the gantry; representing the two horizontal axes mentioned in chapter 2.1.2.

2.3.1.3 Gantry Carriage

The assembly of the wheels, drive-units and brakes is called the gantry carriage. Usually, an RMG is driven by four of these assemblies, each consisting of several wheels. The number of driven wheels with an attached drive-unit, however, depends on the crane and the required characteristics.[32]

2.3.2 Crane Trolley

Since the carriage of the trolley runs on the gantry, it has to over span the gap as well. Moreover, the trolley provides the rotating movement and with the hoisting gear also the vertical movement of the container. Consequently, the signifi-

[31] Kuenz: Sales Media Archive

[32] Conversation, Gebhard Schmelzenbach – Project Manager, Kuenz (3/2/2010)

cantly smaller trolley is more sophisticated than the gantry, since it provides three of four degrees of freedom.[33]

For the following sections, the crane trolley is classified into two parts: an upper and a lower part, separated by the rotating mechanism.

2.3.2.1 Upper Part

The upper part of the trolley includes the carriages and the upper-frame. Since the interface between the upper and lower part is the rotating mechanism, the upper part does not rotate. The blue arrow in Figure 2-5 indicates the moving upper part of the trolley, while the two yellow arrows mark the lower part.

Figure 2-5 Terminal HUPAC in Antwerp[34]

2.3.2.2 Lower Part

According to the previous chapter 2.3.2.1, the complete lower part follows the rotation. It consists of the hoisting gear inclusive housing, the crane cabin as well as the roll-frame, which performs the vertical movement towards the con-

[33] RMG: 2 horizontal linear axis, 1 vertical linear axes and 1 rotation; compare chapter 2.1.2

[34] Kuenz: Sales Media Archive

tainer. However, the interface between the container crane and the container is called the spreader and directly attached to the roll-frame of the crane.[35]

Figure 2-6 illustrates the rotatable lower part of the trolley as well as the spreader.

2.3.3 Spreader

As mentioned in the previous chapter, the spreader is the only part of a container-handling device, which is in contact with the standardized container. Four twistlocks on each edge of the spreader are used to fix the container by attaching them to the corner castings. The female part of the connector is, hereby, the corner casting while the twistlock represents the male one.[36]

The spreader is the most crucial component of a crane, suffering damage from miscalculations in loading and abuse. Specifically, failure of this component can cause serious trouble. A malfunction can lead to safety hazards detrimental to human health and life as well as the risk of property loss.[37]

Figure 2-6 Crane Trolley and Spreader

[35] Conversation, Wolfgang Fink – Head of Service, Kuenz (3/2/2010)

[36] Conversation, Georg Kartnig – Head of Logistics Department, Vienna University of Technology (11/12/2008)

[37] Compare BELLO/LAFFITTE (1999), p. 35

2.4 Shipping Container

International Standard Organization (ISO) Shipping containers are the main carrier for intermodal transportation.[38]

Standardized according ISO 668, the containers are basically large solid boxes made out of metal. The ISO-container significantly improves the loading, storing and transporting of goods and the share of goods transported by container has therefore steadily increased over the last decade. Nowadays, in fact, more than 90 percent of global non-bulk goods travel by container.[39] [40]

2.4.1 Origins

Because of the volume of freight being transferred, it was perfectly reasonable for standardization of the carriers.

Figure 2-7 Malcom McLean[41]

Malcom McLean, a trucker from North Carolina, had the fundamental idea to separate the truck trailer from the wheel bed of his truck.[42] It was in the year 1937, when McLean realized that the largest delay in shipment was the loading and unloading process. He was simply frustrated sitting beside the docks waiting until his freight was handled.[43]

[38] Compare GEORGIJEVIC (2006), p. 199
[39] Compare www.ISO.org (17/2/2010)
[40] Compare EBELING (2009), p. 3
[41] Compare www.usabledesirable.com (16/2/2010)
[42] Compare LAZARTE (2007), p. 37
[43] Compare www.usabledesirable.com (16/2/2010)

It was also Malcom McLean who formulated the saying, “that the shipping industry’s business was moving cargo, not ships”[44]

2.4.2 Characteristics

Malcom McLean’s model, built up as a heavy steel construction, set up the basis for the contemporary ISO shipping container. In fact, the container he introduced included already the corner fittings for easier handling.[45]

[44] LEVINSON (2006), p.376
[45] Compare LAZARTE (2007), p. 37

3 Cost Accounting

This chapter will give an overview of the term cost and cost accounting in general, the different classic costing methods as well as the holistic cost management approaches of TCO and LCC.

3.1 Basics of Cost Accounting

Cost accounting is the entirety of different approaches and methods of collecting, calculating, analyzing and controlling elements of costs. The target is, besides understanding the cost structure of a company, to determine an economical selling price or to detect possible savings. Cost accounting considers monetary means as the economic factor of production, in contrast to financial accounting where it is seen as a measure of economical performance.[46]

Consequently, as Figure 3-1 illustrates, it is necessary to strictly distinguish between the two accounting systems.

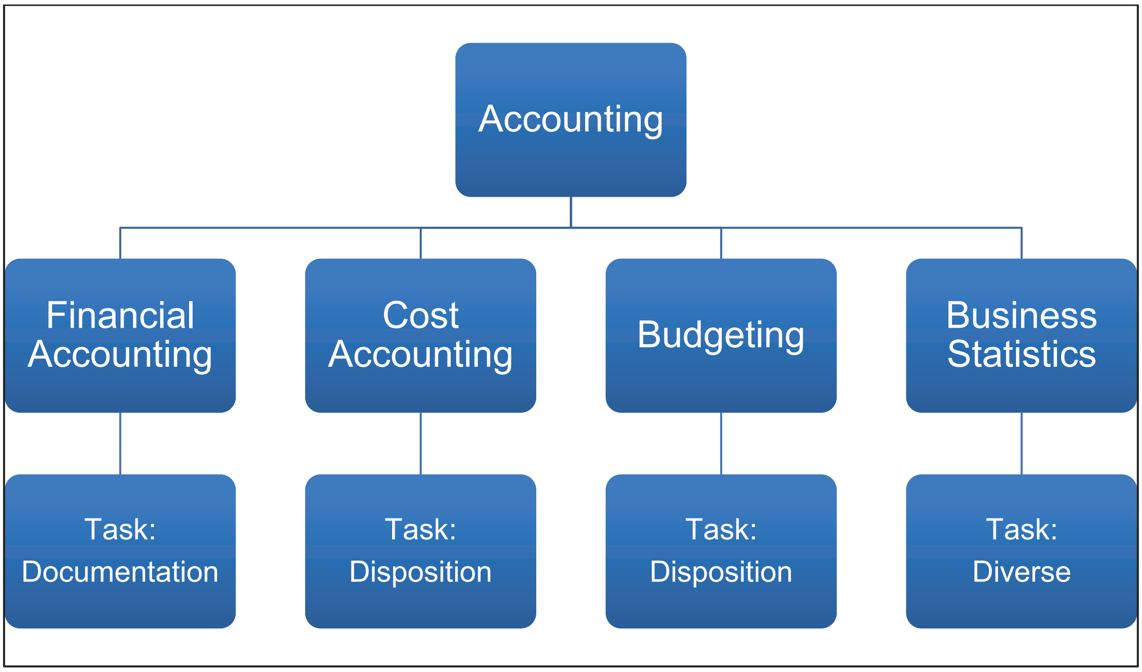

Figure 3-1 Classification of Accounting[47]

Another major difference between financial and cost accounting is the fact that financial accounting basically determines a company's taxation and the frame-

[46] Compare www.Businessdictionary.com (23/10/2010)

[47] Based on KEMMETMUELLER/BOGENSBERGER (2002), p. 15

work of financial accounting has to be, therefore, regulated by law.[48] The major tasks of both instruments, documentation on the one hand and disposition on the other hand, can be seen as the consequence.

The tools and costing methods of cost accounting provide a framework for supervising an enterprise's interior actions and help in both, to understand actual values and to make strategic decisions for the future. However, the term cost of cost accounting is probably to narrow, since it is also necessary to consider revenue data.[49]

3.1.1 Definition of Cost

The usage of the term cost is probably as broad as the literature for accounting itself. Nonetheless, a general approach seems adequate as an introduction for the literature of this thesis. Thus, cost may be defined as **the amount of resources to accomplish a specific objective, commonly valued in monetary amount**.[50] However, the direct translation of the term cost and the German "Kosten" may result in problem, since they are not perfectly equivalent.[51]

At this point, it has to be clarified that this thesis refers to the definition and framework of the German literature of cost and cost accounting.

3.1.2 Cost-cube of Deyhle[52]

Since the term cost is complex and manifold, this chapter will introduce Deyhle's cost-cube as an explanation instrument. The aim of the cost-cube is hereby to strictly differentiate the following three cost pairs and to provide consequently three coexisting considerations of costs:

- **Variable / Fixed Costs**

  Classification criterion: **Are the costs related to the physical existence of the product?** If the answer is "yes" the costs are variable costs, while the answer "no" consequently states that the costs are fixed.

[48] Compare DEIMEL/ISEMANN/MUELLER (2006), p. 23
[49] Compare DEIMEL/ISEMANN/MUELLER (2006), p. 23
[50] Compare MCLANEY/ATRILL (2008), p. 281
[51] Compare KRAEMER (2007), p 33
[52] Compare DEYHLE/HAUSER (2007), pp. 38-39

- **Direct / Indirect Costs**

  Classification criterion: **Are the costs assignable to one cost object?** A positive answer means dealing with direct costs, while not directly assignable costs to a cost object are called indirect costs.

- **Influenceable Costs / Not Influenceable Costs**

  Question: **Are the costs influenceable on the short-term?** The answer "yes" on this question automatically leads to influenceable costs, while not influenceable or influenceable on the long term means dealing with so called not influenceable costs.

As a consequence, the cost-cube is comprised of three axes, each representing a cost pair and, therefore, a different perspective in considering costs:

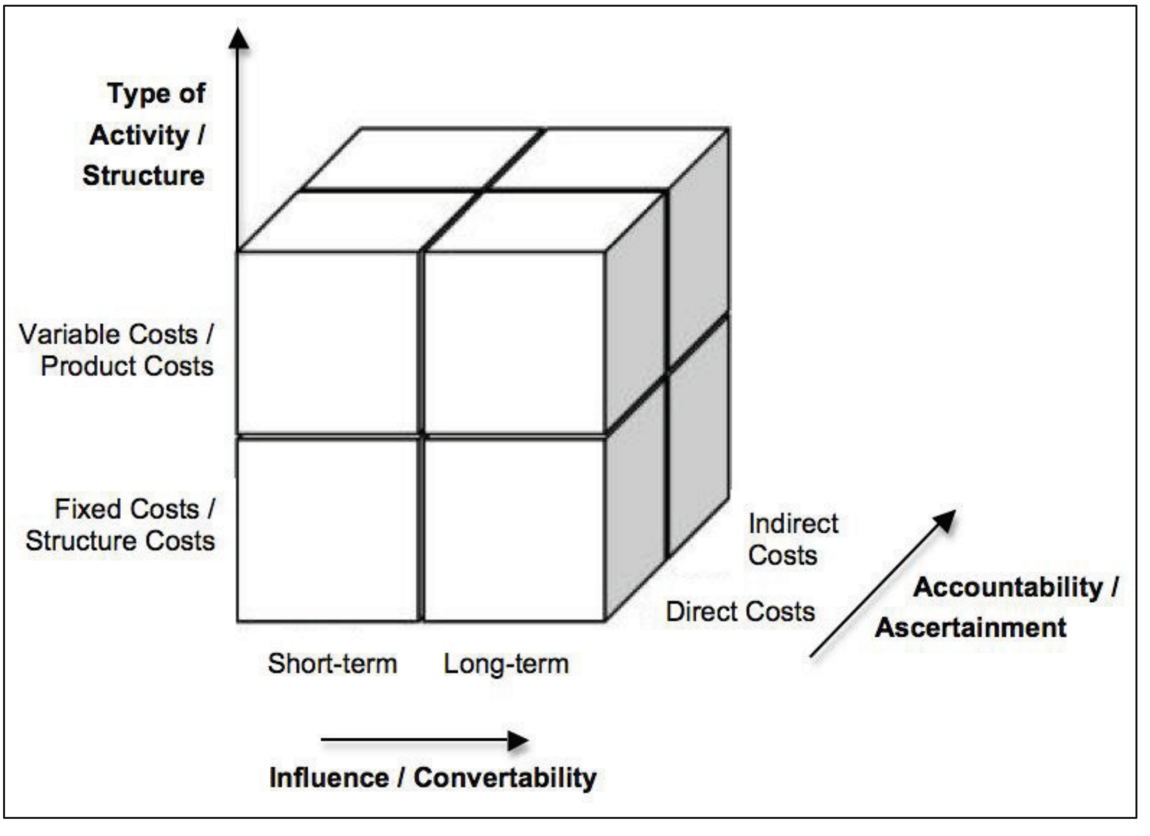

Figure 3-2 „Controller's Cost-cube"[53]

Because of the coexistence of the three cost considerations, each cost position is assignable to one of the eight spaces in the cube.

[53] DEYHLE/HAUSER (2007), p. 41

3.1.2.1 Type of Activity / Structure

The main criterion for the classification of **variable** or fixed costs is the question of whether the costs are necessary for the **physical existence of the product**. More precisely, the output directly and proportionally affects the variable costs, while the fixed costs are not influenced by the output. However, fixed costs may jump from time to time, for example because of additional employment, but are still not proportionally affected by the volume.

As a consequence and referring to the horizontal axis of Figure 3-2, Deyhle has introduced the terms product and structure costs, because influenceable fixed costs on the short-term, as for example additional R&D[54] costs, are not literally "fixed". On the other hand also variable costs can be influenced on the short-run, with a value analysis for example, which flattens the proportional cost function.

3.1.2.2 Accountability / Ascertainment

As the term accountability suggests, the classification of whether costs are direct or indirect costs, depends on whether the costs are directly assignable to one cost object.[55] As a consequence, direct assignable costs are called direct costs while indirect costs have to be distributed to cost centers first.[56]

To underline the difference comparing to the variable/fixed cost pair, both kinds of costs, direct and indirect costs, can be directly influenced by the output of the product. Costs caused due to wear and tear of the tools, for example, are variable cost positions but also indirect costs, because not directly assignable to a cost object.[57] On the other hand also fixed costs could be direct costs, as for example the salary of a product manager.

3.1.2.3 Influence / Convertability

The third axis of the cube represents the possible influence, one basically has or not has on costs. The question is hereby whether cost positions can be actively influenced on the short-term, as for example employment on a leasing basis or advertising costs, which both are instantly influenceable. On the other

[54] R&D = Research and Development

[55] Compare chapter 3.3.1.2

[56] Compare Figure 3-5, p. 24

[57] Compare chapter 3.3.3 „Cost Object Accounting“

hand there are cost positions, as for example not possible withdrawal of personnel because restricted by law, which are either influenceable on the long-term or not at all.

Although most costs should be clearly assignable to either the short or the long-term classification, the time horizon for a sharp separation can be defined, if in doubt, with one year.[58]

3.2 Preparation - The Business Transmission

Since financial accounting is the basis for taxation and has to therefore satisfy law, its values are not suitable for the goals of cost accounting.[59] Before the actual process of cost accounting can take place, it is therefore necessary to transform the expenses from financial accounting, and more precisely from the income statement, to costs.

The **business transmission sheet** can be seen as the corresponding scheme and, consequently, as the interface between financial accounting and cost accounting. Since, all costs are expenses but not all expenses are automatically costs, the actual costs have to be filtered with the help of the following scheme:[60]

[58] Compare www.controlling-wiki.com (7/12/2010)

[59] Compare chapter 3.1

[60] Compare KEMMETMUELLER/BOGENSBERGER (2002), p. 33

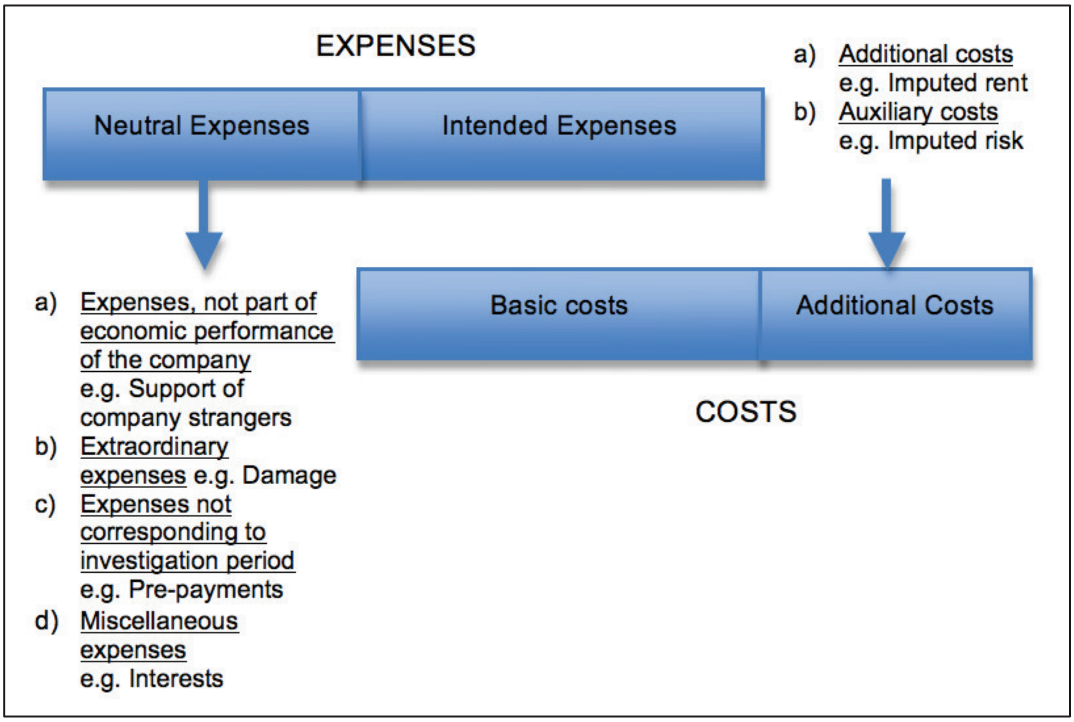

Figure 3-3 Business Transmission Sheet[61]

As Figure 3-3 indicates, the expenses of the financial accounting have to be separated by the neutral expenses, which are either not corresponding to the respective period, the economic performance of the company or because they are extraordinary/miscellaneous. However, the resulting intended expenses are equal to the basic costs. On the other hand, depending on the cost accounting approach, additional costs, as for example imputed costs, are may added to the basic costs.

3.3 The Three-steps of Cost Accounting

An essential part of cost accounting is also the structuring of the required data, even though this is not a real calculation process. Referring to the classic three-step approach of cost element accounting, cost center accounting and cost object accounting, it is only the last step, which is actually carried-out accounting.[62]

Figure 3-4 illustrates the conventional step-wise process, which is the heart of cost accounting and, consequently, provides the base for all cost accounting systems.

[61] Based on KEMMETMUELLER/BOGENSBERGER (2002), p. 36
[62] Compare DEIMEL/ISEMANN/MUELLER (2006), p. 33

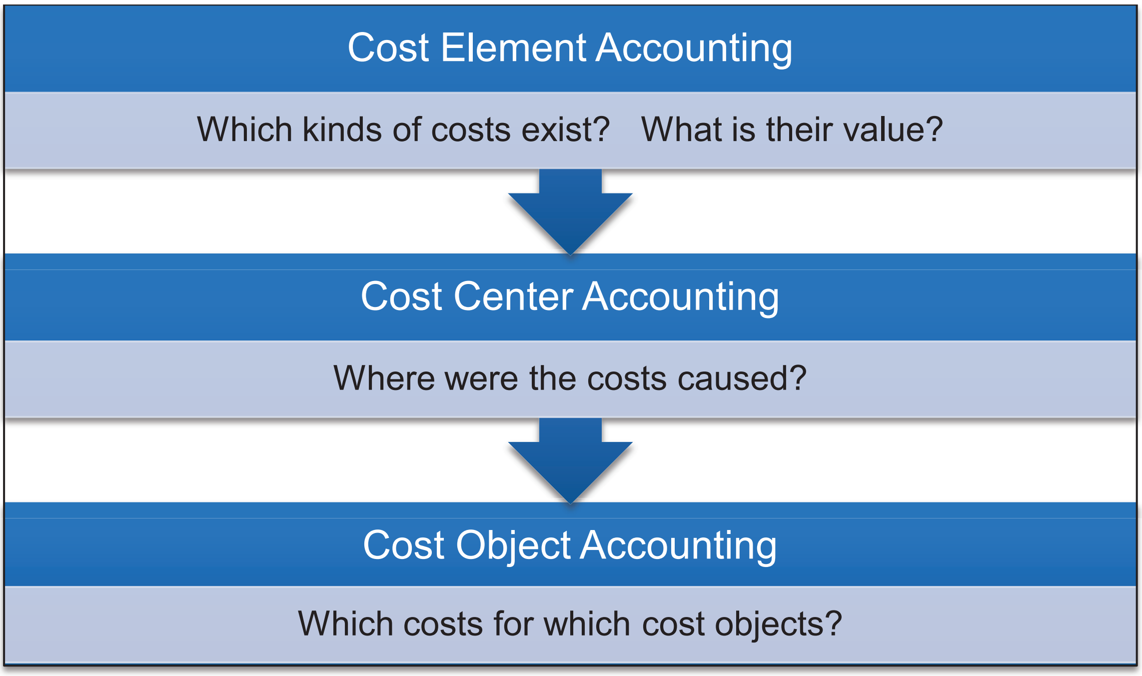

Figure 3-4 Three-step Cost Accounting Approach[63]

Generally speaking, the process starts with detecting the kinds of costs and finishes when the costs are aligned to specific cost objects, as for example a certain product or service.[64]

While Figure 3-4 describes the steps chronologically, the following Figure 3-5 illustrates the same process schematically. Accordingly and referring to this scheme, the following sections will describe the three steps in detail.

[63] Based on HABERSTOCK (2005), p. 10
[64] Compare DEIMEL/ISEMANN/MUELLER (2006), p. 36

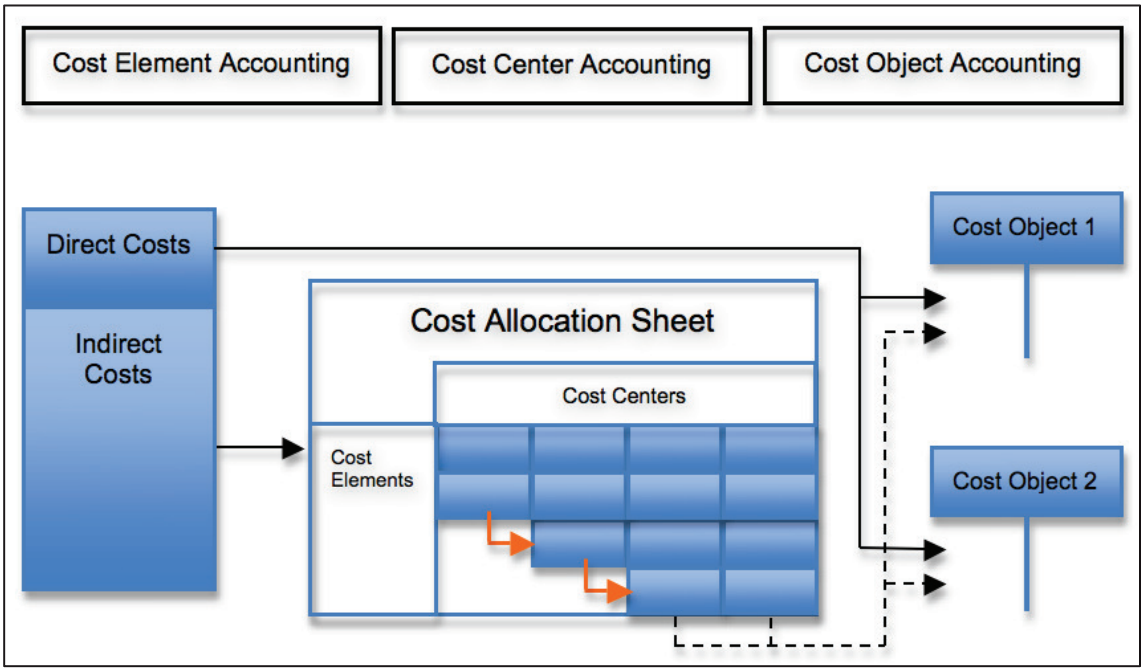

Figure 3-5 Scheme of the Three-step Cost Accounting Approach[65]

3.3.1 Cost Element Accounting

Generally speaking, cost element accounting answers the question, which kinds of costs occur in a certain period and classifies them, for example in accordance to Table 3-1, into cost elements. Accordingly, a cost element is defined in terms of its nature. Moreover, cost element accounting distinguishes the costs in either direct or indirect costs.[66]

3.3.1.1 Classification of Cost Elements

Since law does not regulate cost accounting,[67] the selection and classification of the cost elements is also carried out by the businesses themselves.

Table 3-1 indicates a usual cost element classification in Austria.[68]

[65] Based on FREIDANK (1997), p. 95
[66] Compare THOMMEN (2008), p. 413
[67] Compare DEIMEL/ISEMANN/MUELLER (2006), p. 23 and chapter 3.1
[68] Compare www.kfunigraz.ac.at (23/10/2010)

Cost Element	Description
• Labor Costs	Personnel costs, which include regular wages as well as payroll, benefit and tax (if related).
• Material Costs	Material costs are the valuated consumption of material, used for the production process.
• Energy Costs	Costs caused due to consumption of energy.
• Maintenance, Repair and Operation (MRO) Costs	Costs for the activities to preserve an asset or a product in the initial condition or at least in a state to meet the requirements for ordinary business.
• Tax and Insurance	Costs caused by regular or non-regular payments for tax and insurance related to ordinary business.
• Imputed Costs	Costs, which do not have an expense as a counterpart in financial accounting, e.g. hidden costs for an already paid asset like real estate.
• Miscellaneous Costs	Other costs, which are assignable to ordinary business operations.

Table 3-1 An Exemplary Cost Element Classification[69]

3.3.1.2 Direct and Indirect Costs

Referring to Figure 3-5, direct costs can be immediately assigned to the cost objects without being firstly allocated to the cost centers. Indirect costs are quite the opposite, since they have to be allocated and re-assessed in the cost center accounting phase.[70]

In other words, direct costs can be directly attributed to a service or a product, indirect costs not. In refer to Deyhle's cost-cube, however, the criterion of whether costs are **direct** or indirect is based on their **accountability to one cost object**.[71]

[69] Based on definitions in DEIMEL/ISEMANN/MUELLER (2006) and www.businessdictionary.com (24/10/2010)

[70] Compare DEIMEL/ISEMANN/MUELLER (2006), p. 35

[71] Compare DEYHLE/HAUSER (2007), p. 38 and chapter 3.1.2

3.3.2 Cost Center Accounting

A cost center is a defined entity of a company, like a department, machine or even a person, to whom the indirect costs can be assigned.[72] In refer to the three-step scheme of cost accounting, displayed in Figure 3-4, the cost center accounting represents the necessary steps for allocating and preparing the indirect costs for the cost object accounting phase.

3.3.2.1 Support and Final Cost Centers

Ideally the cost centers are chosen in respect to the given data of the company, necessary for creating the product or service (e.g. material or time plans). The support cost center, however, are hereby only in indirect contact with the creation of the product (or service) as for example the logistic department of a manufacturing company, while the final cost centers directly contribute to it.[73]

3.3.2.2 Cost Allocation Sheet

Cost center accounting allocates the indirect costs with the help of the scheme of the cost allocation sheet, displayed at Figure 3-5.

The basic setup as well as the procedure of this sheet is explained in the following Table 3-2:

[72] Compare www.businessdictionary.com (24/10/2010)

[73] Compare KEMMETMUELLER/BOGENSBERGER (2002), p. 159

		COST CENTERS	
		Support Cost Centers	**Final Cost Centers**
COST ELEMENTS	**Primary Indirect Costs**	**1.** Allocation of the primary indirect costs to the support cost centers	**1.** Allocation of the primary indirect costs to the final cost centers
	Secondary Indirect Costs	**2.** Execution of the internal cost allocation	**2.** Allocation of the primary indirect costs to the final cost centers
			3. Determination of calculation rates for the final cost centers

Table 3-2 Scheme of the Cost Allocating Sheet[74]

3.3.2.3 Allocation of Primary Indirect Costs

The primary indirect costs occur from purchased goods, necessary for the production of the final product. The breakdown and the allocation of these costs is consequently relatively easy, since key-values allow an uncomplicated assignment to the cost centers.[75]

3.3.2.4 Internal Cost Allocation of Secondary Indirect Costs

As Table 3-2 shows, the internal cost allocation handles the more complex secondary indirect costs by allocating them step-wise to the cost centers.

The secondary indirect costs occur in internal processes (IP), and remain therefore within the enterprise. The allocation of these costs is sophisticated, because internal processes affect usually more than one cost center.[76]

Freidank distinguishes the following internal cost allocation methods:[77]

- **Cost Element Method**: The company classifies cost centers just in final cost centers and only the direct costs of the IP are allocated to the re-

[74] Based on BRUEHL (2004), p. 110
[75] Based on FREIDANK (1997), p. 135
[76] Compare BRUEHL (2004), p. 114
[77] Compare FREIDANK (1997), pp. 140-143

ceiving cost center. Indirect costs remain therefore on causing cost center for this period.

- **Cost Center Allocation Method**: Allocation of direct and indirect costs of IP on the receiving cost center. This method is basically possible either between support cost centers or support and final cost centers. However, allocation between final cost centers is not possible. The cost center allocation method is further classified in the "Block Method" and the "Step-wise Method".
- **Cost Center Balancing Method:** Allocation of direct and indirect costs of IP to the receiving cost center, whereby percentages based on the share of direct costs per center define the allocation of indirect costs. This method considers therefore also mutual dependencies of IP.
- **Cost Object Method**: Separate implementation of final cost centers designated for the allocation of self-created activities with the aim of considering the corresponding direct costs of the IP but also indirect costs from other areas. The costs of the causing centers are consequently reduced.

3.3.2.5 Determination of the Calculation Rates

When all indirect costs are allocated to final cost centers, or specifically assigned according to an internal cost allocation method, the respective calculations rates are necessary to assign the costs proportionally-by-cause to the cost objects. Specifically, the basis for the rates is either unit-based (production hours, produced quantity) or value-based (material costs, wages).[78]

3.3.3 Cost Object Accounting

According to the three-step scheme, displayed in Figure 3-4, cost object calculation represents the last step of cost accounting. Specifically, cost object accounting deals with the assignment of the costs to a cost object, as for example a specific product, service or order.[79]

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[78] Compare BRUEHL (2004), p. 117

[79] Compare DEIMEL/ISEMANN/MUELLER (2006), p. 36

3.3.3.1 Classification of Cost Object Accounting

Since the number of cost objects in a company is usually very high, however, it makes sense to group the cost objects with respect to strategic decisions.[80]

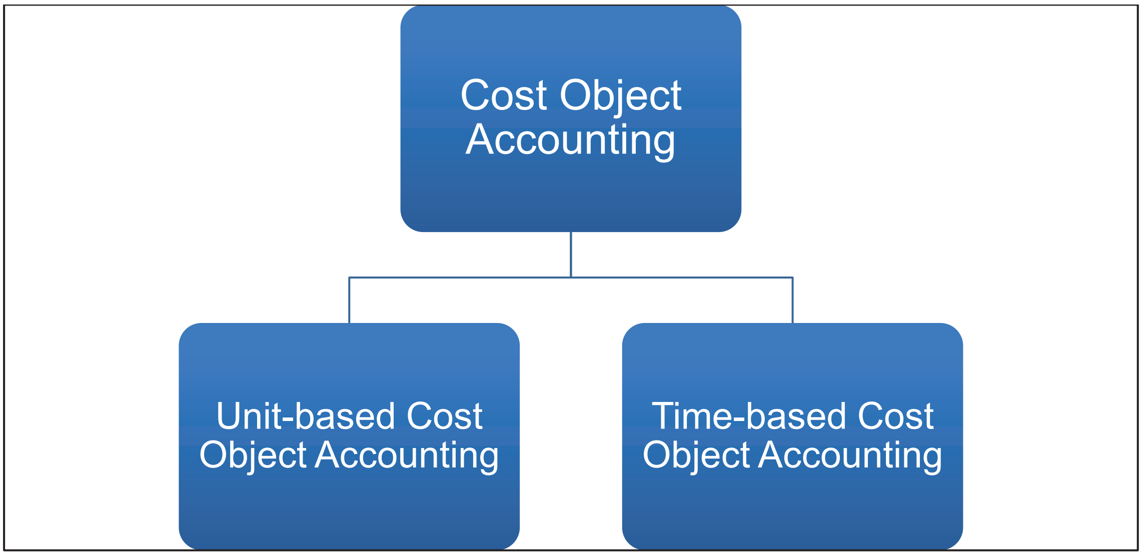

Figure 3-6 Classification of Cost Object Accounting[81]

As a consequence, literature distinguishes cost object accounting in a twofold way. Firstly, **cost object accounting with a time basis**, and secondly, **unit-based cost object accounting**, which is also known under cost unit accounting or simply under "calculation".[82]

3.3.3.2 Unit-based cost object accounting

Unit-based cost object accounting is dedicated for businesses with larger numbers of cost objects, providing additional calculations on a unit basis. Basically the aim of cost unit accounting is to calculate either, and depending on the approach, the prime costs or the manufacturing costs per production unit.[83] [84]

3.3.3.3 Time-based cost object accounting

Time-based cost object accounting, on the other hand, operates on a period base and is dedicated for the calculation of the short-term profit and loss state-

[80] Compare THOMMEN (2007), p 608
[81] Based on KEMMETMUELLER/BOGENSBERGER (2002), p. 180
[82] Compare BRUEHL (2004), p. 120
[83] Compare KEMMETMUELLER/BOGENSBERGER (2002), p. 180
[84] Compare THOMMEN (2008), p. 415

ment. Generally speaking, the aim is to consider and compare all costs with the output in the investigation period.[85]

3.3.3.4 Cost Object Accounting Approaches

The following list of cost object accounting approaches shall give an overview of the possibilities within cost object accounting:[86] [87]

- Job Costing
- Equivalence Number Calculation
- Division Calculation
- Variable Costing - Calculation of the Contribution Margin

Since especially the scheme of job costing is relevant for the practical part of the theses, the approach will be introduced in this chapter.

Job costing splits the costs into direct and indirect cost positions. While the direct costs are directly assigned to the cost objects, the indirect costs have to be allocated by calculation rates. Referring to chapter 3.3.2.5, the basis for these rates is either unit- or value based.[88]

The following Table 3-3 illustrates the calculation of job costing schematically:

[85] Compare FREIDANK (1997), p. 167
[86] Compare FREIDANK (1997), p. 148
[87] Compare KEMMETMUELLER/BOGENSBERGER (2002), p. 237
[88] Compare FREIDANK (1997), p. 148

	Direct Material Costs
+	Indirect Material Costs
+	Direct production Costs
+	Indirect Production Costs
+	Special Direct Costs of Production, e.g. costs for tools and licenses
=	**Manufacturing Costs**
+	Administrative Indirect Costs
+	Selling Indirect Costs
+	Special Direct Costs of Sales, e.g. costs for the packaging of the goods
=	**Prime Costs**

Table 3-3 An Exemplary Calculation Scheme of Job Costing[89]

3.4 Cost Accounting Systems

Basically, cost accounting systems can be subdivided in terms of both, time relation and whether you follow a full costing or marginal costing approach.[90]

3.4.1 Full (Absorption) Costing

Generally speaking, traditional full costing is a past oriented costing approach, which proportionately allocates the total costs of a business to all created products (or services).[91] It can be concluded that the distribution of indirect costs to a certain product, however, might not correspond to the actual consumption.[92] Nevertheless, it can be concluded that the advantage of full costing, compared to marginal costing, is to offer the easier approach.

[89] Based on BRUEHL (2004), p. 123
[90] Compare DEIMEL/ISEMANN/MUELLER (2006), pp. 36-40
[91] Compare BRUEHL (2004), p. 490
[92] Compare GROH (2010), p. 167

3.4.2 Marginal Costing

The classification of variable and fixed costs is not only vital for understanding marginal costing it is also its basic principle. Referring to chapter 3.3.2.1, variable costs of a product are directly and proportionally affected by the output of the product while fixed costs remain constant.

The development of marginal costing can be explained by the weakness of full costing, not offering a separation of this cost pair. The main problem of full costing is consequently the impact fixed costs have on cost objects in cases of varying output. Since all cost objects carry together the fixed costs, a varying quantity significantly affects the calculated costs per unit.[93]

Marginal costing offers the possibility to sell a product for a price which, for sure, covers its variable costs but which do not cover the whole share of fixed costs for the product. The included profit in the price, however, already contributes to the overall fixed costs of the company. The underlying idea of marginal costing is, therefore, to focus on capacity and output as well as on the price situation on the market.[94]

Kemmetmueller and Bogensberger list the following practical examples of marginal costing:[95]

- Break-even Analysis
- Minimum Price
- Critical Output
- Key-value Analysis

It can be concluded that the examples above share the common fact that they are not sufficiently solvable by the classic approach of full costing. That leads to the main advantage in comparison, the possibility of classifying fix and variable costs and, therefore, the attachment of a cost object only by its variable costs (as the minimum e.g. minimum price method).[96]

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[93] Compare BRUEHL (2004), pp. 158-159
[94] Compare KEMMETMUELLER/BOGENSBERGER (2002), p. 207
[95] Compare KEMMETMUELLER/BOGENSBERGER (2002), pp. 242-260
[96] Compare DEIMEL/ISEMANN/MUELLER (2006), p. 40

3.4.3 Actual, Normal and Standard Costing

The further classification of whether the cost accounting approach is based on actual, normal or standard values is covered in this section.

3.4.3.1 Actual Costing

As the name suggests, actual costing is a costing approach, which is based on actual occurred costs of a previous accounting period.[97] This costing approach is, consequently, primarily used for verifying a calculation period afterwards. Furthermore, actual costing provides a comparison of two periods.

However, disadvantages occur from the fact, that fluctuations of costs cannot be considered. Carried-out cost control with actual costing seems therefore not reasonable because of missing planed values.[98]

Actual Costs = Actual Consumption x Actual Price

Equation 3-1 Actual Costs[99]

3.4.3.2 Normal Costing

Normal costing considers **the average of** previously occurring **multiple actual costs**, by taking at least two different periods into account. Thus, normal costing normalizes the fluctuation of values, mentioned as a disadvantage of actual costing. The combination with actual costing provides, consequently, a controlling instrument by analyzing the occurring differences.[100]

Normal Costs = (Actual Costs of Period 1 + Actual Costs of Period 2 + .. + Actual Costs of Period N) / N

Equation 3-2 Normal Costs[101]

3.4.3.3 Standard Costing

Standard costing calculates future, planned costs by the prediction based on actual costs.[102] Proper actual costing is, therefore, absolutely necessary for

[97] Compare STRAETER (2009), p 130
[98] Compare DEIMEL/ISEMANN/MUELLER (2006), pp. 37-38
[99] Based on KEMMETMUELLER/BOGENSBERGER (2002), p. 272
[100] Compare STRAETER (2009), p 130
[101] Own illustration
[102] Compare DEIMEL/ISEMANN/MUELLER (2006), p. 39

standard costing. Specifically, the combination of both congruent measures provides ideal cost control by the comparison of planned and actual values of price, output and costs.[103]

3.5 Holistic Cost Systems

The chapter holistic cost systems introduces the rather new overall cost approaches TCO and LCC. Of special interest is hereby the relationship and, respectively, the ratio of the purchase and the running costs.

In fact both, TCO and LCC, are instruments of the cost management, which can be used to analyze the total costs.[104] This chapter will therefore also clarify the differences and, if coherence is possible, the relationship between these two systems.

3.5.1 Total Cost of Ownership (TCO)

As the term suggests, TCO has to be a calculation model, which takes several cost factors of an ownership into account. Furthermore, since ownership implies the timeframe between starting to own something until not owning it anymore, it is obvious that the costs have to be considered over a certain period.

3.5.1.1 Definition

Ellram stated that TCO is “a complex approach which requires that the buying firm determines which costs it considers most important or significant in the acquisition, possession, use and subsequent disposition of a good or service.”[105] Consequently, this would mean that it is vital to consider all cost aspects of a product (or a service) during its lifetime and to identify the “most important” cost position. However, this does not necessarily imply that TCO also sums up the total costs of that product (or service).

Kraemer sees TCO primarily “as an instrument of the purchase management which aims to consider all occurring costs during the lifetime of a product, beside the price of the purchase.”[106] Furthermore, Kraemer states that the basis of

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[103] Compare KEMMETMUELLER/BOGENSBERGER (2002), p. 273
[104] Compare GLEISZDOERFER (2009), p. 17
[105] ELLRAM (1995), p. 4
[106] KRAEMER (2007), p. 9

the calculated monetary value has to be both, objective and reasonable data as well as the consideration of direct and indirect costs.[107]

Very interesting referring to this thesis is, moreover, the statement of Geiszdoerfer to consider the maintenance costs as a buy-decision for maintenance repair and operation (MRO) components, with the help of TCO.[108] [109] When dealing with components, which involve high maintenance effort, it is perfectly reasonable to identify and compare running costs with purchase costs, before purchasing it.

Since an RMG requires tremendous maintenance costs and, therefore, a big share of total costs,[110] this is definitely the "most important or significant" cost position, as Ellram stated before.

To conclude and formulate a definition in own words,

TCO is an instrument to identify and calculate the total costs of a product (or service) by considering all direct and indirect cost factors during the lifetime of this product (or service).

TCO is, additionally, a tool to determine a priority of importance of these costs.

3.5.1.2 Background

It seems very reasonable to identify other cost drivers beside the initial purchase costs and, moreover, the ration between initial and running costs. A refrigerator, for example, is usually chosen and bought for its attractive price. One might not consider the fact that a more expensive product has also most likely lower energy consumption and, consequently, fewer total costs after a certain timeframe.

In other words, a low price of purchase does not necessarily lead to low costs over the whole life cycle. In many industries the following costs are even five to ten times higher than the initial price of purchase.[111]

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[107] Compare KRAEMER (2007), p. 9
[108] Compare WOUTERS/ANDERSON/WYNSTRA (2005), p. 177
[109] Compare GLEISZDOERFER (2009), p. 36
[110] Compare chapter 1.3
[111] Compare GLEISZDOERFER (2009), pp. 1-2

To sum up, the basic idea of TCO is to provide the management of a purchasing company an instrument for making their decision of whether buying a product (or service) or not. Needless to say is the fact that TCO is, therefore, ideal to compare different offers.[112]

3.5.2 Life Cycle Cost (LCC)

The term LCC also stands for a holistic total cost approach of a product (or service). It is only logical that this method considers the costs of the product (or service) over its life cycle.[113]

3.5.2.1 Definition

According to Jackson and Ostrom, LCC is the „utilization of the concept involves identifying, quantifying, and evaluating all costs associated with ownership of a product.“[114] Even though this is a rather old source of the year 1980, it indicates the similarity, in that case even equality, to the concept TCO. Following Kraemer, two other authors confirmed this view of Jackson and Ostrom.[115] On the other hand, opinions aroused that it is necessary to distinguish between TCO and LCC, specifically, by defining LCC as a part of TCO.[116]

To sum up, LCC is basically a concept very similar to TCO, or at least strongly related. It identifies and considers also all cost factors over the life cycle of a product (or a service).

3.5.2.2 Background

As a consequence of the definition, it follows that the underlying ideas and origins are also very similar to the TCO's. As the term LCC already includes life cycle, however, it seems obvious that the different costs, according to the respective phases of the life cycle of a product (or a service), were also taken into account.[117]

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[112] Compare KRAEMER (2007), p. 6
[113] Compare chapter 3.5.3
[114] JACKSON/OSTROM (1980), p. 8
[115] Compare KRAEMER (2007), pp. 34-35
[116] Compare Table 3-4, p. 37
[117] Compare KRAEMER (2007), pp. 27-28

3.5.3 Total Cost of Ownership (TCO) versus Life Cycle Cost (LCC)

As previously mentioned, several different definitions of both, LCC and TCO, exist in literature. As a consequence, authors also have different opinions regarding the relationship and, furthermore, the differences of these two cost methods.

3.5.3.1 Existing Approaches in Literature

Referring to Geiszdoerfer, the following Table 3-4 displays the opinion of the authors regarding the relationship between TCO and LCC.

LCC = TCO	LCC = Part of TCO	TCO = Part of LCC
Heilala 2006	VDMA 2006	No sources found
White 2006	Ellram 2005	
Suttell 2005	*Kuenz 2010, chapter 3.5.3.2*	
Humphries 2004		

Table 3-4 Comparison of TCO and LCC Definitions in Literature[118]

Referring to Table 3-4 as well as to what Kraemer stated after her recherché in this field, the conclusion is twofold. Firstly, **LCC is either a part of TCO**, because it is not including the purchase costs **or** secondly, **LCC equals TCO**, providing only slightly differences in terms of the perspective. TCO is hereby the instrument exclusively seen from the perspective of the procurement party and, therefore, from the perspective of the customer. LCC offers in this regard also other points of view.[119] [120]

3.5.3.2 Approach for this Thesis

In respect to container cranes, which represent Kuenz's main business,[121] the company defines LCC as the following.

LCC comprises the costs, which occur during operation and, specifically, which are necessary to keep the system in a ready-to-operate state. By

[118] Based on GEISZDOERFER (2009), p. 20
[119] Compare GEISZDOERFER (2009), p. 20
[120] Compare KRAEMER (2007), pp. 34-36
[121] Compare chapter 2

this definition, LCC neither includes purchase or disposal costs nor the costs for electricity.[122]

This definition emphasizes especially the maintenance costs, which also play the major role in the thesis's calculation model.[123]

However, Kuenz's definition of TCO is congruent with the definition of the literature with the only exception of limiting the timeframe. TCO includes, identifies and considers, consequently, all costs during the given period of the system, instead of the whole lifetime. TCO evidentially includes, therefore, also the Kuenz LCC, as defined before.[124]

However, reason for limiting the timeframe is the fact that container cranes face a technology leap every 10 to 15 years and, therefore, the analogically limited timeframe of an economic reasonable full-maintenance contract.[125]

Ultimately, the TCO approach for this thesis results in the calculation of the key-value costs per TEU.[126] This happens by summing up all the costs of a given period and dividing them through the total TEUs of the same timeframe.[127]

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122 Conversation, Michael Geiger – Head of Sales, Kuenz (21/05/2010)
123 Compare chapter 4 and 5.
124 Conversation, Michael Geiger – Head of Sales, Kuenz (21/05/2010)
125 Conversation, Michael Geiger – Head of Sales, Kuenz (7/4/2010); Compare chapter 4.8.2.1
126 Compare chapter 1.3
127 Compare chapter 4.8.2

4 The Way to the Calculation Model

This chapter provides a periodic overview of the development process of the calculation model. Additionally, the following sections will inform about the basic idea behind the calculation model as well as about the major steps iteratively taken during the work.

4.1 Introduction

As the title of this thesis suggests, it was all about to create an appropriated model for the calculation of the total costs and, consequently, for the running costs of a container crane.

Considering the immense influence of the factor time on monetary means, due to interests and uncertainties, it is only logic that the initial costs are far easier to predict than the running costs. Moreover, the running costs of a container RMG are mainly consisting of maintenance costs, which, as the chapter will show, are especially hard to predict.

As a consequence, the initial costs, or more precisely, the costs of purchase have only marginal relevance in creating the model.[128] However, the TCO calculation, as the ultimate aim of this thesis, certainly includes the purchase costs and will be explained in detail in chapter 4.8.[129]

[128] Compare chapter 3.5.3
[129] In accordance to the working definition of chapter 3.5.3.2

4.1.1 Basic Idea for the Model

Due to the fact that Kuenz offers tailor-made high quality cranes, Kuenz RMGs are among the more expensive ones on the market. According to Michael Porter's three generic strategies, the company pursues a focus strategy, offering high-class products for demanding customers.[130] Consequently, this places Kuenz in the bottom on the left hand side of the following Porter illustration.

STRATEGIC ADVANTAGE		
	Outstanding Customer Benefits	Cost Advantage
Industry Wide	DIFFERENTIATION	OVERALL COST LEADERSHIP
Particular Segment Only	FOCUS	

Table 4-1 Porter Generic Strategies[131]

Therefore, the basic idea behind this calculation model is to successfully offer customers competitive full-maintenance contracts, as an additional incentive. That means that Kuenz fully maintains and equips the terminal for the clients for initially defined fees. As a consequence, it is absolutely necessary for Kuenz, as the provider of the contract, to have appropriated knowledge and proof of the upcoming costs.[132]

Additionally, a transparent cost structure will also aid in selling new cranes, because a higher purchase price does not automatically lead to higher overall costs.[133]

[130] Compare PORTER (1980), p. 38
[131] PORTER (1980), p. 39
[132] Conversation, Michael Geiger – Head of Sales, Kuenz (28/1/2010)
[133] Compare chapter 3.5.1.2

4.1.2 Maintenance Costs

As a container crane consists of numerous moving parts, the effort and thus, the costs for maintenance are tremendous.

The fact that a high variety of parts of different technologies are combined to one system makes it difficult to assess the overall maintenance costs. As each technology follows its own rules a lot of knowledge is necessary. Especially, the lifetime investigation of each component requires either a specialist in this very field or prefunded data of the manufacturer.[134]

As a consequence, the maintenance costs are the most crucial part in a running cost investigation and hence, in the total cost approach.

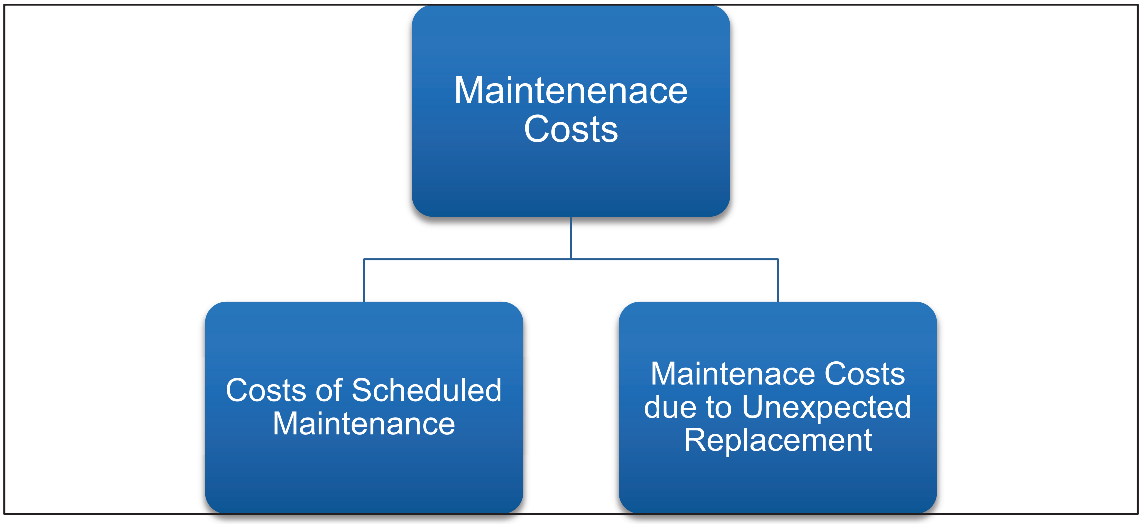

Figure 4-1 Maintenance Costs[135]

With respect to the predictability of occurrence, maintenance costs can be separated into two kinds of costs.[136] Referring to the calculation model, costs for scheduled maintenance and costs for unexpected replacement of parts are distinguished.

4.1.2.1 Scheduled Maintenance Costs

The calculation of scheduled maintenance costs is rather easy as the cost drivers occur in a regular manner, as for example due to periodical oil changes. Additionally, in cases of provided guarantee of suppliers, they have to set an

[134] Compare chapter 4.3.6.2

[135] Self-made figure

[136] Conversation, Wolfgang Fink – Head of Service, Kuenz (17/2/2010)

exact timeframe for exchange or refill of their components, which makes it even easier.

4.1.2.2 Maintenance Costs due to Unexpected Replacement

Contrarily, there is a type of maintenance costs, which is much more difficult to predict. As the name suggests, maintenance costs due to unexpected replacement occur in the case of unpredictable failure, malfunction or breakdown of a part. Thus, these costs are caused by the exchange of components as well as by preventive means to make provision against these kinds of unplanned breaks of operation.[137]

Since we have to deal with wear and tear by rotating and moving parts in general, the lifetime of these components is limited. Hence, in order to estimate the costs, it is necessary to predict how long each part will be fully functional and, furthermore, with which probability this part might possibly break down. Or likewise, if there are multiple parts of the same type in operation, it is essential to be able to predict how many of them will have to be exchanged because of malfunction.[138] [139]

Ultimately, to perform a total cost approach of a container crane the most crucial costs are the maintenance costs, which are caused by unexpected damage of parts. For this reason, the challenge of this thesis and hence, of developing the calculation model, is to determine these costs.

4.2 Begin of the Research

In order to create the requested model in MS Excel, it was necessary to become accustomed to the cranes in general. Therefore, the initial step implicated a detailed research activity to obtain information about the characteristics, dimensions as well as about the exact purpose and strategy of the cranes. Moreover, the location and hence, differences in construction and operating of the cranes, was of interest in this phase.

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[137] Conversation, Michael Geiger – Head of Sales, Kuenz (5/3/2010)

[138] Conversation, Michael Geiger – Head of Sales, Kuenz (9/12/2009)

[139] Compare chapter 4.3.10.2

4.2.1 Visiting Container Terminals in Basel and Werndorf

In the beginning of the work at Kuenz it was, therefore, perfectly reasonable to visit crane terminals to get a feeling for the dimensions and the critical parts. A customer's visit at the Rhenus Alpina AG terminal in Basel was, consequently, carried out as well as a visit of the Cargo Center Graz (CCG), which is operated by the „Steiermaerkische Landesbahnen“ (STLB).[140]

Figure 4-2 Terminal Basel[141] and CCG[142]

4.2.2 Cranes Representing the Basis for the Model

As numerous different Kuenz container cranes exist, the decision was necessary on which installations the calculation model should be based on. Specifically the question was, which crane's data and Bills of Material (BOM)[143] is suitable to represents the program it the best possible way.

Since the thesis should provide a tool for generating full-maintenance contracts for all kinds of Kuenz RMGs,[144] three different characteristic models were chosen.[145]

[140] Conversation, Wolfgang Fink – Head of Service, Kuenz (4/2/2010)
[141] Own photograph
[142] Kuenz: Sales Media Archive
[143] BOM = A complete list of an assembly's sub components. Each position contains information, as for example name of component, quantity, identification number and so on.
[144] Compare chapter 2.2.1
[145] Conversation, Michael Geiger – Head of Sales, Wolfgang Fink – Head of Service, Kuenz (3/2/2010)

- CCG: This is a terminal with two crane installations, located south of Graz. As Kuenz already operates a full-maintenance contract there, gained experiences are easily accessible.
- The Biggest Kuenz RMG Model
- An RMG Installed in a Major European Port

Different cranes mean most likely different suppliers, a varying number of wheels, engines and so on. Although the general structure in the BOM stays the same, this leads to multiple possible different combinations of how a future crane could be composed of.

According to chapter 1.3, the adaptability of the calculation model by choosing the supplier and other main characteristics is one of the requirements for the calculation model of the thesis.

4.3 Maintenance Costs due to Unexpected Replacement Sheet[146]

Since this MS Excel sheet is supposed to calculate the crucial part of the maintenance costs, it is both, a lot of work as well as the heart-piece of the calculation model.

4.3.1 Introduction

According to chapter 3.5.3.2, Kuenz defines LCC as all costs, which are necessary to keep the system in a ready-to-operate state during a given period of time. As a result, Kuenz LCC is congruent with the maintenance costs defined in chapter 4.1.2. Consequently, It was only logical to choose the same classification for the MS Excel model as for the maintenance costs, separated in, maintenance costs due to unexpected replacement and scheduled maintenance costs.

4.3.2 Data Acquisition

Once the three crane installations were fixed as a basis for the model,[147] the familiarization with the respective BOMs was the logical next step. This was

[146] Compare chapter 4.1.2.2 for the definition
[147] Compare chapter 4.2.2

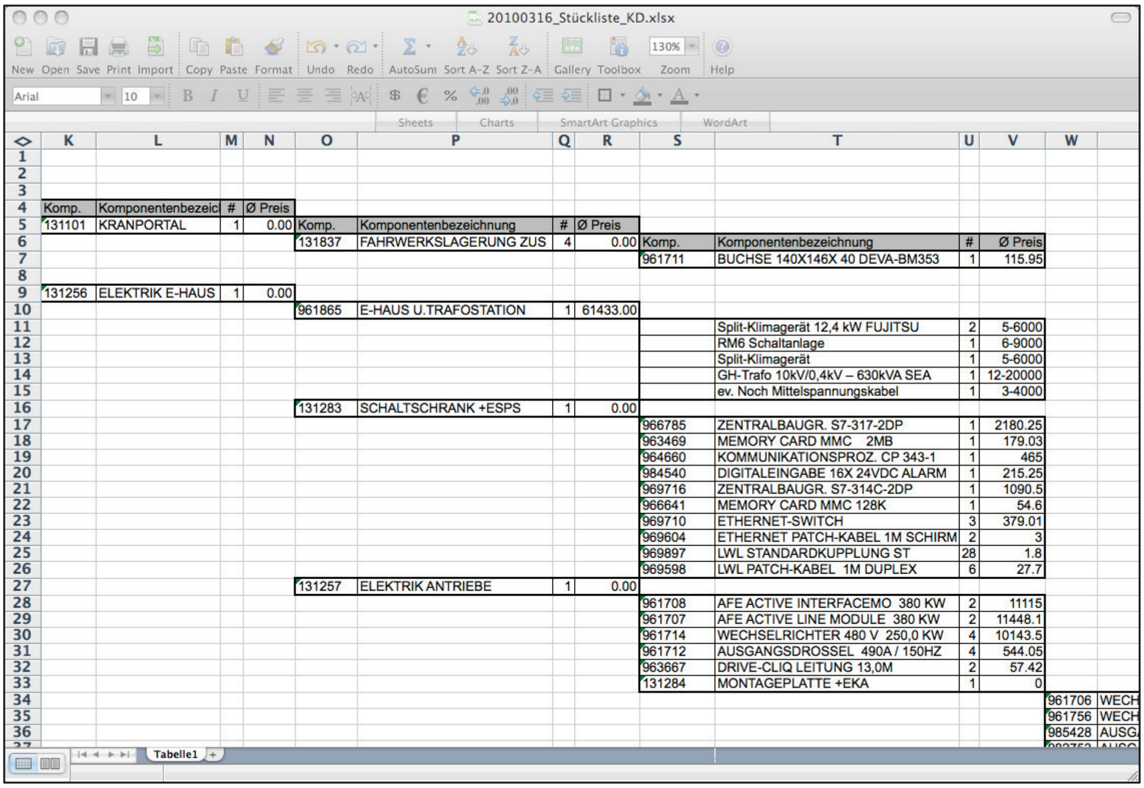
essential to understand the setup and composition of a container crane and, in regard to the chosen cranes, to make the first step towards the model.

4.3.2.1 Program PSIPenta

Kuenz uses the Enterprise Resource Planning (ERP) software PSIPenta to manage and organize all kinds of data required for daily business and projects. The program also contains all BOMs of the Kuenz projects and was, therefore, the most important data source for the calculation model.

4.3.2.2 Implementation in Microsoft (MS) Excel

The first steps included the unfolding and understanding of the BOM provided by PSIPenta as well as the implementation of the data in a MS Excel BOM. The underlying reason was, that the structure of a BOM is laid out more clearly, if composed at **one** MS Excel sheet, even though there were more then 2.000 rows on the MS Excel sheet. However, it is easier to understand and illustrate a BOM in form of a one-page structure-tree, than page by page in the ERP program.



	K	L	M	N	O	P	Q	R	S	T	U	V	W	
1														
2														
3														
4	Komp.	Komponentenbezeic	#	Ø Preis										
5	131101	KRANPORTAL	1	0.00	Komp.	Komponentenbezeichnung	#	Ø Preis						
6					131837	FAHRWERKSLAGERUNG ZUS	4	0.00	Komp.	Komponentenbezeichnung	#	Ø Preis		
7									961711	BUCHSE 140X146X 40 DEVA-BM353	1	115.95		
8														
9	131256	ELEKTRIK E-HAUS	1	0.00										
10					961865	E-HAUS U.TRAFOSTATION	1	61433.00						
11										Split-Klimagerät 12,4 kW FUJITSU	2	5-6000		
12										RM6 Schaltanlage	1	6-9000		
13										Split-Klimagerät	1	5-6000		
14										GH-Trafo 10kV/0,4kV – 630kVA SEA	1	12-20000		
15										ev. Noch Mittelspannungskabel	1	3-4000		
16					131283	SCHALTSCHRANK +ESPS	1	0.00						
17									966785	ZENTRALBAUGR. S7-317-2DP	1	2180.25		
18									963469	MEMORY CARD MMC 2MB	1	179.03		
19									964660	KOMMUNIKATIONSPROZ. CP 343-1	1	465		
20									984540	DIGITALEINGABE 16X 24VDC ALARM	1	215.25		
21									969716	ZENTRALBAUGR. S7-314C-2DP	1	1090.5		
22									966641	MEMORY CARD MMC 128K	1	54.6		
23									969710	ETHERNET-SWITCH	3	379.01		
24									969604	ETHERNET PATCH-KABEL 1M SCHIRM	2	3		
25									969897	LWL STANDARDKUPPLUNG ST	28	1.8		
26									969598	LWL PATCH-KABEL 1M DUPLEX	6	27.7		
27					131257	ELEKTRIK ANTRIEBE	1	0.00						
28									961708	AFE ACTIVE INTERFACEMO 380 KW	2	11115		
29									961707	AFE ACTIVE LINE MODULE 380 KW	2	11448.1		
30									961714	WECHSELRICHTER 480 V 250,0 KW	4	10143.5		
31									961712	AUSGANGSDROSSEL 490A / 150HZ	4	544.05		
32									963667	DRIVE-CLIQ LEITUNG 13,0M	2	57.42		
33									131284	MONTAGEPLATTE +EKA	1	0		
34													961706	WECH
35													961756	WECH
36													985428	AUSG

Figure 4-3 Structured BOM in MS Excel

In the unfolded structured BOM, shown in Figure 4-3, the horizontal steps represent the different levels of hierarchy. The four columns of each position, hereby, indicate identification-number, name, quantity and price of the respective component. It follows that the overall quantity of a given part, is the local quantity multiplied with the quantity of the subordinated group, and so forth.

4.3.3 Considered Parts

As already mentioned in chapter 4.1.2, the prediction of the running costs is crucial and difficult. One reason, therefore, was the selection of the parts, as this chapter will show.

A LCC investigation requires considering just those parts, which actually create costs in the same period.[148] However, costs caused by regular and planned maintenance are considered and explained separately in chapter 4.4. As a consequence, the aim of the structured BOM, introduced in chapter 4.3.2.2, is to include just parts, which are not supposed to last ten years. It can be concluded that the questioned components are those, which cause maintenance costs due to unplanned replacement, indicated in chapter 4.1.2.2.

Basically, there are two ways to consider whether a certain element lasts these ten years, or not. Required are, therefore, either experienced values or a fundamental calculation.[149]

4.3.3.1 Measures to Shorten the Bill of Material (BOM)

In regard to the previous chapter, the process of eliminating all the components, which are supposed to last ten years and more, shortened the list; for example, by removing solid parts of the steel structure, which should, if well constructed, persist forever.[150]

Additionally, components, which are too small regarding their monetary amount, could be eliminated from the BOM. Reason for that is the marginal impact on the result as well as the reduction of elements in the list. However, these parts, such as standardized screws and washers, can be considered as a lump sum afterwards.[151]

[148] Compare chapter 3.5.3.2
[149] Conversation, Peter Lerchmueller – Engineering, Kuenz (10/2/2010)
[150] Conversation, Georg Schuch – CTO, Kuenz (5/3/2010)
[151] Conversation, Wolfgang Fink – Head of Service, Kuenz (8/2/2010)

Nevertheless it needs to be mentioned, that the changing activity of a “cheep part” could result in high costs due to the necessary exchange time for the service technician or required auxiliary equipment (AE). The process of eliminating “cheap parts” was, therefore, ongoing and carried out parallel to the estimation of the depending exchange times.[152]

Especially during this phase of work, the support of the Kuenz service department was invaluable and absolutely necessary for the progress of the work. Consequently, it was possible to pre-select the majority of the parts. In regard to the selection criteria of a 10 years lifetime, however, several questionable parts were left, which could not be immediately assigned in the first place.

4.3.3.2 Questionable Parts

Particularly electrical parts were hard to assess, as the wear and tear patterns of these components are not obvious. It was therefore necessary to consult the electrics department to modify the BOM from an electrical and electromechanical point of view. Questionable electrical parts, however, are components affected either by wear and tear or malfunction.[153]

Mechanical specialists on the other hand, verified questionable components, such as big bolts and ball bearings.

4.3.4 One Basic Bill of Material (BOM)

The next step towards the calculation model was the process of joining the BOMs of the three characteristic cranes to one basic BOM. Needless to say is the fact that the different cranes had partly different components and assemblies in the BOM. Whenever there was a difference in the structure, the other option was inserted in the basic BOM as well.

However, Only the two most important variants/suppliers, in cases of three or more options, were considered.[154] [155]

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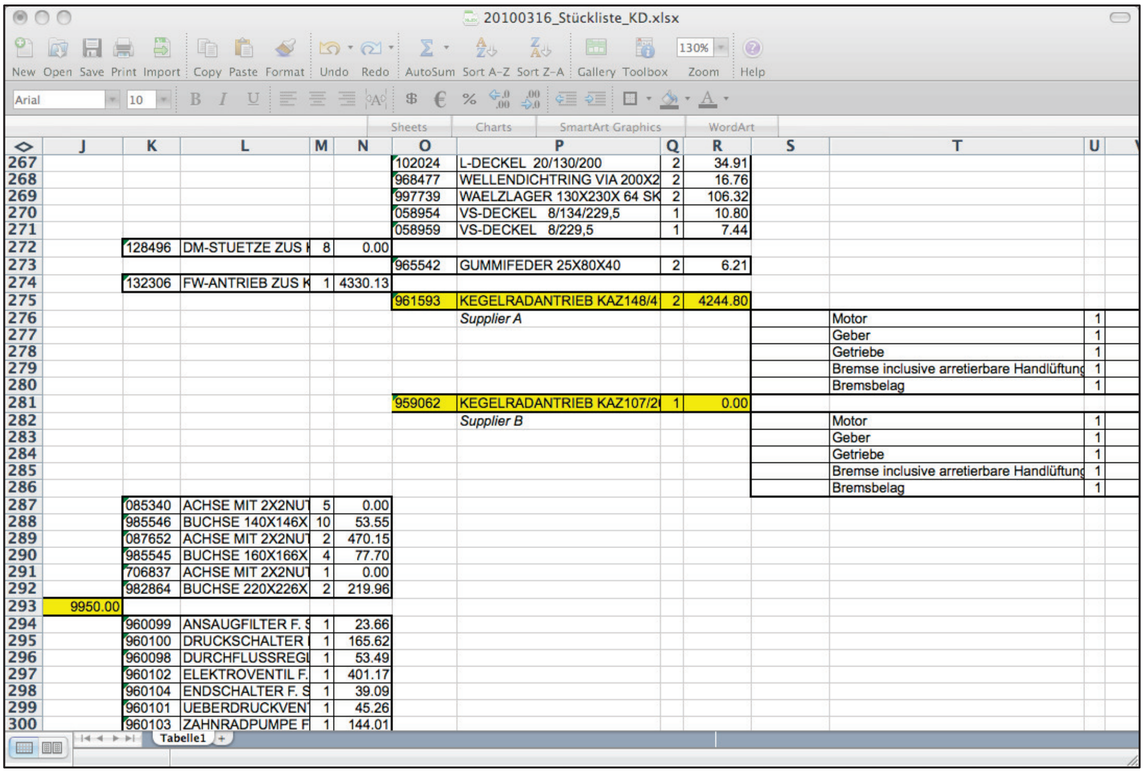
[152] Compare chapter 4.3.6.2

[153] Conversation, Werner Buechele – Electronics, Kuenz (19/2/2010)

[154] <u>Explanation</u>: Three possible options due to three different cranes as a maximum, but technically more than three potential suppliers on the market.

[155] Conversation, Wolfgang Fink – Head of Service, Kuenz (19/2/2010)



	J	K	L	M	N	O	P	Q	R	S	T	U
267						102024	L-DECKEL 20/130/200	2	34.91			
268						968477	WELLENDICHTRING VIA 200X2	2	16.76			
269						997739	WAELZLAGER 130X230X 64 SK	2	106.32			
270						058954	VS-DECKEL 8/134/229,5	1	10.80			
271						058959	VS-DECKEL 8/229,5	1	7.44			
272		128496	DM-STUETZE ZUS K	8	0.00							
273						965542	GUMMIFEDER 25X80X40	2	6.21			
274		132306	FW-ANTRIEB ZUS K	1	4330.13							
275						961593	KEGELRADANTRIEB KAZ148/4	2	4244.80			
276							*Supplier A*				Motor	1
277											Geber	1
278											Getriebe	1
279											Bremse inclusive arretierbare Handlüftung	1
280											Bremsbelag	1
281						959062	KEGELRADANTRIEB KAZ107/2(	1	0.00			
282							*Supplier B*				Motor	1
283											Geber	1
284											Getriebe	1
285											Bremse inclusive arretierbare Handlüftung	1
286											Bremsbelag	1
287		085340	ACHSE MIT 2X2NUT	5	0.00							
288		985546	BUCHSE 140X146X	10	53.55							
289		087652	ACHSE MIT 2X2NUT	2	470.15							
290		985545	BUCHSE 160X166X	4	77.70							
291		706837	ACHSE MIT 2X2NUT	1	0.00							
292		982864	BUCHSE 220X226X	2	219.96							
293	9950.00											
294		960099	ANSAUGFILTER F. S	1	23.66							
295		960100	DRUCKSCHALTER	1	165.62							
296		960098	DURCHFLUSSREGL	1	53.49							
297		960102	ELEKTROVENTIL F.	1	401.17							
298		960104	ENDSCHALTER F. S	1	39.09							
299		960101	UEBERDRUCKVENT	1	45.26							
300		960103	ZAHNRADPUMPE F	1	144.01							

Figure 4-4 Different Options of an Assembly in the Structured BOM

As Figure 4-4 illustrates, two possible suppliers for a drive unit exist. The component assemblies are hereby vertically arranged to have one row dedicated for each part. This measure made navigation, in general, and especially the programming easier afterwards.[156]

4.3.4.1 Assistance of the Purchase Department

Unfortunately, since many assembly groups are procured as one order from the supplier, the PSIPenta systems also displays just one price for the assembly, respectively.[157] However, in the case of damage concerning only a sub-part of the assembly it is also necessary to only change exactly this part. Moreover, since the BOM was created with the PSIPenta software, also the BOMs of these assemblies were missing.

Required were, consequently, both, the BOM of the purchased assemblies and the prices of each sub-part.

A meeting with the purchase department was, therefore, initiated to address these requirements. With a result that the contacts of the respective supplier

[156] Compare chapter 4.5.2.3

[157] Conversation, Wolfgang Fink – Head of Service, Kuenz (8/2/2010)

were obtained as well as that the purchase department provided assistance during the process of obtaining the data.

The following list indicates the relevant crane modules:

- E-housing
- Supply Cable Chain
- Flexible Cable Tray
- Cable Drum
- Bevel Gear Drive
- Rail Tongs
- Disk Break
- Engine of the Rotating Mechanism
- Crane Cabin
- Control Unit
- Spreader

4.3.4.2 Contact with Suppliers

Besides asking for the BOMs and the prices for the single parts, the opportunity was also used for getting information about the lifetime of these components. Although the majority of necessary data was given, the values regarding lifetime were rather approximated than precise. Specifically, supplier representatives tend to be rather too optimistic concerning lifetime of their parts, compared to the experience Kuenz technicians have made.[158]

4.3.5 Operation Hours (OH) Instead of Years as the Basis

After figuring out the relevant parts, the even bigger question was the lifetime of each component. Initially and as previously mentioned, the decision was to use a timescale based on years, since the customer wants to know what the annual costs are. Nonetheless, in due course of developing the calculation model, a timescale based on OH of the main contactor turned out as more promising. Specifically, the new approach was to use OH as the framework for the calculation, while the conversion into years should follow afterwards.[159]

[158] Conversation, Wolfgang Fink – Head of Service, Kuenz (2/3/2010)

[159] Conversation, Michael Geiger – Head of Sales, Wolfgang Fink – Head of Service, Kuenz (5/3/2010)

The basic idea of using OH as the timescale is that the relevant parts also suffer as a function of the OH. Time also influences lifetime, due to the weight of the construction, but there is no comparison to the complex burden under load and movement.[160]

4.3.5.1 Advantages of a Timescale based on OH

Another reason for using OH as the framework are possible significant differences in OH per year. Especially in the first year of a terminal, the number of OH is usually quite low, because of marginal utilization and thus, low workload. In addition, an economic crisis, for example, could also influence the OH as well as a favorable usage of one crane in a multi-crane terminal.[161]

4.3.5.2 Time Incremental for the Investigation: 4.000 OH of the Main Contactor

An incremental of 4.000 OH represents the average OH of the main contactor per year over the lifetime of a container RMG.[162]

However, the question is why an incremental at all?

It was necessary to create a matrix with **rows and columns, because of two variables** per component, **costs and lifetime**. To consider therefore the point of time when the costs actually occur made it necessary to separate the time in sub-periods.

[160] Conversation, Wolfgang Fink – Head of Service, Kuenz (5/3/2010)

[161] Conversation, Michael Geiger – Head of Sales, Wolfgang Fink – Head of Service, Kuenz (5/3/2010)

[162] Conversation, Wolfgang Fink – Head of Service, Kuenz (5/3/2010)

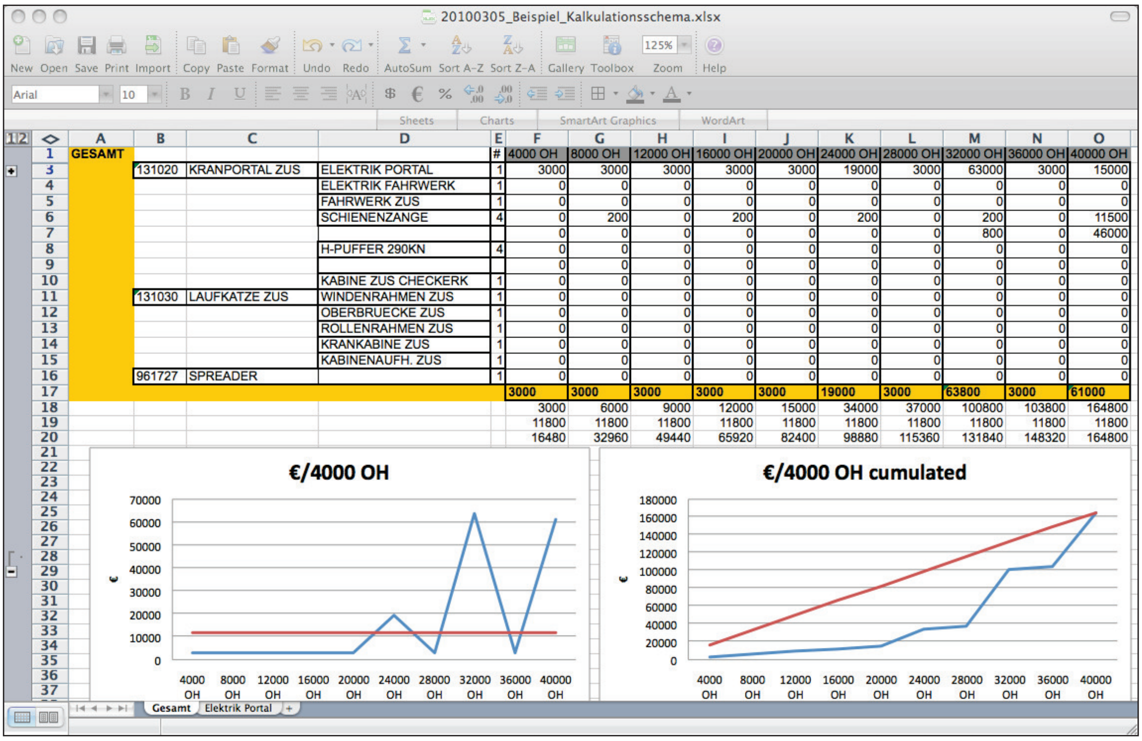


Figure 4-5 An Exemplary OH-matrix

Figure 4-5 illustrates this matrix schematically: The columns represent the 4.000 OH periods, while each row is dedicated for one component. As visible in the diagrams at the bottom, the exemplary costs occur mainly in the later 4.000 OH-periods and the average costs per year (red graph, left diagram: average per year over 10 years) leads to high costs in the beginning, even though they were mainly caused in the later periods.

Although the initial idea was to investigate the costs over 10 years,[163] the adaption towards OH also includes the change to a longer investigation timeframe of 52.000 OH. In refer to the 4.000 OH-intervals that would, consequently, lead to 13 years of operation. The reason for the longer timeframe, however, is to strategically investigate the cost development and thus, to find the ideal length for a full-maintenance contract.[164]

Additionally, an extended timeframe could also aid in considering terminals, which operate significantly more than 4.000 OH per year.[165]

[163] Compare chapter 1.3

[164] Conversation, Wolfgang Fink – Head of Service, Christian Immler – Service, Kuenz (17/3/2010)

[165] Conversation, Wolfgang Fink – Head of Service, Kuenz (17/3/2010)

Ultimately, the idea behind this scheme was to sum up each 4.000 OH-interval at the end of the MS Excel. This would finally lead to the sum of how much the crane costs per each 4.000 OH-period, due to maintenance of unexpected exchange.

4.3.6 Required Data

At this point, the relevant parts were arranged in a structure and combined with the framework of the OH-matrix. In order to get the required information and also to have a hierarchy in regard to the importance of this information, the following order was planned:[166]

1. Own experiences in form of already existing Kuenz full-maintenance contracts, as for example, carried out at the CCG Terminal and the practical experiences Kuenz service technicians have made in maintaining Kuenz container cranes.
2. The data of crane operators or service companies, which are in charge of maintaining Kuenz cranes.
3. The knowledge of suppliers and manufacturers of the relevant parts.

As previously mentioned, suppliers tend to be rather too optimistic than realistic if asked for the lifetime of their products. This reason and also the fact that practical values are of course more suitable for the calculation model, lead to the priority above.[167]

4.3.6.1 Data of Existing Full-maintenance Contracts

In accordance to the hierarchy of information of the previous chapter, the data of Kuenz's full-maintenance contracts were implemented in the first step. In this case it was of great advantage that regarding these terminals both was known, the OH per year as well as the quantity of parts changed. Whenever an element was changed, it was consequently considered by marking the respective 4.000 OH-period as well as by adding a note regarding the changed quantity.

[166] Conversation, Wolfgang Fink – Head of Service, Christian Immler – Service, Kuenz (17/3/2010)

[167] Conversation, Wolfgang Fink – Head of Service, Christian Immler – Service, Kuenz (17/3/2010)

Interestingly, unexpected parts occurred which have not been present in the BOM so far. It was therefore necessary to either find a corresponding similar element or consider it in a new row.

Unfortunately, many rows in the OH-matrix were still without information after this process. Since the existing full-maintenance contracts were rather young, many initial parts were still in use, even though, they would not last for 52.000 OH.[168] As a consequence, it was necessary to arrange a meeting with the Kuenz service specialists in order to address these issues.

4.3.6.2 Data of Kuenz Service Personnel

Since the service technicians have worked many years as crane service specialists for Kuenz, they have gained a lot of experience in this field. However, as the form had about 1.000 rows at this point, it would take some time to get the required information. For this reason, the already filled-out Figure 4-6 from a later stage shall be used to explain this process in more detail.

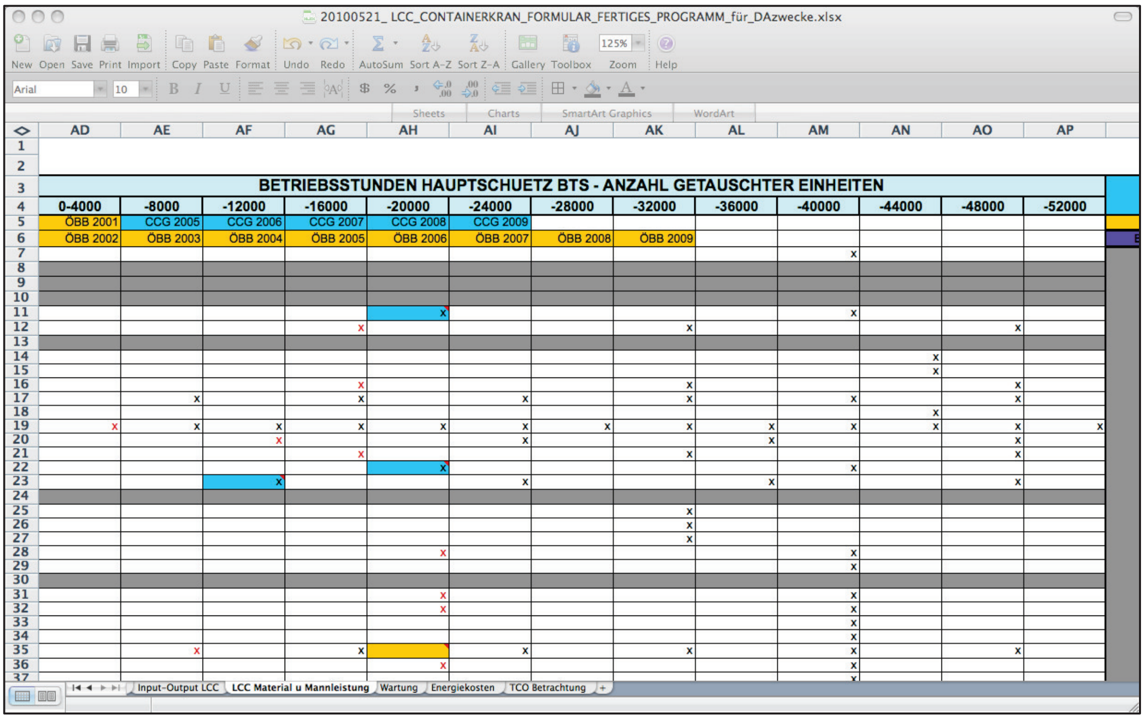


Figure 4-6 Lifetime Data filled in with "x"[169]

[168] Conversation, Wolfgang Fink – Head of Service, Kuenz (22/3/2010)

[169] Color blue and yellow indicate the experience of existing full-maintenance contracts; compare chapter 4.3.6.1

Figure 4-6 illustrates the way of how the Kuenz service technicians have entered their experience regarding lifetime of each component. Hereby, a cell marked with “x” means that it is most likely that the respective part has to be changed in this very OH-period, indicated by the column where the “x“ is located. For example, if the second 4.000 OH-column is marked with “x” the practical lifetime of the component is in between 4.000 and 8.000 OH. Needless to say is the fact that the assumption regarding the lifetime data is normal circumstances.[170]

Furthermore, the service department came up with the great idea to implement columns for the AE, required additionally to change the components. For instance, to change a heavy part you might need a forklift truck or even a mobile crane. And for the exchange of a lamp on an elevated position, for example, a lifting platform is required.[171]

Additionally, the times of how long the AE is needed were required as well as how long the service technician needs to change one unit of this part in general.[172]

Accordingly, the following columns were added to the form, each dedicated to a time in hours and per one unit of the respective component:[173]

- The Time a Service Technician Needs to Change the Part: This is the time-span beginning with the occurrence of the malfunction alarm until the part is changed. Assumptions are that both, the technician and the required material are on-site.

And the required time of the following AEs (if needed):

- Mobile Crane: with five tones and 35 meter reach ability
- Lifting Platform: with an reachable height of 35 meters
- Fork-lift Truck: capable to lift two tones

Figure 4-7 shows, hereby, the additional columns located centrally between the price of material and the OH-matrix (columns X-AA).

[170] Compare chapter 5.1 – „Assumptions for the Calculation Model“
[171] Conversation, Christian Immler – Service, Kuenz (17/3/2010)
[172] Conversation, Christian Immler – Service, Kuenz (17/3/2010)
[173] Conversation, Wolfgang Fink – Head of Service, Christian Immler – Service, Oliver Neier – Service, Kuenz (17/3/2010)

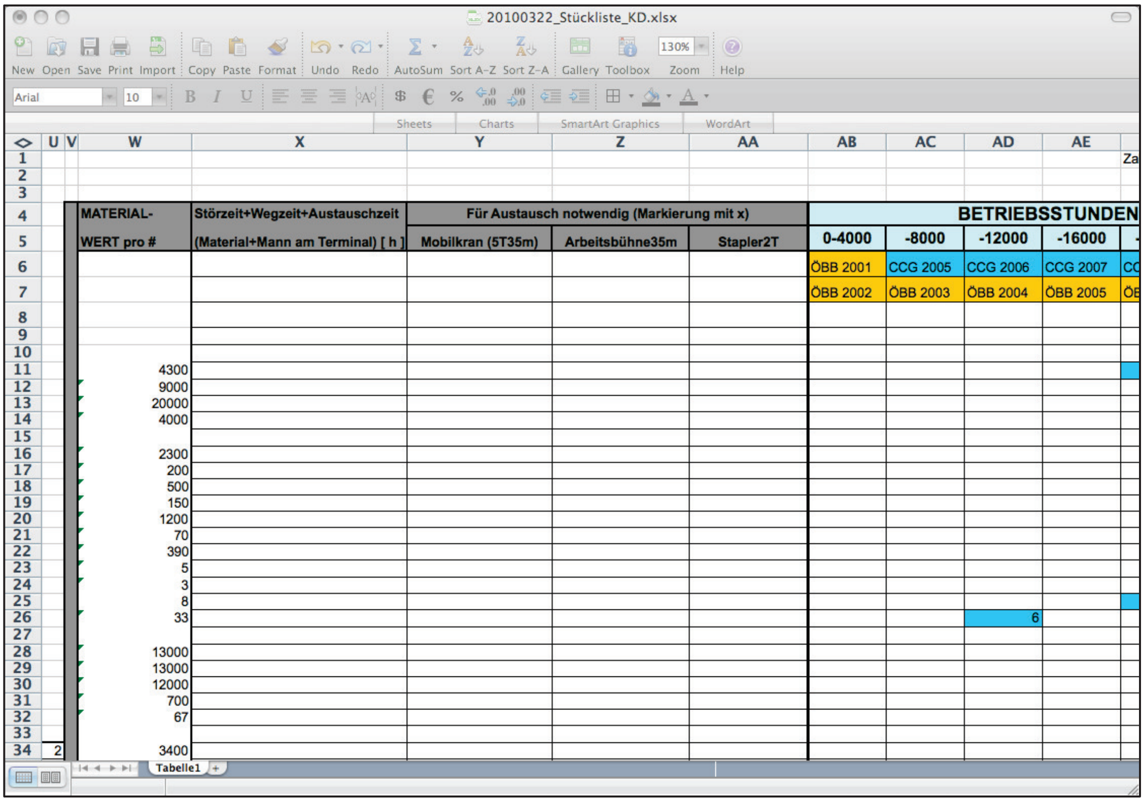


Figure 4-7 Additional Columns for the Required Exchange Times

The basic idea of implementing the additional columns was, to collect the experiences of the Kuenz service personnel regarding the previously specified times. Afterwards, it was possible to connect the times with hourly wage-rates and to add it to the material costs in order to know what one exchange of a part actually costs.[174]

4.3.6.3 Data of Service Companies

Information and data from service companies were, unfortunately, hard to get. Although crane operators were willing to cooperate, they still were not allowed to pass the complete maintenance files of the cranes. However, since the experience of Kuenz was provided as well as the information of the suppliers, the calculation model had a sufficient basis.[175]

4.3.6.4 Data of Supplier

As previously mentioned the lifetime information about parts provided by the suppliers was rather too optimistic compared to the practical values. Neverthe-

[174] Conversation, Wolfgang Fink – Head of Service, Christian Immler – Service, Kuenz (17/3/2010)

[175] Conversation, Wolfgang Fink – Head of Service, Kuenz (7/4/2010)

less, useful input and suggestions for the model were given as well as all the required purchase costs and BOMs.

4.3.7 Operation Hour (OH) Ratio between the Axis

Since the time fragments were changed from years to 4.000 OH-intervals,[176] it was also necessary to introduce a ratio between the crane's axes. Setting up such a collective is required for bringing the minor axes on the same basis as the major axis, which is defined by OH of the main conductor.[177]

Basically the following axis exist on a container RMG:[178]

- Hoisting Gear
- Trolley Carriage
- Rotating Mechanism
- Crane Carriage

To demonstrate, a component, which is part of the crane carriage, is only those OH under full load, the crane carriage actually moves. The main conductor counts the OH, however, from switching the crane on until switching the crane off. [179]

OH COLLECTIVE BASIS MAIN CONDUCTOR = 1.000	
BTS HOISTING GEAR	0.527
BTS TROLLEY CARRIAGE	0.328
BTS ROTATING MECHANISM	0.048
BTS CRANE CARRIAGE	0.499

Figure 4-8 Factors of the Crane's Axis

Figure 4-8 shows the average OH-collective of the CCG. To illustrate these factors above, 1.000 OH of the main conductor would mean at the same time 499 OH of the crane carriage.

[176] Compare chapter 4.3.5

[177] Conversation, Michael Geiger – Head of Sales, Kuenz (3/3/2010)

[178] Compare chapter 2.3

[179] Conversation, Michael Geiger – Head of Sales, Kuenz (3/3/2010)

4.3.8 Hourly Wage-rates

In order to further prepare the MS Excel sheet for the calculation, it was necessary to define and calculate certain hourly wage-rates. As the customer service department had filled in times, required for exchanging the parts, the wage-rates were also needed to sum up the costs per part. Referring to chapter 4.3.6.2, the columns for the exchange times were added to the OH-matrix and filled out with the data submitted by the Kuenz service technicians.

As a consequence, the hourly wage-rates were needed for the following categories:[180]

- Service Personnel: in charge of maintaining the crane. Assumption again is that the technician is on-site.

AE necessary for changing certain parts:

- Mobile Crane: with five tones and 35 meters reach ability
- Lifting Platform: with an reachable height of 35 meters
- Fork-lift Truck: capable to lift two tones

Moreover, also required were the flat-charges for the transportation of the three AE above.[181]

4.3.8.1 Service Personnel

A service company has to be on-site, or at least near by the terminal, to fulfill the requirements for a full-maintenance contract.[182]

In order to get a general value for the calculation, both was considered, the Kuenz hourly wage-rate for the service personnel as well as those from operators and maintenance companies. Accordingly, the wage-rates of Crane Tech, „the leading provider of training and related services in the material handling industry“[183], and of the STLB[184] were taken into consideration.

Ultimately, the received data were taken into account as the mean value, representing the basis for the calculation model. However, in order to calculate

[180] Compare chapter 4.3.6.2
[181] Conversation, Gerald Winter – Logistics, Kuenz (30/4/2010)
[182] Conversation, Wolfgang Fink – Head of Service, Kuenz (28/4/2010)
[183] www.cranetech.com (16/10/2010)
[184] The STLB are maintaining the CCG terminal for Kuenz

a specific contract afterwards, the value might be specified towards the circumstances of the crane.

4.3.8.2 Support from the Logistics Department

The logistics department provided the required values for the AE. Moreover, also the idea to separately consider and thus, implement the flat-charges for the transport was suggested by the department. Specifically, operations in Austria, Belgium, North-Germany and the Ruhr-region were considered for the mean values of the wage-rates and flat-rates of the AE.[185]

The orange boxes on the top of the following Figure 4-9 indicate the values for the hourly wage-rates. Specifically, the upper row indicates hereby the hourly wage-rates for the AE, while the lower row represents the flat-rates for the transport of the AE.

As a consequence, the costs for changing one part are the sum of the material costs, the time of changing this part multiplied with the respective wage-rate plus the same procedure for the AE; plus adding the flat-charge for the roundtrip to the terminal.

4.3.9 Kuenz Prime Costs

In order to not only consider the material costs, it was necessary to get and implement the Kuenz prime costs for each position.[186] The definition as well as the explanation of prime costs can be found in chapter 3.3.3.4.[187]

The controlling department provided hereby the calculation of the Kuenz prime costs by taking the already implemented material costs of the program PSI Penta as the basis.

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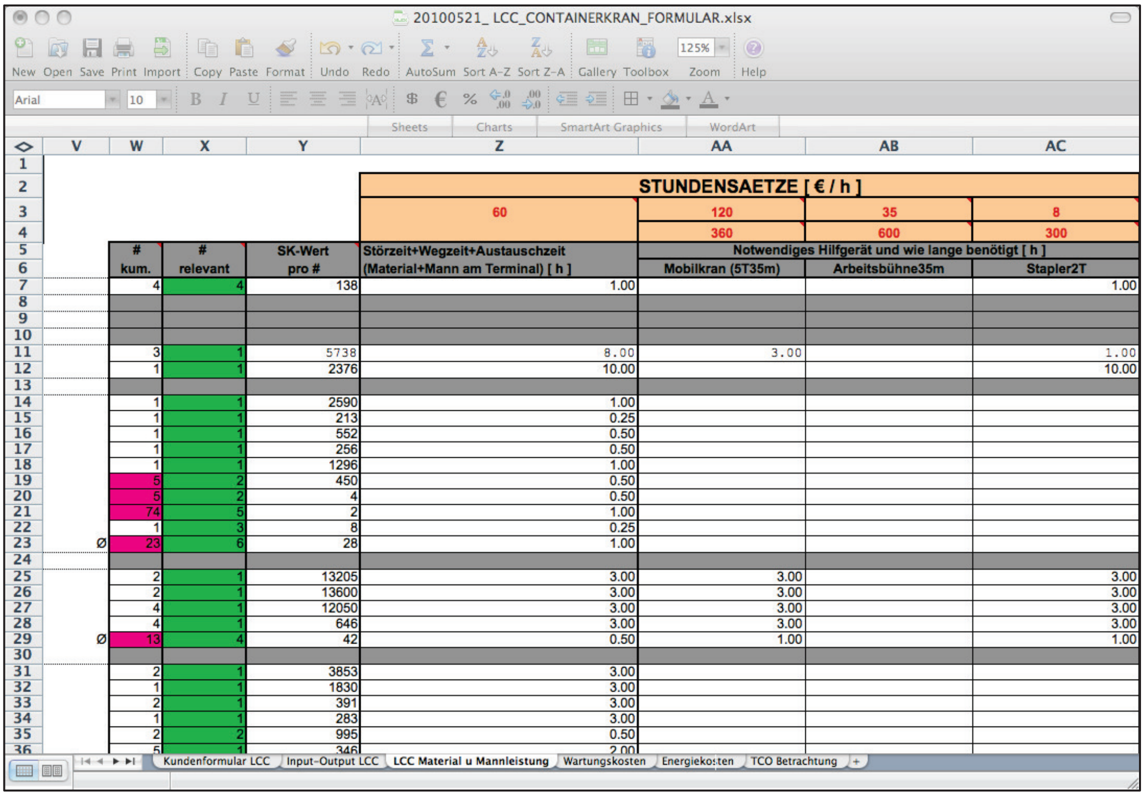
[185] Conversation, Gerald Winter – Logistics, Kuenz (30/4/2010)

[186] Conversation, Artur Rauter – Head of Controlling, Kuenz (14/4/2010)

[187] Compare Table 3-3, p. 31



	V	W	X	Y	Z	AA	AB	AC
1								
2					STUNDENSAETZE [€ / h]			
3					60	120	35	8
4						360	600	300
5		#	#	SK-Wert	Störzeit+Wegzeit+Austauschzeit	Notwendiges Hilfgerät und wie lange benötigt [h]		
6		kum.	relevant	pro #	(Material+Mann am Terminal) [h]	Mobilkran (5T35m)	Arbeitsbühne35m	Stapler2T
7		4	4	138	1.00			1.00
8								
9								
10								
11		3	1	5738	8.00	3.00		1.00
12		1	1	2376	10.00			10.00
13								
14		1	1	2590	1.00			
15		1	1	213	0.25			
16		1	1	552	0.50			
17		1	1	256	0.50			
18		1	1	1296	1.00			
19		5	2	450	0.50			
20		5	2	4	0.50			
21		74	5	2	1.00			
22		1	3	8	0.25			
23	Ø	23	6	28	1.00			
24								
25		2	1	13205	3.00	3.00		3.00
26		2	1	13600	3.00	3.00		3.00
27		4	1	12050	3.00	3.00		3.00
28		4	1	646	3.00	3.00		3.00
29	Ø	13	4	42	0.50	1.00		1.00
30								
31		2	1	3853	3.00			
32		1	1	1830	3.00			
33		2	1	391	3.00			
34		1	1	283	3.00			
35		2	2	995	0.50			
36		5	1	346	2.00			

Figure 4-9 Prime Costs Instead of Material Costs

The column right besides the green column in Figure 4-9 (column Y) represents the former material costs column, which was changed to Kuenz prime costs.

4.3.10 Quantity of Parts Considered

Regardless whether exchange time or prime costs; everything so far was based on one unit of a certain part.[188] However, most of the parts occur more than one time in the crane's BOM. Therefore, it was necessary to cumulate the quantity of each element in regard to the superior structure.[189]

4.3.10.1 Quantity of Cumulated Parts

Due to the step-wise structure of the BOM implemented in the MS Excel sheet, the quantity of an element had to be firstly multiplied with the superior assembly, and so forth. In addition, it was possible to reduced the list and hence, the complexity, by merging the same components at one position. The following figure indicates the result of this process.

[188] Compare chapter 4.3.6.2 and 4.3.9

[189] Compare chapter 4.3.2.2

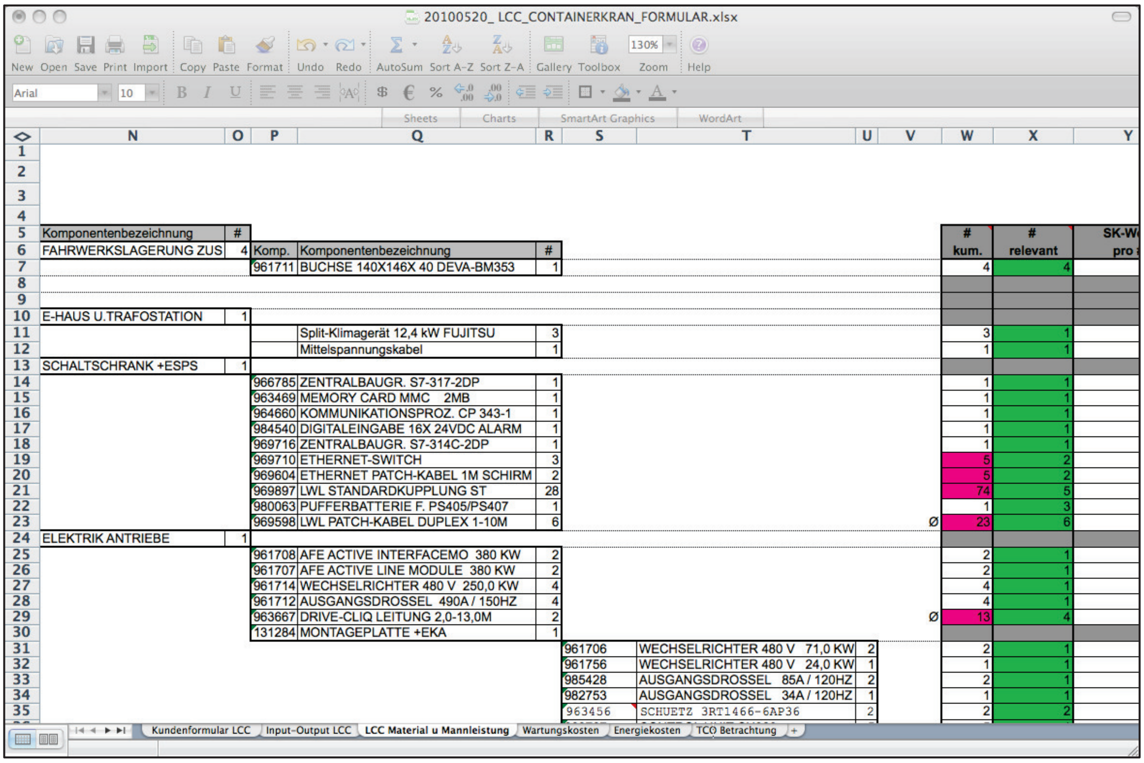


Figure 4-10 Quantity of the Cumulated Parts

The bush on the first position (Figure 4-10; line 7, column P-R) has a quantity of 1 per superior assembly, which on the other hand has a quantity of 4. Consequently, there are four bushes overall if there are no further assemblies with this bush in the BOM. As a result, the right column of Figure 4-10 (MS Excel line 7, column W) indicates the quantity of the bushes.

However, in cases of further assemblies containing the same element, the total number was counted and the quantity in the right column of the first part was changed, accordingly. Furthermore, as Figure 4-10 also points out, the respective positions were marked with the color pink, while the others rows were removed.

Nonetheless, the quantity, which should be considered for the calculation, was still not known.[190]

4.3.10.2 Quantity of Relevant Parts

With respect to the calculation, the number of each element that is actually considered has to be defined. Therefore, another column in the MS Excel sheet

[190] Compare chapter 4.1.2.2

was inserted for representing the quantities of each element, which will directly affect the calculation.

It is only logical that the number, filled into this column is somewhere in between the quantity of the cumulated parts and the quantity of one.[191] Figure 4-10 also shows this column, highlighted with the green color, positioned right of the column for the cumulated parts.

The same scheme of chapter 4.3.6 was followed, for obtaining the information of how many units of each part have to be considered for the calculation. The data of the Kuenz full-maintenance contracts were therefore investigated firstly. If something was changed there, the number of the parts was automatically known as well. The only difficulty, hereby, was the fact that the CCG terminal consists of two cranes and the maintenance documentation does not distinguish whether a component was changed at crane 1 or 2.[192]

For the remaining positions either the service department or the Kuenz service technicians could help with their rich experience.

4.3.11 Calculation

Multiple iteration steps characterized the calculation of this MS Excel sheet, maintenance costs due to unexpected replacement. Reason for that was the complexity on the one hand and ongoing gained knowledge on the other hand.

Therefore, this chapter will only introduce the first approach towards the first results overall. With respect to the chronology of events, changes and adaption of the calculation approach will be later on referred to.

4.3.11.1 Introduction

The basic idea was to calculate the sum of each 4.000 OH-period. This method combines two major advantages. Firstly, "costs per period" provides the information about the point of occurrence of the costs and the composition. Moreover, it enables an overview of the cost development and one might conclude until when it is economical feasible to carry out a full-maintenance contract.[193]

[191] Compare chapter 4.3.3 and 4.3.10.1

[192] Conversation, Gernot Rieger – Service, STLB (9/3/2010)

[193] Conversation, Guenther Bischof – CEO, Michael Geiger – Head of Sales, Kuenz (5/3/2010)

Consequently, it was necessary to know, which parts are supposed to be exchanged, and in which period.[194] Moreover, the costs,[195] quantity,[196] basic exchange time and the time of the AE,[197] if needed, and the hourly wage rates,[198] were required.

4.3.11.2 Formula

Referring to the previous chapter 4.3.11.1, a formula on MS Excel had to be generated, taking all these data into consideration. Consequently, the formula for every part and hence, for every single row, had the following composition.

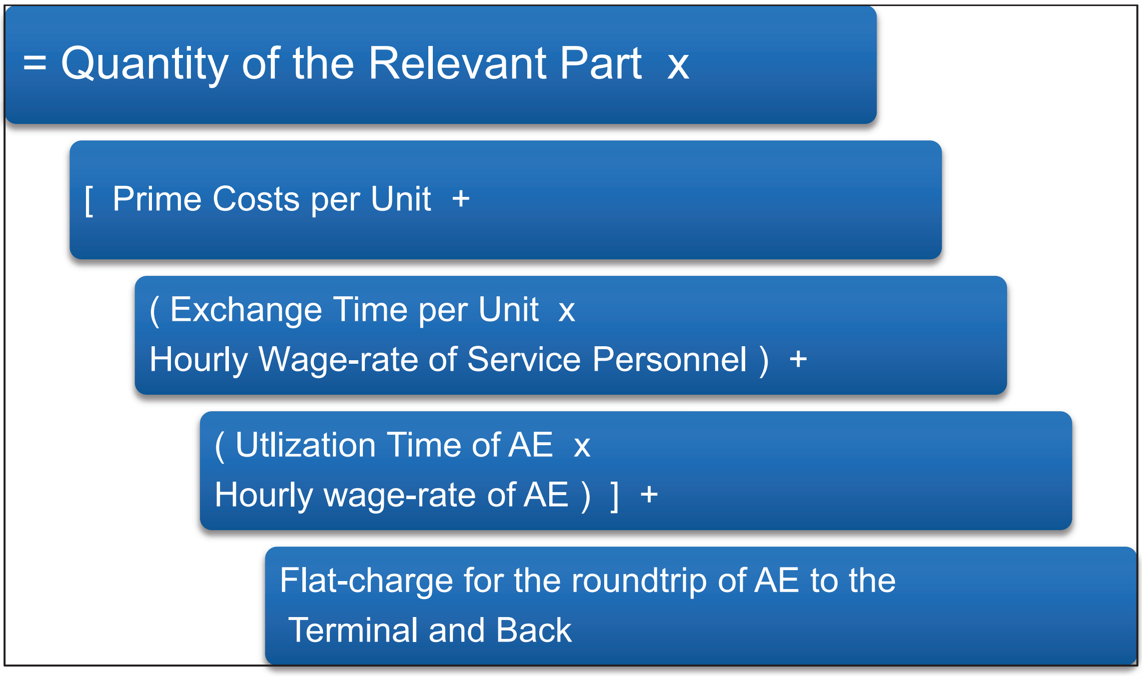
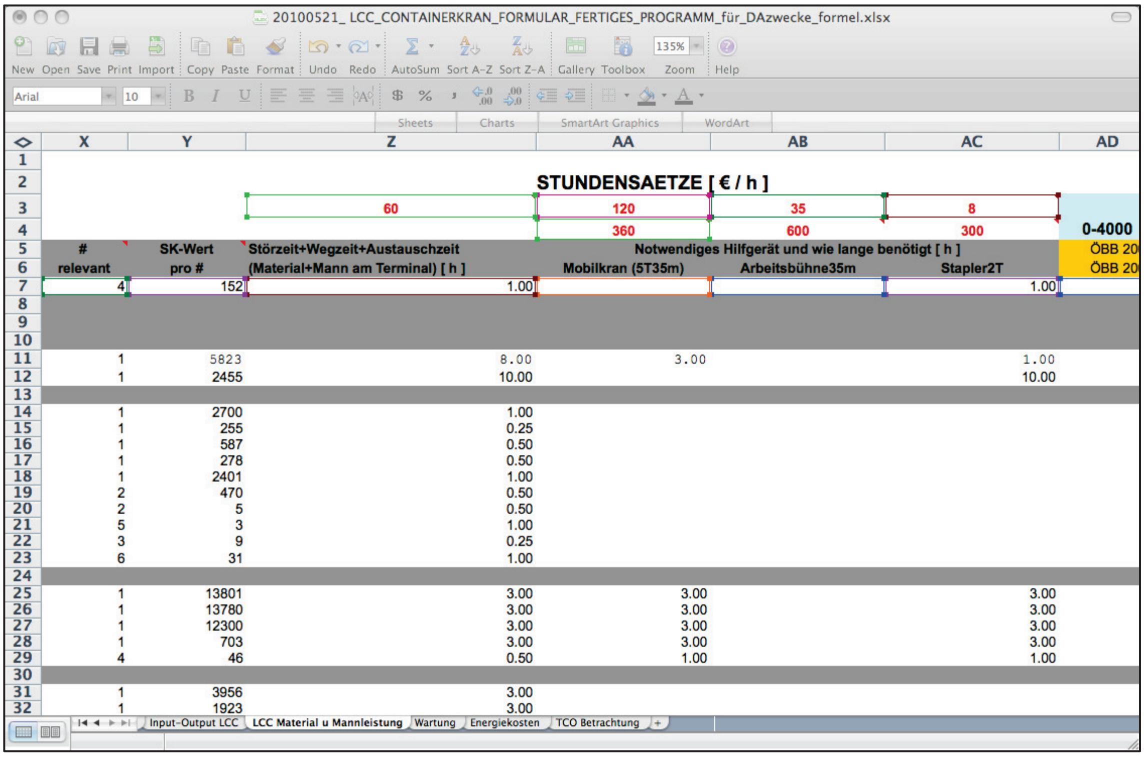


Figure 4-11 Maintenance Costs due to the Unexpected Replacement Formula

Basically, this formula was implemented into the same MS Excel sheet by using, mathematical operators and if clauses. As demonstrated in the following Figure 4-12, only data was queried with the formula above, which is also stored on the same sheet.

[194] Compare chapter 4.3.3 and 4.3.6
[195] Compare chapter 4.3.2 and 4.3.9
[196] Compare chapter 4.3.10.2
[197] Compare chapter 4.3.6.2
[198] Compare chapter 4.3.8



	X	Y	Z	AA	AB	AC	AD
1							
2				STUNDENSAETZE [€ / h]			
3			60	120	35	8	
4				360	600	300	0-4000
5	#	SK-Wert	Störzeit+Wegzeit+Austauschzeit	Notwendiges Hilfgerät und wie lange benötigt [h]			ÖBB 20
6	relevant	pro #	(Material+Mann am Terminal) [h]	Mobilkran (5T35m)	Arbeitsbühne35m	Stapler2T	ÖBB 20
7	4	152	1.00			1.00	
8							
9							
10							
11	1	5823	8.00	3.00		1.00	
12	1	2455	10.00			10.00	
13							
14	1	2700	1.00				
15	1	255	0.25				
16	1	587	0.50				
17	1	278	0.50				
18	1	2401	1.00				
19	2	470	0.50				
20	2	5	0.50				
21	5	3	1.00				
22	3	9	0.25				
23	6	31	1.00				
24							
25	1	13801	3.00	3.00		3.00	
26	1	13780	3.00	3.00		3.00	
27	1	12300	3.00	3.00		3.00	
28	1	703	3.00	3.00		3.00	
29	4	46	0.50	1.00		1.00	
30							
31	1	3956	3.00				
32	1	1923	3.00				

Figure 4-12 Queried Data by the Formula

Figure 4-12 also illustrates the fact that not all parts require AE for the exchange (blank cells; line 14-23, columns AA-AC). The previously mentioned if-clause was needed for exactly these cases in order not to add the fixed costs of the AE's roundtrip to the total costs for changing the part.[199]

4.3.11.3 Placement of the Formula and the Algorithm

The placement of the formula and the methodology of calculating was definitely a challenge. Since the data changed from row to row, it was required to make an intermediate result for each row in the respective period where the "x" was placed. It was not possible to directly calculate the gross-sums of each 4.000 OH-interval. An identical OH-matrix was therefore added, like the one the Kuenz service personnel had used to mark the interval of part exchange with „x".[200]

Specifically, every „x" in the new OH-matrix was subsidized with the previously described formula.

[199] Explanation: 0 * x = 0 but 0 + x = x; therefore the if-clause

[200] Compare chapter 4.3.6.2

Consequently, the total costs for changing a certain component, with its respected quantity, were returned in the column representing its expected lifetime.

The followowing Figure 4-13 shows the second table with the only difference of displaying the values, returned by the formula, instead of the “x”.

4.3.11.4 Result

After the measure introduced in the previous chapter, the gross-sums for each OH-period were calculated as the final result of the sheet.

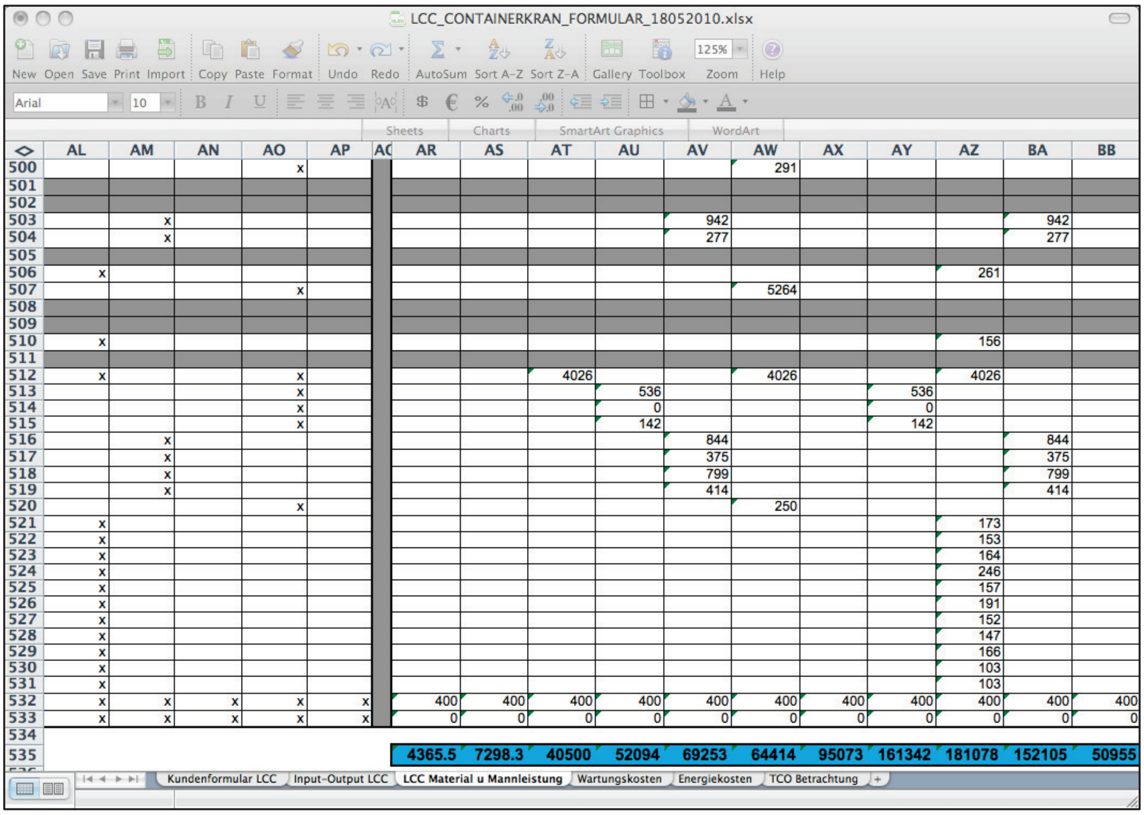


Figure 4-13 Gross-sums of Each 4.000 OH-period

Specifically, as Figure 4-13 also points out, the sums of each column were computed at the bottom of the sheet, representing the overall maintenance costs due to unexpected exchange per 4.000 OH-period.

At this point, overall meant that the material positions, valuated at Kuenz prime costs, were considered as well as personnel and AE costs, directly related to the respective exchange of the components.

Admittedly, this method had its disadvantages when changes in terms of lifetime of a certain part occur. A reconsideration of the lifetime by repositioning of the respective “x” in the OH-matrix did not automatically change the cell with the formula. This results in both, additional work and the possibility of human error.[201]

However, this problem could have been solved with the help of the Kuenz IT department in a later stage of the practical work. With respect to the chronology of the events the new approach will be introduced in chapter 4.5.3.5.

In order to influence the result actively by the input of the user, additional adaptations were performed and are described in chapter 4.5.2.3.

4.4 Scheduled Maintenance Cost Sheet

The term “scheduled” implies a planned, known sequence. Every future action, which is known before, is easy to deal with. Accordingly, the calculation of scheduled maintenance costs was far easier to predict than the maintenance costs due to unexpected replacement.[202]

4.4.1 Introduction

As the name suggests, the purpose of this MS Excel sheet is to calculate the scheduled maintenance costs, described in chapter 4.1.2.1. The combination of the maintenance costs due to unexpected replacement and the scheduled maintenance costs calculated in this chapter, results in the total maintenance costs according to chapter 4.1.2.

4.4.2 Data Acquisition

Regular activities according to a strict schedule, like changing a filter or oil, cause the scheduled maintenance costs. Since these actions are known before and carried out as a periodical routine, it was easy to get the majority of the necessary information.[203]

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[201] Conversation, Wolfgang Fink – Head of Service, Kuenz (3/5/2010)
[202] Compare chapter 4.1.2
[203] Compare chapter 4.1.2.1

4.4.2.1 Time Plan of Scheduled Maintenance

In fact, every Kuenz crane has the information about component, timeframe and treatment in the computer system, which helps the service personnel to carry out the right maintenance work at the right time.[204]

The suppliers are also keen to define service intervals, in order to set the basis for a warranty. Only if these intervals are afterwards strictly adhered and provable, the guaranty of the part is valid.[205]

The Kuenz time plan is classified in the following categories:[206]

- Kuenz Identification Number
- Name of the Component
- Supplier
- Maintenance Activity
- OH-interval
- Time Interval (measured in day, week, month(s) and year)

However, suppliers may set two constraints, the OH-interval as well as the time interval. This measurement is reasonable in cases of a provided warranty and comparable with a V-belt in a car.[207] [208]

4.4.2.2 Implementation in MS Excel

Since the time plan was available in MS Excel, the given data were basically taken and modified towards the requirements of the sheet. It was only reasonable to construct a similar framework as for the sheet maintenance costs due to unexpected replacement with the same OH-matrix.[209]

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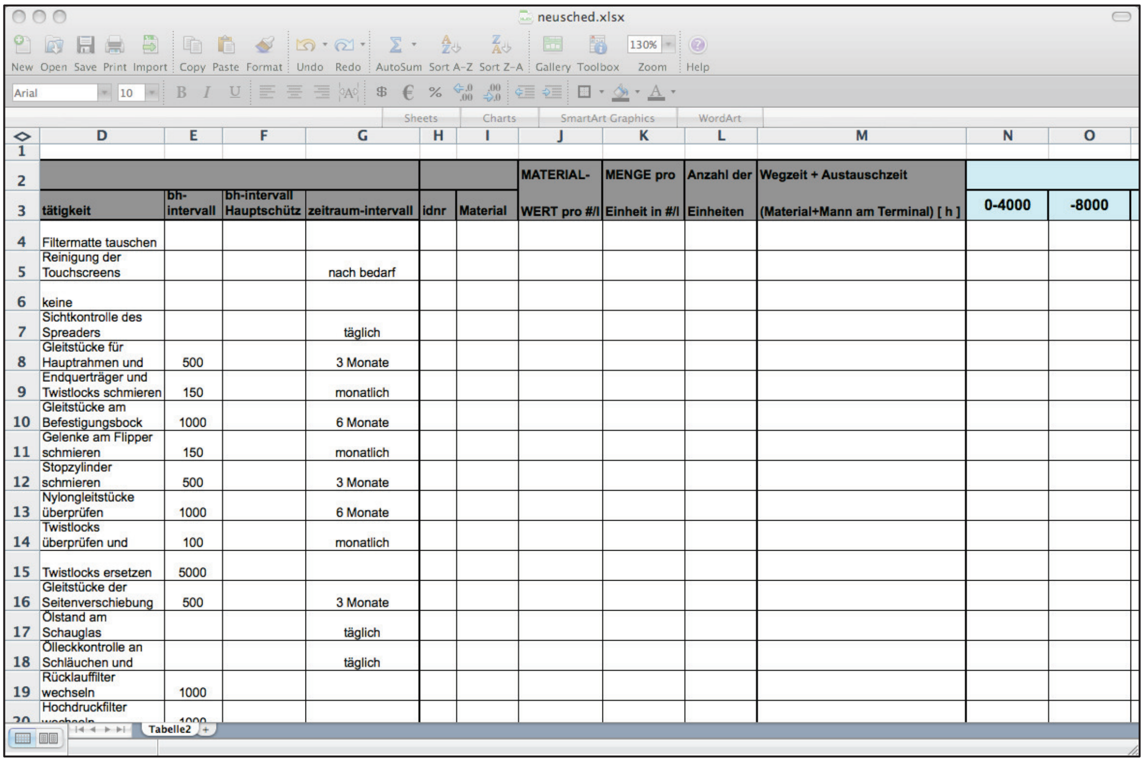
[204] Conversation, Wolfgang Fink – Head of Service, Kuenz (1/4/2010)
[205] Conversation, Christian Immler – Service, Kuenz (17/3/2010)
[206] Compare Kuenz's container crane „Fristenplan"
[207] Conversation, Wolfgang Fink – Head of Service, Kuenz (3/17/2010)
[208] A V-belt is, for example, necessary to change within 60.000 km or at the latest after 5 years.
[209] Compare chapter 4.3.2.2 and 4.3.5.2



	D	E	F	G	H	I	J	K	L	M	N	O
1												
2							MATERIAL-	MENGE pro	Anzahl der	Wegzeit + Austauschzeit		
3	tätigkeit	bh-intervall	bh-intervall Hauptschütz	zeitraum-intervall	idnr	Material	WERT pro #/l	Einheit in #/l	Einheiten	(Material+Mann am Terminal) [h]	0-4000	-8000
4	Filtermatte tauschen											
5	Reinigung der Touchscreens			nach bedarf								
6	keine											
7	Sichtkontrolle des Spreaders			täglich								
8	Gleitstücke für Hauptrahmen und	500		3 Monate								
9	Endquerträger und Twistlocks schmieren	150		monatlich								
10	Gleitstücke am Befestigungsbock	1000		6 Monate								
11	Gelenke am Flipper schmieren	150		monatlich								
12	Stopzylinder schmieren	500		3 Monate								
13	Nylongleitstücke überprüfen	1000		6 Monate								
14	Twistlocks überprüfen und	100		monatlich								
15	Twistlocks ersetzen	5000										
16	Gleitstücke der Seitenverschiebung	500		3 Monate								
17	Ölstand am Schauglas			täglich								
18	Ölleckkontrolle an Schläuchen und			täglich								
19	Rücklauffilter wechseln	1000										
20	Hochdruckfilter wechseln	1000										

Figure 4-14 Scheduled Maintenance Cost Sheet

Figure 4-14 shows the added columns and the added OH-matrix besides the already existing six categories of the Kuenz time plan.[210]

To begin with, it was necessary to subjoin a column for the material or substance, with which the maintained part needs to be treated. For example, if a certain oil of a drive-unit has to be changed, the drive unit is the maintained component and the oil is the substance (column I).

In the second place, also the dedicated Kuenz identification number (column H) of the substance had to be added as well as the respective costs per unit, liter or cartridge (column J). For instance, a unit could represent a filter, while liter stands for the required oil amount; and a cartridge represents the unit of lubrication grease.[211]

Moreover, a column was required to define the amount of the unit, liter or cartridge of the substance described before, which is necessary for the maintenance activity (column K).

---

[210] Compare chapter 4.4.2.1 „Time Plan of Scheduled Maintenance“

[211] Conversation, Wolfgang Fink – Head of Service, Kuenz (1/4/2010)

Finally, a column was added to represent the time in hours, which a service technician needs in average to execute this activity. More precisely, this timeframe represents the time the technician needs to get from the workplace to the respective component, to perform the maintenance activity itself and to return afterwards (column M).[212] [213]

To summarize, the data of the scheduled maintenance time plan were taken and added by material (or substance), the costs, the amount and the necessary time, required for performing the maintenance. As previously mentioned, the OH-matrix was also attached, to get the costs per 4.000 OH-periods again.[214]

In contrast to some activities of the maintenance costs due to unexpected exchange, AE are not necessary for the scheduled maintenance activities, since no fundamental components are changed.[215]

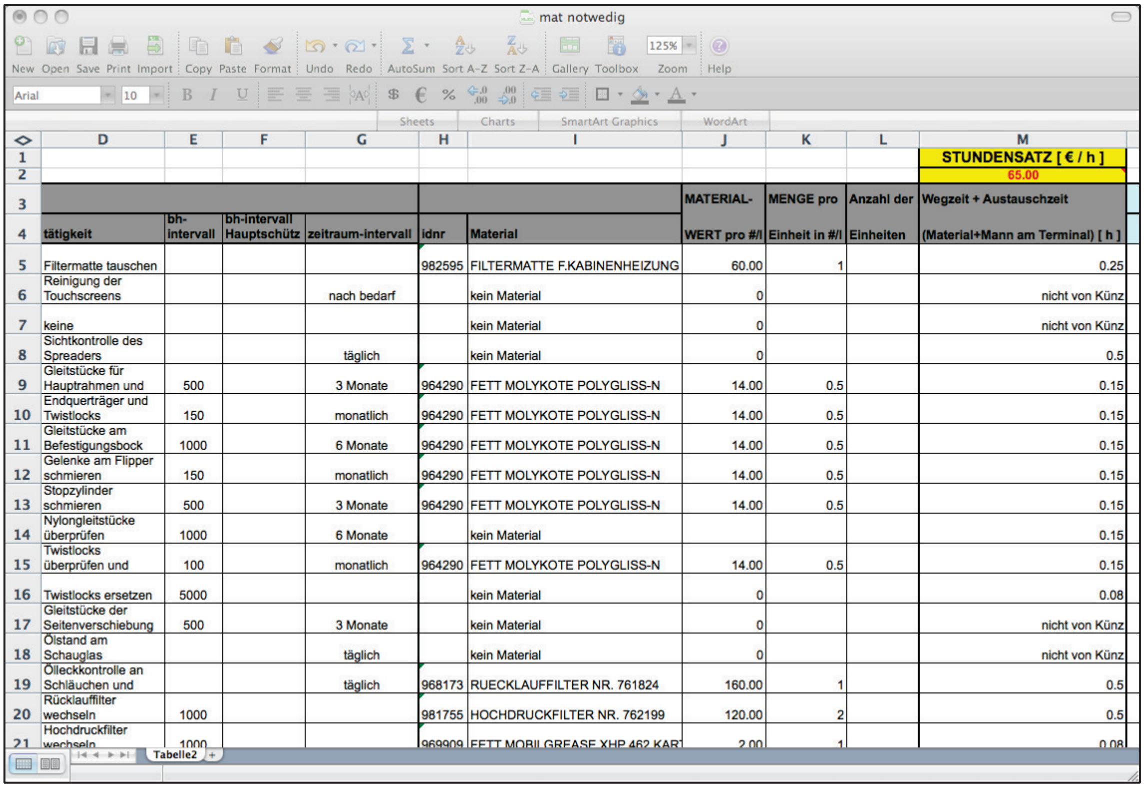
4.4.3 Required Data

As it was necessary for chapter 4.3 Maintenance Costs due to Unexpected Replacement, the process for the second MS Excel sheet was also supported by the Kuenz service personnel

4.4.3.1 Time Needed for Performing Maintenance

Specifically, the times for the maintenance activities according to the time plan were needed, introduced in chapter 4.4.2.1. Therefore, it was only logical to consult the Kuenz service technicians, who perform the scheduled maintenance regularly.

[212] Conversation, Christian Immler – Service, Kuenz (1/4/2010)
[213] Compare chapter 4.3.6.2
[214] Compare chapter 4.3.5.2
[215] Conversation, Wolfgang Fink – Head of Service, Kuenz (8/4/2010)



	D	E	F	G	H	I	J	K	L	M
1										STUNDENSATZ [€ / h]
2										65.00
3							MATERIAL-	MENGE pro	Anzahl der	Wegzeit + Austauschzeit
4	tätigkeit	bh-intervall	bh-intervall Hauptschütz	zeitraum-intervall	idnr	Material	WERT pro #/l	Einheit in #/l	Einheiten	(Material+Mann am Terminal) [h]
5	Filtermatte tauschen				982595	FILTERMATTE F.KABINENHEIZUNG	60.00	1		0.25
6	Reinigung der Touchscreens			nach bedarf		kein Material	0			nicht von Künz
7	keine					kein Material	0			nicht von Künz
8	Sichtkontrolle des Spreaders			täglich		kein Material	0			0.5
9	Gleitstücke für Hauptrahmen und	500		3 Monate	964290	FETT MOLYKOTE POLYGLISS-N	14.00	0.5		0.15
10	Endquerträger und Twistlocks	150		monatlich	964290	FETT MOLYKOTE POLYGLISS-N	14.00	0.5		0.15
11	Gleitstücke am Befestigungsbock	1000		6 Monate	964290	FETT MOLYKOTE POLYGLISS-N	14.00	0.5		0.15
12	Gelenke am Flipper schmieren	150		monatlich	964290	FETT MOLYKOTE POLYGLISS-N	14.00	0.5		0.15
13	Stopzylinder schmieren	500		3 Monate	964290	FETT MOLYKOTE POLYGLISS-N	14.00	0.5		0.15
14	Nylongleitstücke überprüfen	1000		6 Monate		kein Material				0.15
15	Twistlocks überprüfen und	100		monatlich	964290	FETT MOLYKOTE POLYGLISS-N	14.00	0.5		0.15
16	Twistlocks ersetzen	5000				kein Material	0			0.08
17	Gleitstücke der Seitenverschiebung	500		3 Monate		kein Material	0			nicht von Künz
18	Ölstand am Schauglas			täglich		kein Material	0			nicht von Künz
19	Ölleckkontrolle an Schläuchen und			täglich	968173	RUECKLAUFFILTER NR. 761824	160.00	1		0.5
20	Rücklauffilter wechseln	1000			981755	HOCHDRUCKFILTER NR. 762199	120.00	2		0.5
21	Hochdruckfilter wechseln	1000			969909	FETT MOBILGREASE XHP 462 KART	2.00	1		0.08

Figure 4-15 Required Execution Times for the Maintenance Activities

Luckily, support was provided to fill out the roughly 250 positions, each representing a maintenance activity.

Figure 4-15 (column M) indicates the demanded maintenance time per activity in hours.

4.4.3.2 Amount of Substance Needed for Performing Maintenance

As mentioned in chapter 4.4.2.2, the unit depends on the material (or substance) required for the maintenance activity.

For instance, in the case of oil replenishment, the amount is indicated in liter. Consequently, the question would be how many liters are needed for this maintenance activity in order to refill the respective drive-unit, for example. Since the suppliers of components that run in an oil-bath dictate the exact amount of required oil, it was quite easy to get the data. In case of changing filters it was also simply to get the number of required filters, and so forth.

However, the prediction of the necessary amount of lubrication grease cartridges was more difficult in order to maintain components, which require so. In these specific cases, it was again the service department, which provided the necessary experience data.

As Figure 4-15 also outlines, not all activities needed a certain substance for executing the scheduled maintenance. Examples are activities such as, cleaning a screen or performing a visual inspection (row 6 and 8).

Positions with neither an exchange time nor an assigned material substance indicated in Figure 4-15, however, were questionable maintenance activities. That means, actions which had to be executed according the Kuenz time-plan, and consequently to satisfy the suppliers, but which also were not realistic in general or terms of their frequency.[216]

4.4.4 Hourly Wage-rate

As the goal of this sheet was to predict the costs of the scheduled maintenance, the last thing needed was the wage-rate of the service personnel performing the maintenance. Following the scheme of the first MS Excel sheet,[217] the wage-rate was necessary to transform the required time of the technicians for each part in costs.

In accordance to chapter 4.3.8.1, the hourly wage-rate for the service personnel was calculated as the average value of the wage-rates of the following (service) companies in order to get a general value:

- Kuenz Service Personnel
- STLB
- Crane Tech

Interesting at this point were the different values between the wage-rates of maintenance due to unexpected replacement and scheduled maintenance.[218] The explanation therefore is that the wage-rate for the uncertain occurrence of the maintenance due to unexpected replacement is averagely higher than the of scheduled maintenance.[219]

[216] Conversation, Wolfgang Fink – Head of Service, Kuenz (26/4/2010)
[217] Compare chapter 4.3.8
[218] Compare Figure 4-9, p. 59
[219] Conversation, Gerald Winter – Logistics, Kuenz (28/4/2010)

4.4.5 Kuenz Prime Costs[220]

Analogically to chapter 4.3.9, it was also necessary to change the costs of the material (or substance), required for the maintenance activities, into Kuenz prime costs.

4.4.6 Calculation

Basically, all the necessary data for calculating the scheduled maintenance costs were gathered in the previous sections. Since a similar framework was constructed for this sheet as for the maintenance costs due to unexpected replacement, also a likewise calculation approach followed.[221]

The basic idea was to create the sum of the costs per 4.000 OH-periods again.[222] This, in combination with the results of the unexpected replacement, set the basis for a subsequent creation of the overall maintenance costs.

4.4.6.1 Formula

The following Figure 4-16 shows the formula, which was introduced to get the first results of the scheduled maintenance costs.

Figure 4-16 Formula of the Scheduled Maintenance Costs

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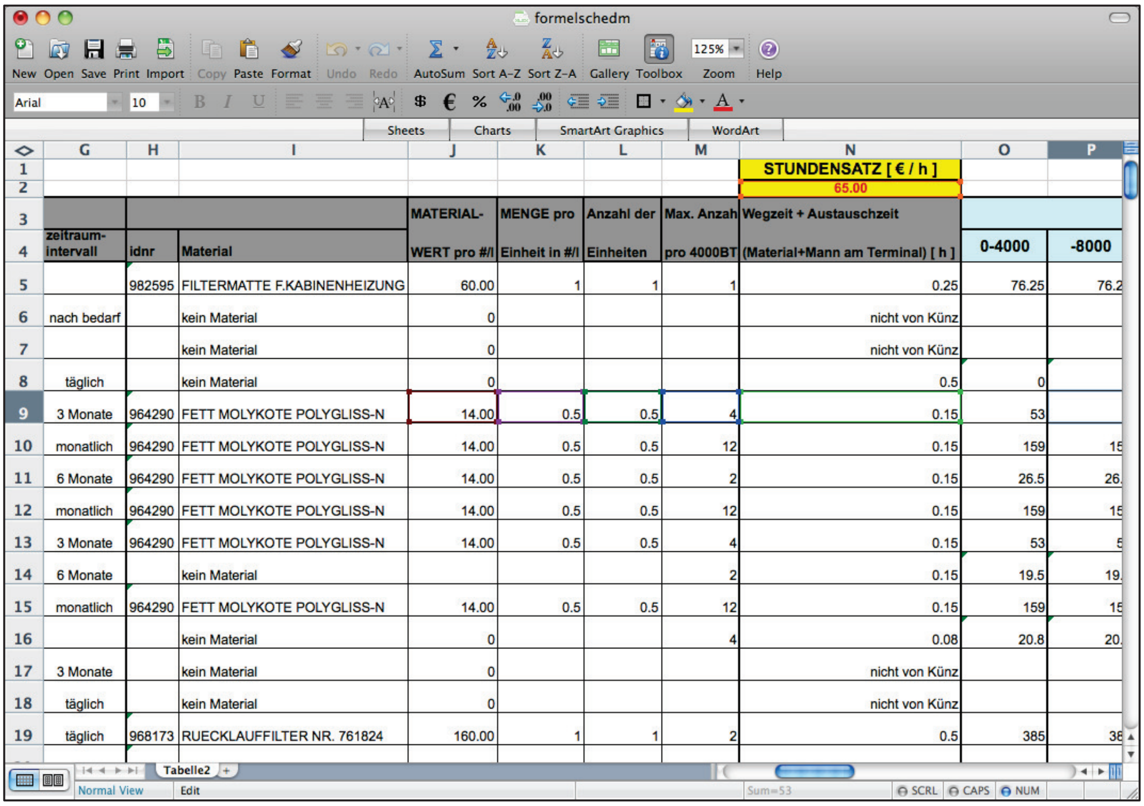
[220] Compare Table 3-3, p. 31
[221] Compare chapter 4.3.11
[222] Compare chapter 4.3.5.2

A given maintenance activity has to be carried out in a certain interval according to the dictation of the supplier. As a consequence, the frequency of how often this is the case during 4.000 OH of the main conductor was known. Furthermore, this specific maintenance operation might require a certain amount of a material (or a substance), which is valued at Kuenz prime costs. Additionally, the service technician needs a certain time to execute per maintenance activity, which is then multiplied by the respective hourly wage-rate.



	G	H	I	J	K	L	M	N	O	P
1								STUNDENSATZ [€ / h]		
2								65.00		
3				MATERIAL-	MENGE pro	Anzahl der	Max. Anzah	Wegzeit + Austauschzeit		
4	zeitraum-intervall	idnr	Material	WERT pro #/l	Einheit in #/l	Einheiten	pro 4000BT	(Material+Mann am Terminal) [h]	0-4000	-8000
5		982595	FILTERMATTE F.KABINENHEIZUNG	60.00	1	1	1	0.25	76.25	76.2
6	nach bedarf		kein Material	0				nicht von Künz		
7			kein Material	0				nicht von Künz		
8	täglich		kein Material	0				0.5	0	
9	3 Monate	964290	FETT MOLYKOTE POLYGLISS-N	14.00	0.5	0.5	4	0.15	53	
10	monatlich	964290	FETT MOLYKOTE POLYGLISS-N	14.00	0.5	0.5	12	0.15	159	15
11	6 Monate	964290	FETT MOLYKOTE POLYGLISS-N	14.00	0.5	0.5	2	0.15	26.5	26.
12	monatlich	964290	FETT MOLYKOTE POLYGLISS-N	14.00	0.5	0.5	12	0.15	159	15
13	3 Monate	964290	FETT MOLYKOTE POLYGLISS-N	14.00	0.5	0.5	4	0.15	53	5
14	6 Monate		kein Material				2	0.15	19.5	19.
15	monatlich	964290	FETT MOLYKOTE POLYGLISS-N	14.00	0.5	0.5	12	0.15	159	15
16			kein Material	0			4	0.08	20.8	20.
17	3 Monate		kein Material	0				nicht von Künz		
18	täglich		kein Material	0				nicht von Künz		
19	täglich	968173	RUECKLAUFFILTER NR. 761824	160.00	1	1	2	0.5	385	38

Figure 4-17 Queried Data by the Scheduled Maintenance Costs Formula

Figure 4-17 indicates the queried data of the previously described procedure of the formula.

At this point, it has to be said that this solution is also not fully satisfying, because an auxiliary column for the frequency, of how often a maintenance activity has to be carried out in a 4.000 OH-timeframe, was needed (Figure 4-17, column M). The auxiliary column indicated simply the number of how often the maintenance interval (column F) fits into the 4.000 OH-period. With a result, that problems occur if the maintenance interval is not precisely dividable by the 4.000 OH.[223]

Ideally, the formula had a mechanism implemented and would consider therefore itself how often a maintenance operation has to be carried out as a function of the maintenance interval of this operation. Moreover, in cases where the interval is not exactly dividable by 4.000 OH it has to be counted and monitored how many OH have to be additionally considered for the next period. Consequently, these periods may differ from each other in terms of the frequency of a maintenance operation.

Ultimately, it was possible to implement such a formula with the help of the Kuenz IT department. However, in respect to the chronology of events this approach will be introduced in chapter 4.5.3.5.

4.4.6.2 Placement of Formula and Algorithm

In analogy to the calculation of the maintenance due to unexpected replacement sheet, also a two-step calculation was introduced. Firstly, it was necessary to calculate horizontally for each period with the formula of the previous chapter and secondly, the gross sums per 4.000 OH-period were created vertically.[224]

4.5 Input/Output (I/O) Interface

As the name of the I/O interface suggests, this MS Excel sheet is the major interface between a person and the program, providing both, input parameters and the actual result of the maintenance costs as the output.

4.5.1 Introduction

Kuenz defines LCC as all costs, necessary for keeping a system in a ready-to operate state during a given timeframe.[225] According to this definition, LCC is the sum of the generated costs in the chapters 4.3 “Maintenance Costs due to Unexpected Replacement” and 4.4 “Scheduled Maintenance Cost”.[226]

[223] Conversation, Wolfgang Fink – Head of Service, Christian Immler – Service, Kuenz (3/5/2010)

[224] Compare chapter 4.3.11

[225] Compare working definition LCC, chapter 3.5.3.2

[226] Compare chapter 4.1.2

The purpose of the I/O interface is, therefore, to present and illustrate the LCC of the respective container crane. Moreover, since this sheet was one of the key works towards the objectives of this thesis, another requirement was the adaptability of the LCC towards certain characteristics of the crane.[227][228]

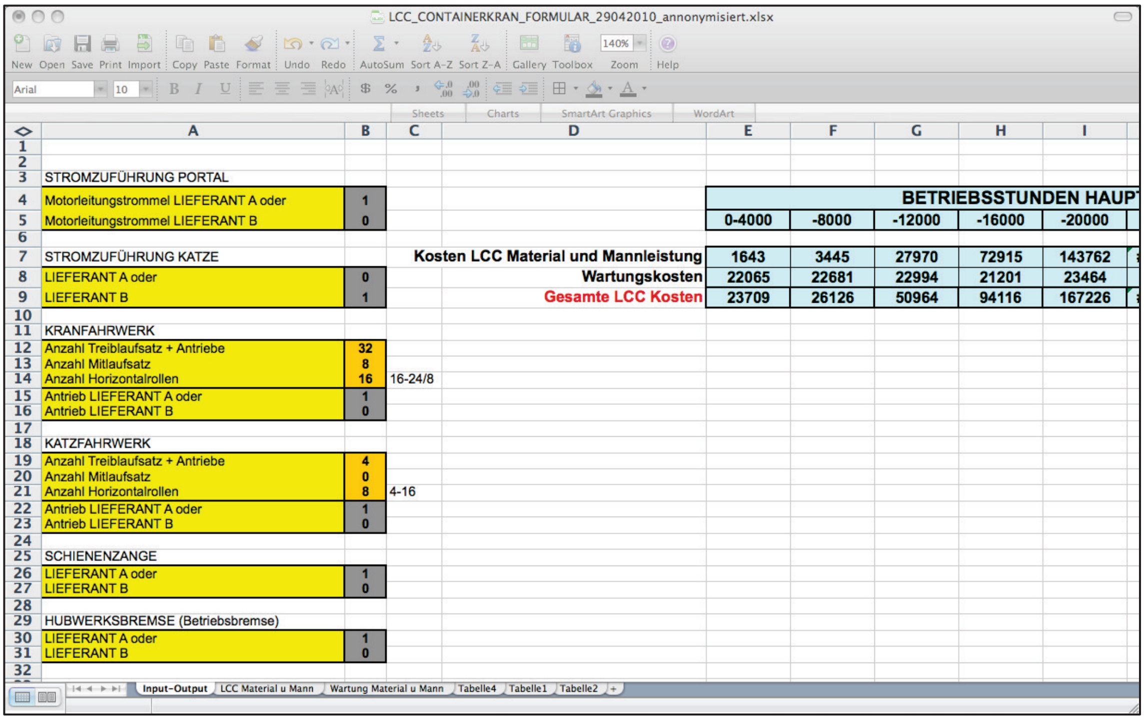


Figure 4-18 Initial I/O Formula

4.5.2 Input – Characterization of the Crane

Initially, the characterizations of the container crane, visible on the left side of Figure 4-18, were implemented. Consequently, the following categories allowed the user to modify the crane and hence, the result in the first place:

- Power Supply of the Gantry
- Power Supply of the Trolley
- Gantry Carriage
- Trolley Carriage
- Rail Tongs
- Hoisting Gear Operation Brakes

[227] Conversation, Michael Geiger – Head of Sales, Kuenz (28/1/2010)

[228] Compare chapter 1.3

Specifically, the user either selects one out of the two major suppliers[229] or the number of wheels.

4.5.2.1 Final Characteristics

The number of additional selection boxes to further specify the container crane increased steadily during the work.

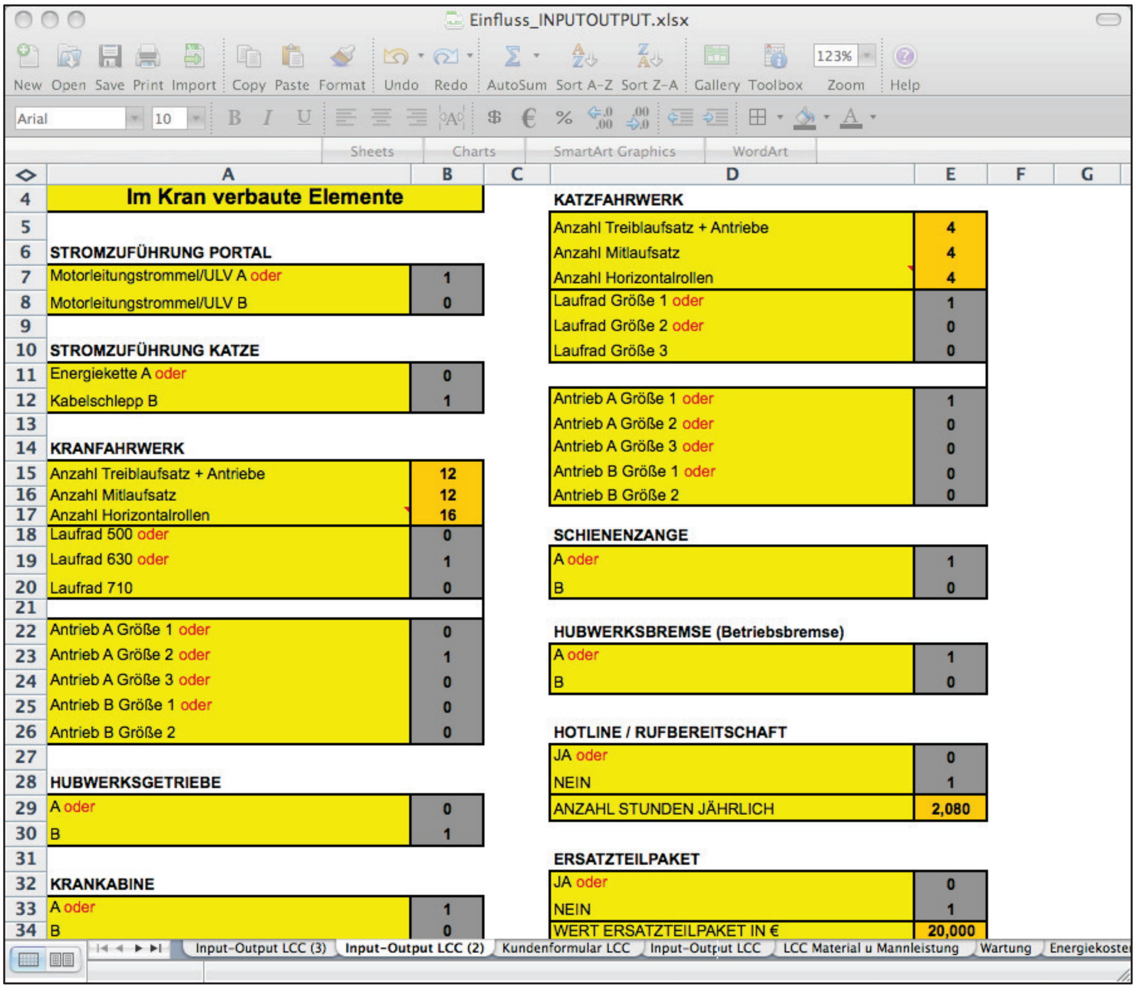


Figure 4-19 Final Characterization Options

Figure 4-19 shows all characterization options of the final calculation model in two rows, for better visibility. There are two major reasons for introducing the final stage of this process already in the beginning of this chapter. On the one hand it serves the purpose of a better structuring as the corresponding ideas developed stepwise and on the other hand it is necessary to better understand the following measures. Especially, in regard to chapter 4.5.2.3, in which the

[229] Compare chapter 4.3.4

impact of the input in the database on the maintenance sheet is explained, it is vital to understand the input options of the mask.

In short, the following selections were added in comparison to the initial mask:[230]

- Hoisting Gearbox
- Crane Cabin
- Hotline
- Spare Part Kit

Additionally, according to Figure 4-19, the size of the wheels as well as the size of the attached drive-units is now selectable. Reason for keeping both sizes variable is that all combinations are possible, which is also demonstrated in the praxis by existing crane instillations.[231]

4.5.2.2 Selection of the Characterizations

Referring to Figure 4-19, the user could either select one out of the two options, e.g. supplier, the number and size of wheels or the number of driven wheels and the performance of the attached drive-units.

The aim was to implement the selection possibility between two suppliers in an exclusive-or (x-or)[232] fashion. But since the easiest way was to use a binary system with “0” and “1”, it was possible to select both possibilities by accident. Therefore, it was also implemented an if-clause, which verifies whether there is a “0” and a “1” selected. If this is not the case, a message below the selection box occurs, informing the user to double-check his input.[233]

[230] Compare Figure 4-18, p. 74

[231] Conversation, Wolfgang Fink – Head of Service, Kuenz (30/4/2010)

[232] Exclusive or = either option A or option B, to select both options at the same time is not possible

[233] Conversation, Wolfgang Fink – Head of Service, Kuenz (27/3/2010)

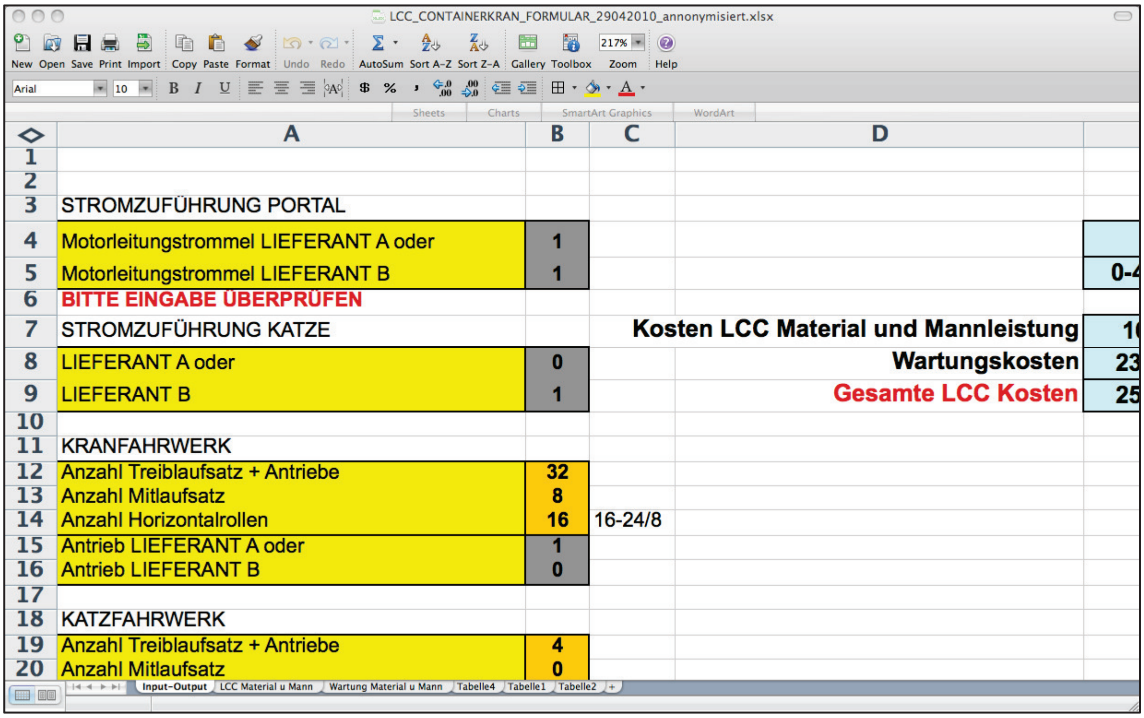


Figure 4-20 Selection out of Two Possible Supplier and Verification

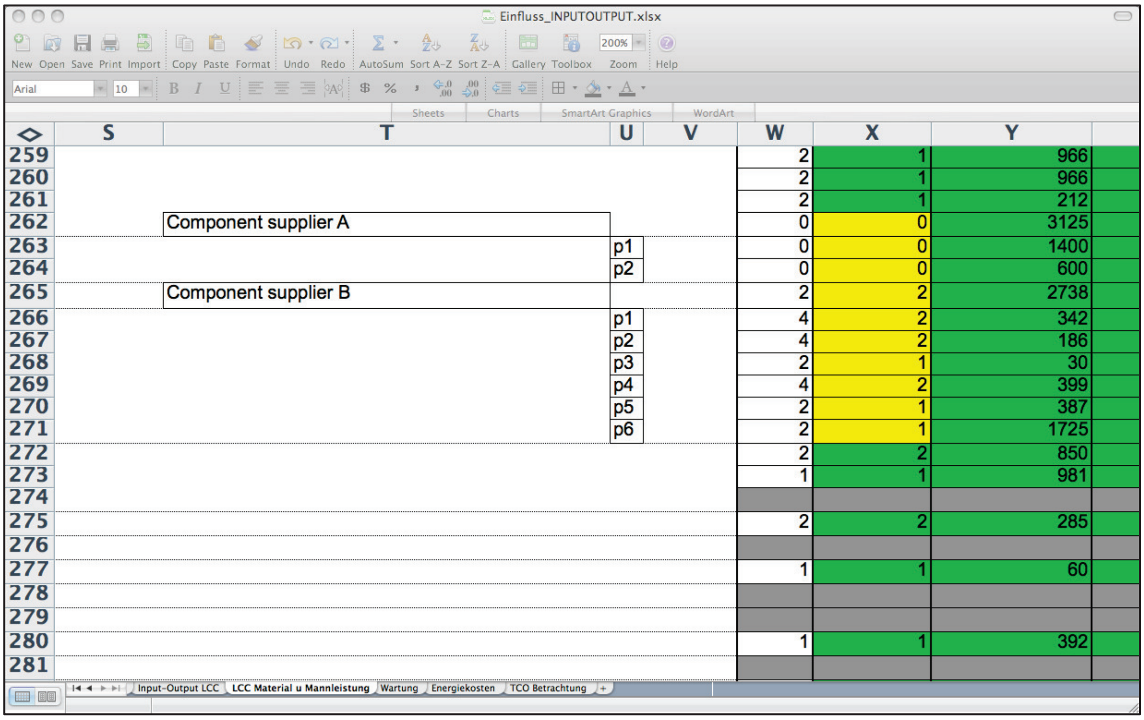
Figure 4-20 illustrates the case in which the user accidentally selects both options.

4.5.2.3 Impact of the Characterizations on the Maintenance Sheets

The user's input parameter directly influence the data stored on the sheet (database) and, consequently, the result displayed in the turquoise cells. The following example, in accordance to Figure 4-20, explains what actually happens inside the database, once a supplier is chosen.

Important in the following two figures, is the fact that the yellow marked cells represent variable values, which depend on the input data.

<u>Selection between Two Suppliers</u>:



	S	T	U	V	W	X	Y
259					2	1	966
260					2	1	966
261					2	1	212
262		Component supplier A			0	0	3125
263			p1		0	0	1400
264			p2		0	0	600
265		Component supplier B			2	2	2738
266			p1		4	2	342
267			p2		4	2	186
268			p3		2	1	30
269			p4		4	2	399
270			p5		2	1	387
271			p6		2	1	1725
272					2	2	850
273					1	1	981
274							
275					2	2	285
276							
277					1	1	60
278							
279							
280					1	1	392
281							

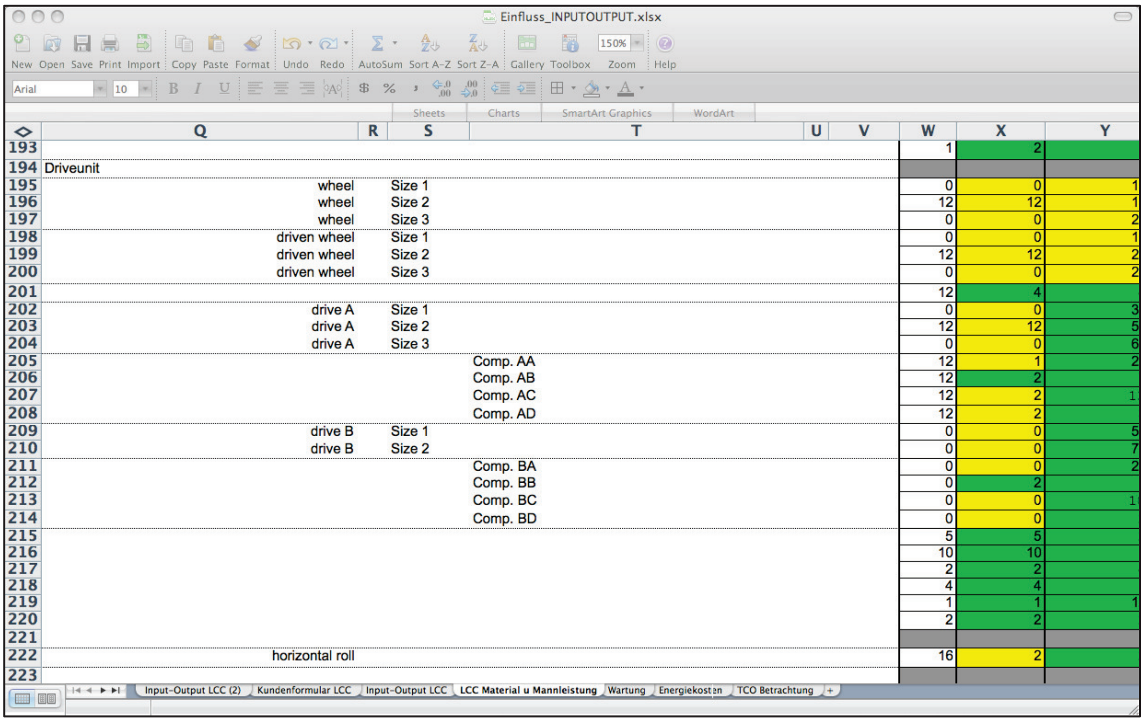
Figure 4-21 Impact of the Input Data on the Database

The formula of the relevant quantity of the respective parts is connected with the „0“ and „1“ of the I/O interface. Referring to Figure 4-20 and Figure 4-21, the user has obviously selected component B. Consequently, the calculation takes only the sub-components of component B into account. Accordingly, the relevant quantities of the parts, composing component A, are switched to zero. This mechanism ensures that only the chosen „costs“ are considered.

<u>Selection of the Wheel Configuration</u>:

The implementation of the selection and characterization of the crane wheels according to Figure 4-20, was more challenging. The corresponding Figure 4-22 demonstrates the impact of selecting the crane wheels on the database. Again, the yellow cells are depending on the input data.

First of all, the total number of wheels can be divided into those who have a drive unit attached and by those who have not. Consequently, the number of driven wheels also defines the quantity of drive units. Additionally, the wheel size and the desired drive unit have to be defined. Accordingly, this number of driven wheels can be directly assigned to the relevant quantity cell of the respected sized wheel and drive-unit. As in the previous example, the components that were not selected got a „0“ in the column for the relevant quantity of the formula.



	Q	R	S	T	U	V	W	X	Y
193							1	2	
194	Driveunit								
195	wheel		Size 1				0	0	1
196	wheel		Size 2				12	12	1
197	wheel		Size 3				0	0	2
198	driven wheel		Size 1				0	0	1
199	driven wheel		Size 2				12	12	2
200	driven wheel		Size 3				0	0	2
201							12	4	
202	drive A		Size 1				0	0	3
203	drive A		Size 2				12	12	5
204	drive A		Size 3				0	0	6
205				Comp. AA			12	1	2
206				Comp. AB			12	2	
207				Comp. AC			12	2	1
208				Comp. AD			12	2	
209	drive B		Size 1				0	0	5
210	drive B		Size 2				0	0	7
211				Comp. BA			0	0	2
212				Comp. BB			0	2	
213				Comp. BC			0	0	1
214				Comp. BD			0	0	
215							5	5	
216							10	10	
217							2	2	
218							4	4	
219							1	1	1
220							2	2	
221									
222	horizontal roll						16	2	
223									

Figure 4-22 Impact of Selecting the Crane Wheels on the Database

Figure 4-22 indicates that the user has obviously chosen size 2 for the wheels as well as the second size of the drive-units A.

Furthermore, the calculation has to distinguish between two philosophies towards wheel-rail contact. The first option is a wheel flange that serves to provide side support. The second option is a combination of a standard wheel without a flange but which is supported by horizontal roles, to ensure that the wheels stay on the rail.[234]

Consequently, if the number of horizontal roles in the input mask is set on „0“, the costs for the wheels increase by the difference between the costs of „normal“ and “flanged” wheels, and vice versa. Figure 4-22 also indicates the respective cost positions on the very top right-hand side, which are the only prime cost positions marked yellow.

<u>Selection and Definition of Hotline and Spare Part Kit</u>:

[234] Conversation, Gebhard Schmelzenbach – Project Manager, Kuenz (5/4/2010)

The hotline option is an additional incentive Kuenz offers his clients. If selected, the client gets an exclusive hotline for professional support inclusive on-call duty of Kuenz technicians.[235] The consequence for the calculation is simply that the selected hours per year, multiplied with the respective hourly wage-rate, will be added to the yearly costs.[236] The requested hours per year, for this service, are directly related to the sheet maintenance costs due to unexpected replacement and hence, affect the calculation.

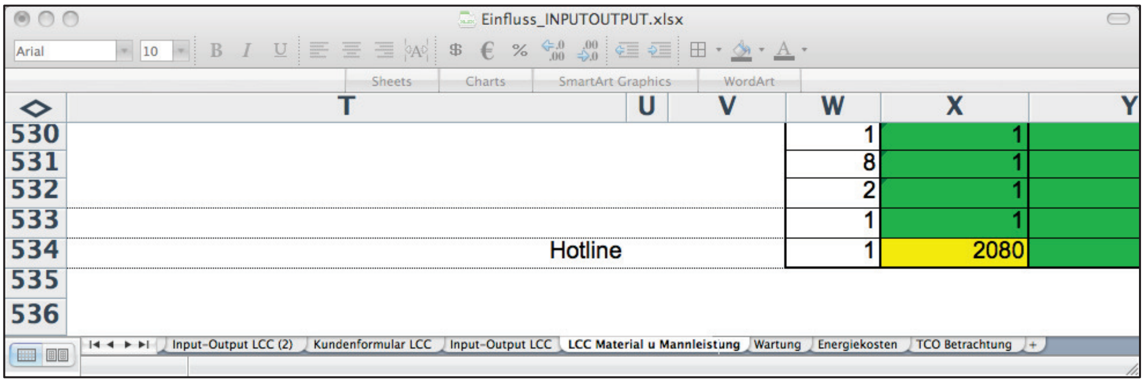


Figure 4-23 Implementation of the Hotline in the Database

The spare-part kit, however, directly affects the result in the first year by the defined costs displayed on the I/O interface. In order to maintain a crane terminal without longer downtimes, it is absolutely necessary to have the most important spare-parts on-site.[237] As a consequence, the spare part selection helps to further adapt the model to a real contract.

4.5.3 Output – Displayed Life Cycle Cost (LCC) as the Result

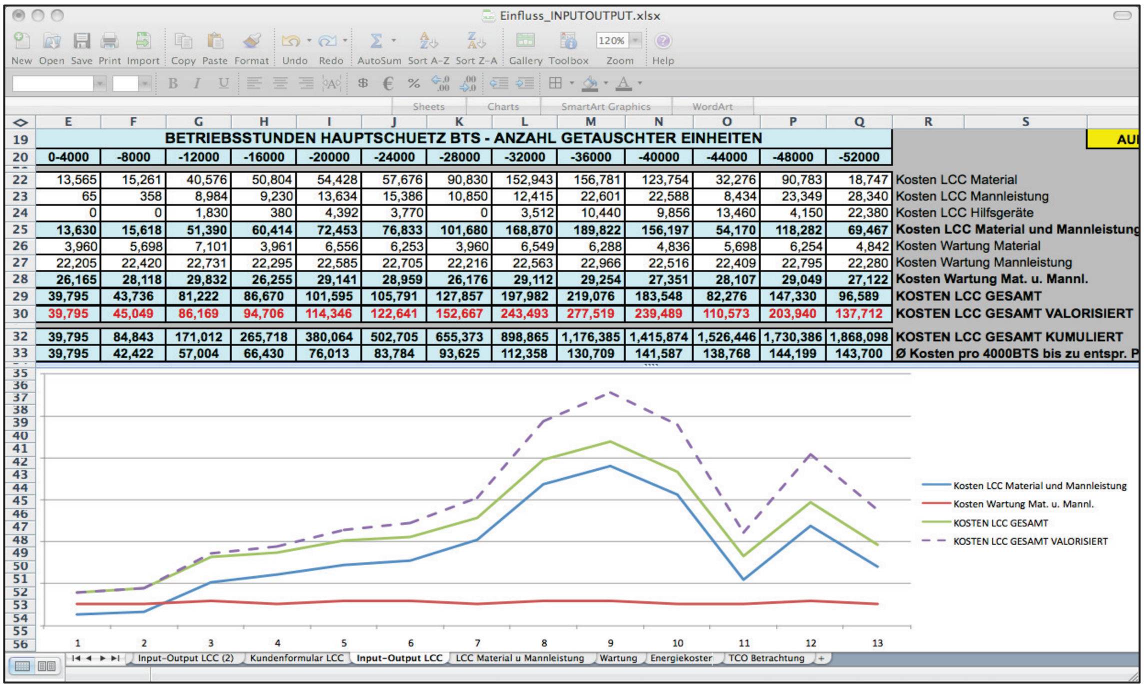
The result of the two maintenance cost sheets were placed on the I/O interface. The one-rowed results, which are the vertical sums of each period representing both, scheduled maintenance costs and costs caused due to unexpected exchange, were therefore simply duplicated. Figure 4-18 on page 74 displays besides the initial input also these costs as the output, in the turquoise cells, and

[235] Conversation, Wolfgang Fink – Head of Service, Kuenz (20/5/2010)
[236] Compare Figure 4-19, p. 75 - input for the hotline
[237] Conversation, Wolfgang Fink – Head of Service, Kuenz (20/5/2010)

the total LCC as the computed sum.[238] Evidentially, the classification in 4.000 OH-periods remained.[239]

4.5.3.1 Final Appearance

In accordance to the chapter, 4.5.2 „Input – Characterization of the Crane", the initial setup is compared to the final approach in this chapter as well. The following sections will focus on a detailed explanation of the reasons for an implementation of the improvements, outlining the differences between the initial and the final version. Consequently, Figure 4-24 shows the final output section of the MS Excel I/O interface.



	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
19	BETRIEBSSTUNDEN HAUPTSCHUETZ BTS - ANZAHL GETAUSCHTER EINHEITEN													
20	0-4000	-8000	-12000	-16000	-20000	-24000	-28000	-32000	-36000	-40000	-44000	-48000	-52000	
22	13,565	15,261	40,576	50,804	54,428	57,676	90,830	152,943	156,781	123,754	32,276	90,783	18,747	Kosten LCC Material
23	65	358	8,984	9,230	13,634	15,386	10,850	12,415	22,601	22,588	8,434	23,349	28,340	Kosten LCC Mannleistung
24	0	0	1,830	380	4,392	3,770	0	3,512	10,440	9,856	13,460	4,150	22,380	Kosten LCC Hilfsgeräte
25	13,630	15,618	51,390	60,414	72,453	76,833	101,680	168,870	189,822	156,197	54,170	118,282	69,467	Kosten LCC Material und Mannleistung
26	3,960	5,698	7,101	3,961	6,556	6,253	3,960	6,549	6,288	4,836	5,698	6,254	4,842	Kosten Wartung Material
27	22,205	22,420	22,731	22,295	22,585	22,705	22,216	22,563	22,966	22,516	22,409	22,795	22,280	Kosten Wartung Mannleistung
28	26,165	28,118	29,832	26,255	29,141	28,959	26,176	29,112	29,254	27,351	28,107	29,049	27,122	Kosten Wartung Mat. u. Mannl.
29	39,795	43,736	81,222	86,670	101,595	105,791	127,857	197,982	219,076	183,548	82,276	147,330	96,589	KOSTEN LCC GESAMT
30	39,795	45,049	86,169	94,706	114,346	122,641	152,667	243,493	277,519	239,489	110,573	203,940	137,712	KOSTEN LCC GESAMT VALORISIERT
32	39,795	84,843	171,012	265,718	380,064	502,705	655,373	898,865	1,176,385	1,415,874	1,526,446	1,730,386	1,868,098	KOSTEN LCC GESAMT KUMULIERT
33	39,795	42,422	57,004	66,430	76,013	83,784	93,625	112,358	130,709	141,587	138,768	144,199	143,700	Ø Kosten pro 4000BTS bis zu entspr. P

Figure 4-24 Final Appearance of the Result

Comparing Figure 4-18 and Figure 4-24, there are basically two things, which had changed. Firstly, there is a deviation in the number of rows of the result displayed in the turquoise cells and secondly, the values are now transparently illustrated in the diagram.

4.5.3.2 Graphical Illustration

Adding a diagram as an additional output had two different reasons. Firstly, the increasing rows of the result led to an increased complexity of the overall ap-

[238] Compare chapter 3.5.3.2
[239] Compare chapter 4.3.5.2

pearance and secondly, as visible in the following Figure 4-25, the results of the maintenance costs per 4.000 OH-period had a high variance. Since it was also the question how long a full-maintenance contract makes economically sense,[240] the diagram could by illustrating the cost profile also help in this regard.

Moreover, the diagram pointed out a crucial issue of the first approach during the work. As maintenance costs, regardless whether scheduled or unexpected, have a periodical consideration in the calculation, prime-numbered-period costs were naturally considered too low. Reason for that is simply the fact that prime numbers are only dividable by either themselves or 1. Consequently, especially higher prime numbered periods, like 13, 11 and 7, included just the costs, which occur in these years for the first time.[241]

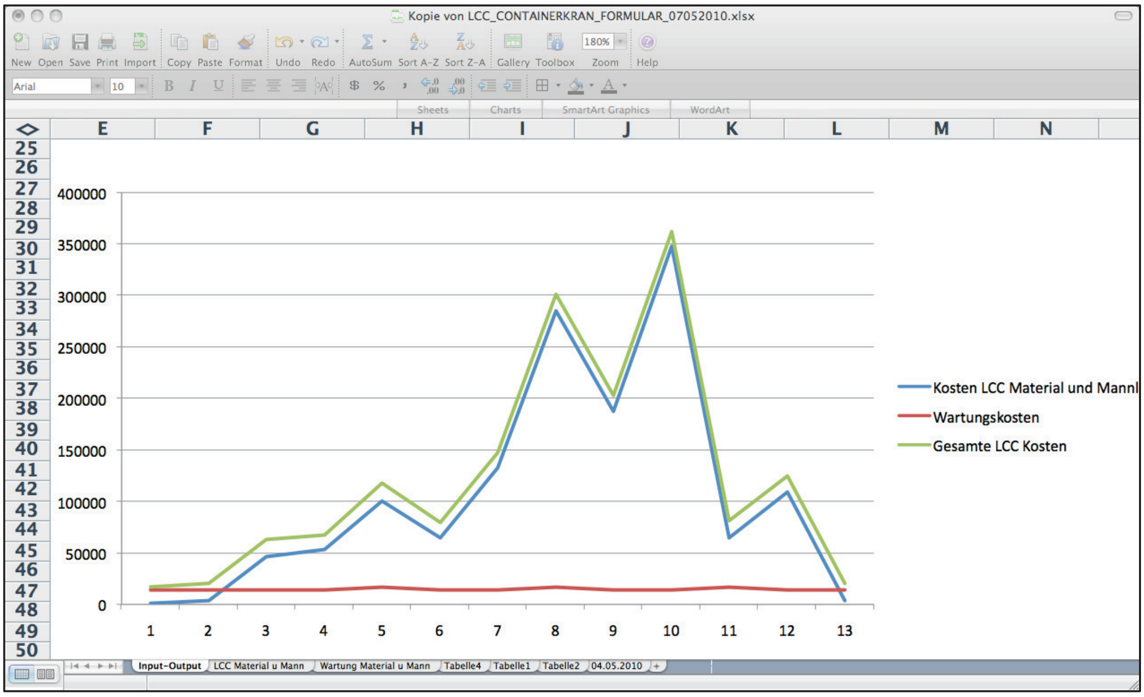


Figure 4-25 Issue of Low Costs in the Prime-numbered Periods

Again, as Figure 4-25 points out, the costs of prime-numbered periods were considered as too low. Contrarily, the maintenance costs of periods 8, 10 or 12, were basically considered too high, because costs of periods 2, 3, 4, 5 and 6, partially contributed to the costs of them.

---

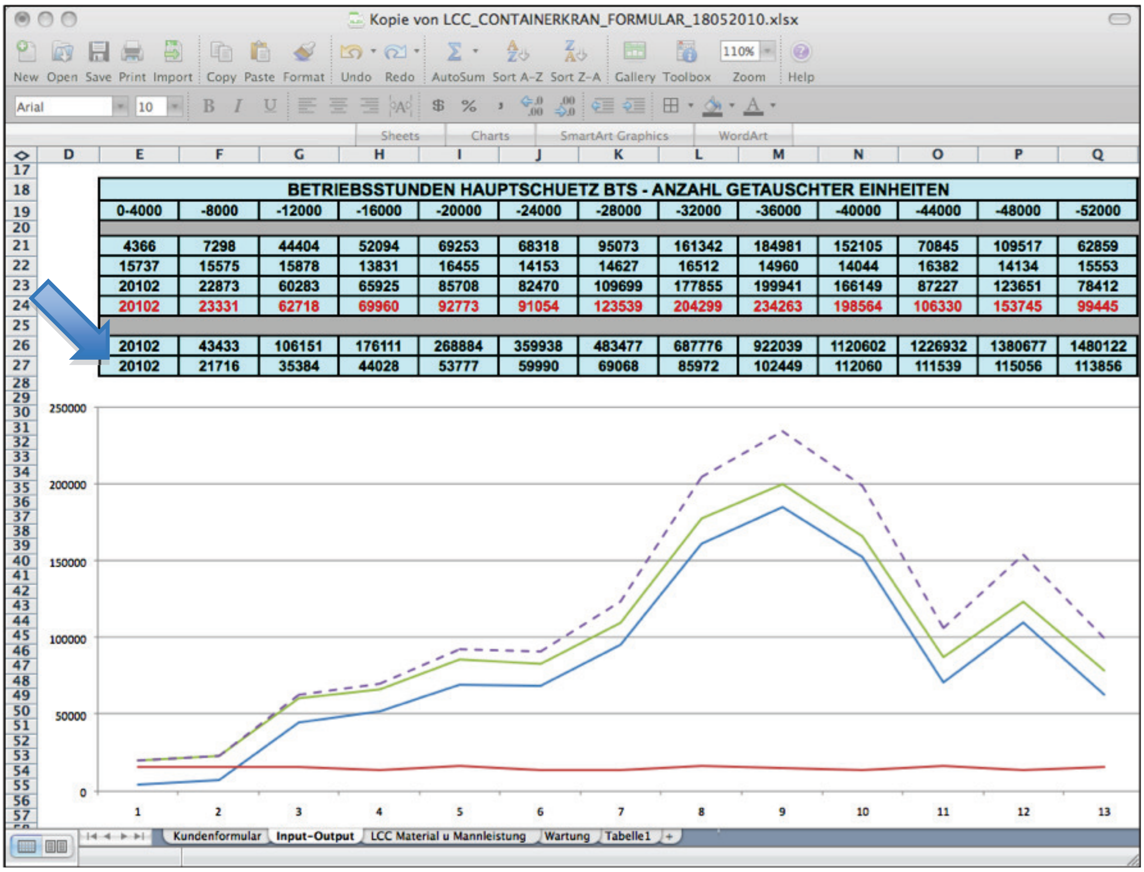
[240] Conversation, Guenther Bischof – CEO, Kuenz (5/3/2010)

[241] Explanation: prime numbers = 1, 3, 5, 7, 11, 13, .. are just dividable by 1 and themselves. Consequently costs occurring **every** 2, 3, 4 ,5 and 6 years never hit a prime-numbered year!

The situation could be improved by relocating maintenance cost positions, eventually providing a more smoothened function. Figure 4-26 illustrates the resulting profile of the cost function.

4.5.3.3 Accumulating and Averaging the Costs

The basic idea behind accumulating the costs and to subsequently divide the resulting sum by the number of periods until this very point was to analyze the development of the cost profile. As a consequence, it can be reviewed how much the LCC is in average per year as a function of the investigation period. Figure 4-26 illustrates this analyzing measure:



BETRIEBSSTUNDEN HAUPTSCHUETZ BTS - ANZAHL GETAUSCHTER EINHEITEN												
0-4000	-8000	-12000	-16000	-20000	-24000	-28000	-32000	-36000	-40000	-44000	-48000	-52000
4366	7298	44404	52094	69253	68318	95073	161342	184981	152105	70845	109517	62859
15737	15575	15878	13831	16455	14153	14627	16512	14960	14044	16382	14134	15553
20102	22873	60283	65925	85708	82470	109699	177855	199941	166149	87227	123651	78412
20102	23331	62718	69960	92773	91054	123539	204299	234263	198564	106330	153745	99445
20102	43433	106151	176111	268884	359938	483477	687776	922039	1120602	1226932	1380677	1480122
20102	21716	35384	44028	53777	59990	69068	85972	102449	112060	111539	115056	113856

Figure 4-26 Accumulation of the LCC per Period and Averaging per Period[242]

The blue arrow indicates the two rows, representing the previously mentioned accumulation and average per period of the valorized LCC[243] (red font).

[242] Compare schema with Figure 4-5, p. 51

[243] Compare chapter 4.5.4.1

Specifically, the first of the two rows is the sum of the LCC until this period. This means that in this row every column sums up the LCC (red font) from the beginning, the first column on the left, until directly above.

The second row is then the average LCC per period until this period, taking the sum from above divided by the number of periods, which are accumulated until this period.

For example, the third column: The sum of the valorized LCC (red font) until the third period is 20102 + 23331 + 62718 = 106515. Consequently, the average of the LCC in the first 3 periods is 106515 / 3 = (~)35384.[244]

At this point, I have to repeat that 4.000 OH of the main conductor, representing the measurement for a period, is in average also equal to a year.[245]

In short, this measure points out that the average LCC per year over a timeframe is highly depending on the duration of this timeframe.[246]

4.5.3.4 Separation of LCC in Material and Personnel Nature

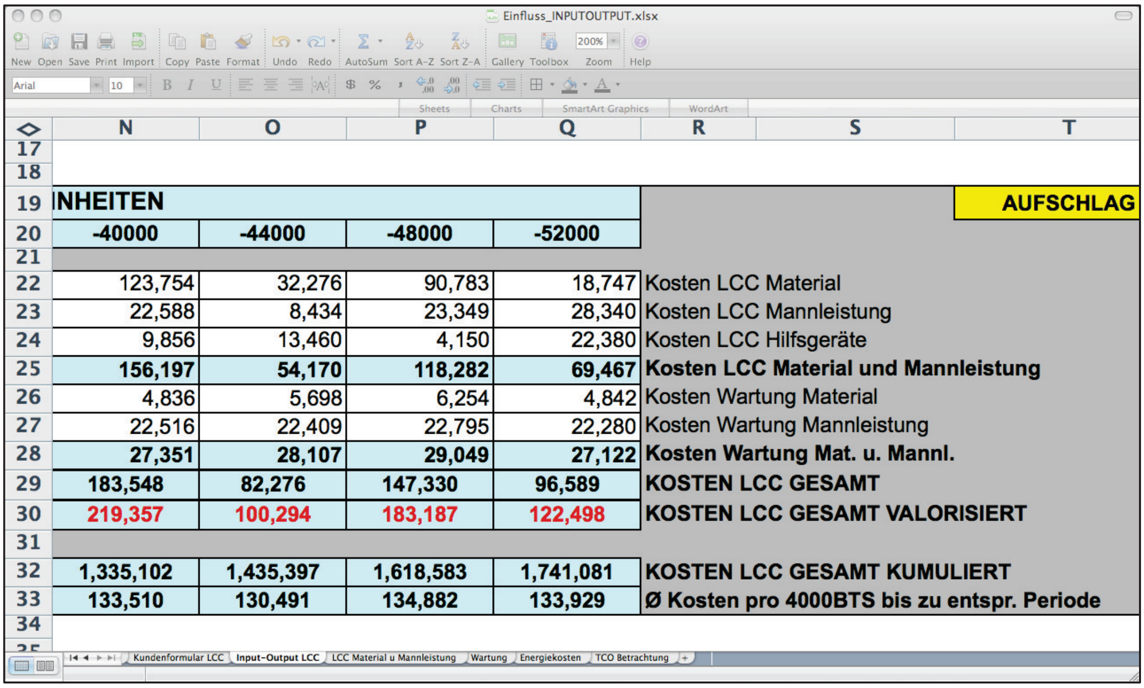
At the end presentation on the 19th of May, the great idea to separate the maintenance costs according to whether they are caused by material, personnel, or AE. Such a classification, carried out for both, scheduled maintenance and maintenance due unexpected exchange, would make the LCC even more transparent for the client.[247]

[244] Result rounded due to suppressed decimals

[245] Compare chapter 4.3.5.2

[246] Conversation, Michael Geiger – Head of Sales, Wolfgang Fink – Head of Service, Kuenz (19/5/2010)

[247] Conversation, Christian Immler – Service, Kuenz (19/5/2010)



	N	O	P	Q	R	S	T
17							
18							
19	INHEITEN						AUFSCHLAG
20	-40000	-44000	-48000	-52000			
21							
22	123,754	32,276	90,783	18,747	Kosten LCC Material		
23	22,588	8,434	23,349	28,340	Kosten LCC Mannleistung		
24	9,856	13,460	4,150	22,380	Kosten LCC Hilfsgeräte		
25	**156,197**	**54,170**	**118,282**	**69,467**	**Kosten LCC Material und Mannleistung**		
26	4,836	5,698	6,254	4,842	Kosten Wartung Material		
27	22,516	22,409	22,795	22,280	Kosten Wartung Mannleistung		
28	**27,351**	**28,107**	**29,049**	**27,122**	**Kosten Wartung Mat. u. Mannl.**		
29	**183,548**	**82,276**	**147,330**	**96,589**	**KOSTEN LCC GESAMT**		
30	**219,357**	**100,294**	**183,187**	**122,498**	**KOSTEN LCC GESAMT VALORISIERT**		
31							
32	**1,335,102**	**1,435,397**	**1,618,583**	**1,741,081**	**KOSTEN LCC GESAMT KUMULIERT**		
33	**133,510**	**130,491**	**134,882**	**133,929**	**Ø Kosten pro 4000BTS bis zu entspr. Periode**		
34							

Figure 4-27 Separated Result of the Maintenance Costs in Material/Personnel/AE Category

Figure 4-27 shows the additional rows in the white cells, which equal, summed up, the turquoise rows of scheduled maintenance costs and maintenance costs due to unexpected replacement, underneath.[248]

The therefore required adaptations in the two maintenance sheets are explained in the following chapter 4.5.3.5.

4.5.3.5 Necessary Changes of the Maintenance Sheets due to the Input

Since the formula of the maintenance sheets had included material, personnel (and AE)[249] in the first place it was necessary to separately calculate them.[250] As the formula calculated sub-results in an OH-matrix,[251] it moreover became necessary to create additional OH-matrices to have separate matrices for material-, personnel- (and AE-) costs, respectively.

[248] Figure 4-27: Row 22-24 = row 25; row 26-27 = row 28; row 27 + 28 = row 29; valorized row 29 = row 30 (compare chapter 4.5.4.1)

[249] Only the sheet maintenance cost due to unexpected replacement includes auxiliary devices

[250] Compare chapters 4.3.11.2 and 4.4.6.1

[251] Compare chapters 4.3.11.3 and 4.4.6.2

Maintenance Costs due to Unexpected Exchange Sheet:

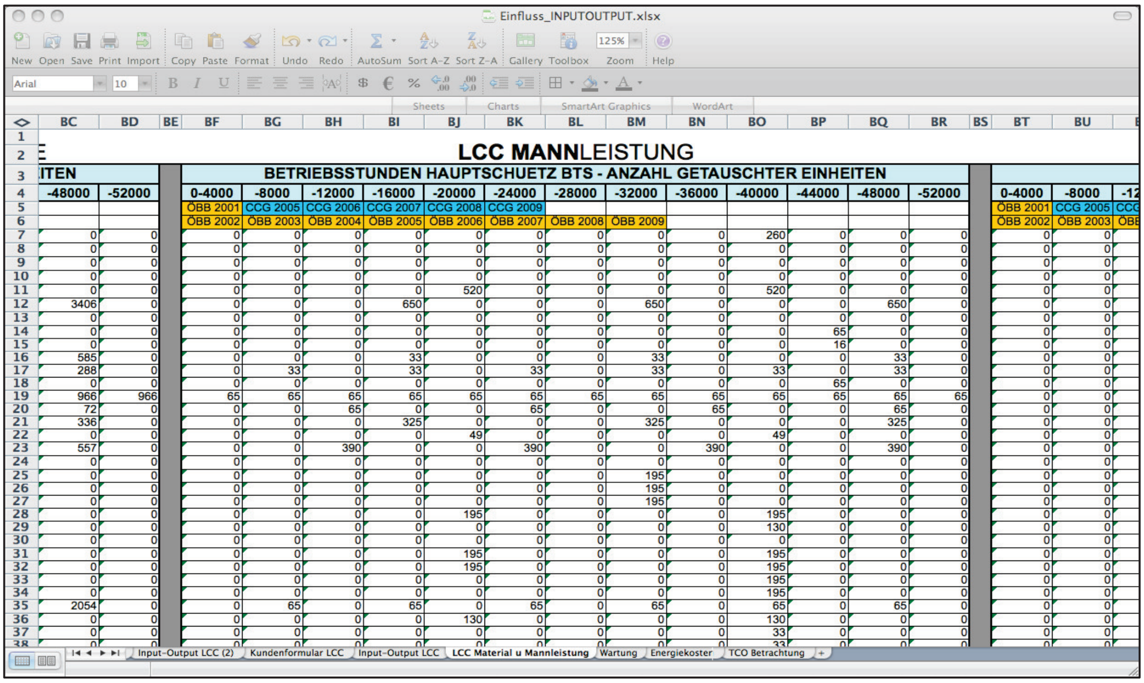


Figure 4-28 Additional OH-matrices for Separating Material/Personnel/AE Costs

Figure 4-28 displays the additional tables. As already mentioned, the added OH-matrices were necessary to have one matrix for each cost part (material, personnel, AE) and, moreover, it was important to keep the original one to verify the results afterwards.

Hence, four matrices would create a huge effort in maintaining the sheet and, especially, in cases of changes. With respect to chapter 4.3.11.3, the first approach was to duplicate the table with the „x“ of the service technicians[252] and to manually insert the formula in every „marked“ cell. Accordingly, a repositioning of one “x” would result in four-times repositioning of the respective formula.

Fortunately, the IT department helped to transform the initial formula into a more general one, which simply checks whether the reference table has “x” in the respective cell, or not. If this is the case, the formula calculates the costs by querying the same elements as the initial formula, illustrated in Figure 4-11 on page 62. If this is not the case, meaning the cell in the reference table is empty, the formula returns „0“.

[252] Compare chapter 4.3.6.2

The exact same procedure was applied for the other three tables with the only exception that the formula only consisted of those elements requested for each table (material-, personnel- and AE costs).

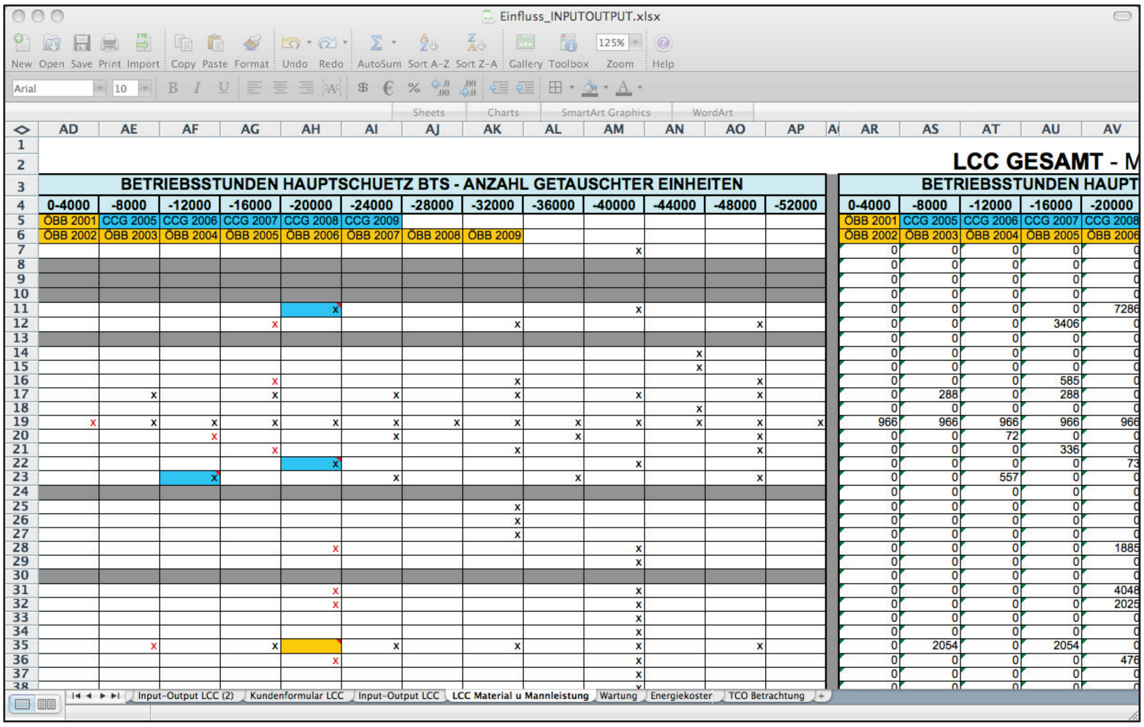


Figure 4-29 Automatic Formula Mechanism for Unexpected Maintenance Costs

As Figure 4-29 illustrates, the cells of the reference table labeled with „x" define the cells of the identical table, which are then filled with the return value calculated by the formula. As mentioned before, every blank cell leads to „0" in the other table.

To summarize, the new approach allows the user to control the maintenance costs in the identical four tables just by managing the „x" in the reference OH-table. For example, if practical experiences show that a part lasts for a duration, different to the duration indicated in the table, the authorized user can change it easily by moving the „x".[253]

<u>Scheduled Maintenance Cost Sheet</u>:

Since the scheduled maintenance activities do not require AE, the second maintenance cost sheet is required to separate the costs in those of material and

[253] Conversation, Wolfgang Fink – Head of Service, Christian Immler – Service, Kuenz (19/5/2010)

those of personnel nature.[254] In accordance to the previous section it follows, that two tables were added for having three tables in overall (material, personnel and total scheduled maintenance costs).

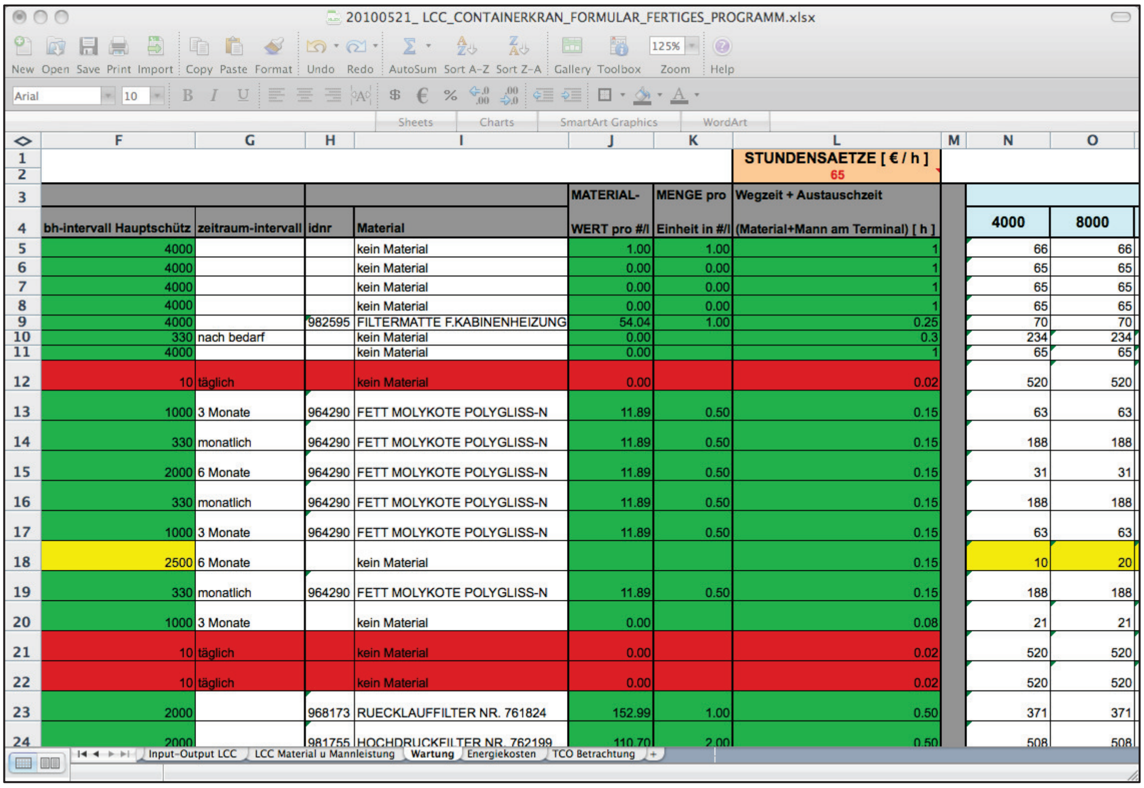
However, it was much more complicated to automate the calculation model for this sheet, because the maintenance intervals were defined by values and not by the „x“ in a reference table.

As a consequence, the required new formula has to check the value of the interval, compare it with the period length of 4.000 OH and, accordingly, either return the calculation value in the respective cell or not. Additionally, the formula had to consider whether there is a difference of the previous 4.000 OH-periods and the cumulated intervals of this maintenance activity until this point.

For example a maintenance interval of 2.500 OH would result in 1 activity in the first but 2 maintenance activities in the second 4.000 OH-period. This can be explained by the fact that **2.500** fits in **0-4.000** whereas both, 2.500+2.500=**5.000** and 2.500+2.500+2.500=**7.500,** fit in the interval **4.000-8.000** OH.

The following Figure 4-30 illustrates the described example, whereby the mentioned difference of the first and second period is marked with the yellow color on the right side. The maintenance interval of 2.500 OH for this activity is defined in the same row on the very left side.

[254] Compare chapter 4.4.2.2



20100521_ LCC_CONTAINERKRAN_FORMULAR_FERTIGES_PROGRAMM.xlsx

	F	G	H	I	J	K	L	M	N	O
1–2							STUNDENSAETZE [€ / h] 65			
3					MATERIAL-	MENGE pro	Wegzeit + Austauschzeit			
4	bh-intervall Hauptschütz	zeitraum-intervall	idnr	Material	WERT pro #/l	Einheit in #/l	(Material+Mann am Terminal) [h]		4000	8000
5	4000			kein Material	1.00	1.00	1		66	66
6	4000			kein Material	0.00	0.00	1		65	65
7	4000			kein Material	0.00	0.00	1		65	65
8	4000			kein Material	0.00	0.00	1		65	65
9	4000		982595	FILTERMATTE F.KABINENHEIZUNG	54.04	1.00	0.25		70	70
10	330	nach bedarf		kein Material	0.00		0.3		234	234
11	4000			kein Material	0.00		1		65	65
12	10	täglich		kein Material	0.00		0.02		520	520
13	1000	3 Monate	964290	FETT MOLYKOTE POLYGLISS-N	11.89	0.50	0.15		63	63
14	330	monatlich	964290	FETT MOLYKOTE POLYGLISS-N	11.89	0.50	0.15		188	188
15	2000	6 Monate	964290	FETT MOLYKOTE POLYGLISS-N	11.89	0.50	0.15		31	31
16	330	monatlich	964290	FETT MOLYKOTE POLYGLISS-N	11.89	0.50	0.15		188	188
17	1000	3 Monate	964290	FETT MOLYKOTE POLYGLISS-N	11.89	0.50	0.15		63	63
18	2500	6 Monate		kein Material			0.15		10	20
19	330	monatlich	964290	FETT MOLYKOTE POLYGLISS-N	11.89	0.50	0.15		188	188
20	1000	3 Monate		kein Material	0.00		0.08		21	21
21	10	täglich		kein Material	0.00		0.02		520	520
22	10	täglich		kein Material	0.00		0.02		520	520
23	2000		968173	RUECKLAUFFILTER NR. 761824	152.99	1.00	0.50		371	371
24	2000		981755	HOCHDRUCKFILTER NR. 762199	110.70	2.00	0.50		508	508

Input-Output LCC | LCC Material u Mannleistung | Wartung | Energiekosten | TCO Betrachtung

Figure 4-30 Automatic Formula Mechanism for Scheduled Maintenance Costs

Ultimately, supported by the IT department, the calculation of the scheduled maintenance costs is fully automatic by now. Adaptations of maintenance intervals can be easily made by just changing the values in the respective green column, visible on the very left in Figure 4-30. This makes a repositioning of the „x", which is required for the other maintenance sheet, unnecessary.

Still, there were two major reasons for keeping the table with „x" for the maintenance sheet due to unexpected replacement. Firstly, the maintenance periods were not as precise as for the scheduled maintenance, where suppliers dictate the timeframe and secondly, is was necessary to slightly adapt the intervals in order to smoothen the cost profile.[255]

4.5.4 Further Input – Time Influence on Costs and Monetary Means

These additional input parameters allow for an influence on the given result by simulating the time influence on monetary means. The user can affect the LCC either by defining a percentage rate, which increasingly affects the costs of the

[255] Compare chapter 4.5.3.2, especially Figure 4-25, p. 82

following years[256] or by defining the changes of the Kuenz prime costs in percent for each year separately.

The first measure considers the point of occurrence of the costs and changes only the output, while the second measure makes the model adaptable for the future, by changing the prime costs in the database.

4.5.4.1 Discount Rate according to the Net Present Value Calculation[257]

In order to consider the point of time when the costs actually occur, it was necessary to introduce a valorization of future costs.[258] Specifically, assumed is that future costs are relatively more affected by the increasing time variance from the base year 2010.

Therefore, both was implemented, an input field, where the user can define a positive or negative discount rate, which is the determining factor of the valorization of future costs and the equation based on this input. The equation follows, hereby, the compound interest theory used also for net present value calculations.

Referring to the definition of chapter 4.3.5.2, 4.000 OH are equal to one year. Therefore a given discount rate (i) would increase future costs by the following Equation 4-1:

$$C_{NV} = C_N \times (1 + i)^N$$

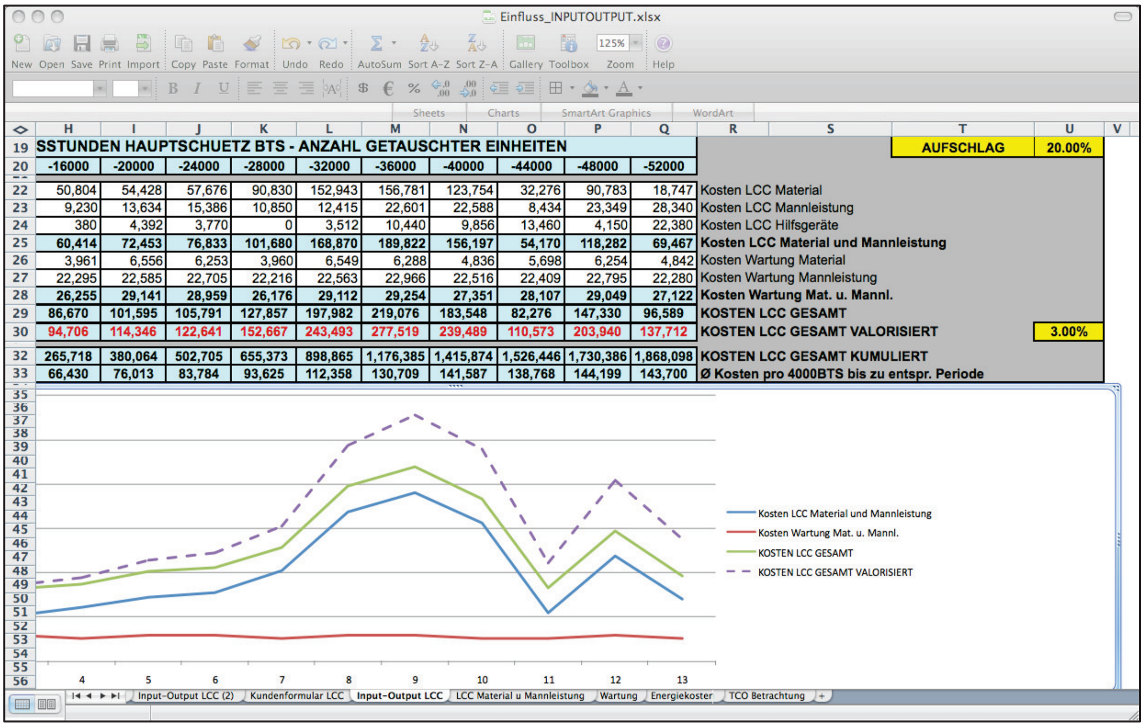
Equation 4-1 Valorization of Future Costs[259]

This means that the valorized costs (C_{NV}) of a given year are equal to the costs of this very year (C_N) multiplied by the time dependency, which is a function of the discount rate (i) entered as the input. More precisely, the time dependency is defined as the sum of 1 and the discount rate (i) to the power of the index of

[256] Compound interest rate, compare BRUEHL (2004), p. 72
[257] Compare BRUEHL (2004), p. 72
[258] Conversation, Michael Geiger – Head of Sales, Kuenz (20/5/2010)
[259] Present value, compare BRUEHL (2004), p. 76

the year (^{N}). N counts from 0, terming the base year 2010, until 11, referring to 2021.

The following Figure 4-31 indicates the valorized LCC (C_{NV}), the basis LCC (C_N) as well as the respective discount rate.



	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
19	SSTUNDEN HAUPTSCHUETZ BTS - ANZAHL GETAUSCHTER EINHEITEN												AUFSCHLAG	20.00%
20	-16000	-20000	-24000	-28000	-32000	-36000	-40000	-44000	-48000	-52000				
22	50,804	54,428	57,676	90,830	152,943	156,781	123,754	32,276	90,783	18,747	Kosten LCC Material			
23	9,230	13,634	15,386	10,850	12,415	22,601	22,588	8,434	23,349	28,340	Kosten LCC Mannleistung			
24	380	4,392	3,770	0	3,512	10,440	9,856	13,460	4,150	22,380	Kosten LCC Hilfsgeräte			
25	60,414	72,453	76,833	101,680	168,870	189,822	156,197	54,170	118,282	69,467	Kosten LCC Material und Mannleistung			
26	3,961	6,556	6,253	3,960	6,549	6,288	4,836	5,698	6,254	4,842	Kosten Wartung Material			
27	22,295	22,585	22,705	22,216	22,563	22,966	22,516	22,409	22,795	22,280	Kosten Wartung Mannleistung			
28	26,255	29,141	28,959	26,176	29,112	29,254	27,351	28,107	29,049	27,122	Kosten Wartung Mat. u. Mannl.			
29	86,670	101,595	105,791	127,857	197,982	219,076	183,548	82,276	147,330	96,589	KOSTEN LCC GESAMT			
30	94,706	114,346	122,641	152,667	243,493	277,519	239,489	110,573	203,940	137,712	KOSTEN LCC GESAMT VALORISIERT			3.00%
32	265,718	380,064	502,705	655,373	898,865	1,176,385	1,415,874	1,526,446	1,730,386	1,868,098	KOSTEN LCC GESAMT KUMULIERT			
33	66,430	76,013	83,784	93,625	112,358	130,709	141,587	138,768	144,199	143,700	Ø Kosten pro 4000BTS bis zu entspr. Periode			

Figure 4-31 Valorization of the LCC

The valorized LCC are highlighted by the red font and directly underneath of the basis LCC, calculated as the sum of the maintenance costs of chapter 4.3 and 4.4.[260]

Figure 4-31 (column U, row 30) also indicates the discount rate, the determining factor of the valorization. The yellow marked percentage gives the user another input parameter to customize the calculation model to a given practical situation.

4.5.4.2 Yearly Changes of Kuenz Prime Costs

The idea of the second additional input parameters was to make the prime cost basis of the calculation model easily adaptable for the next years.

Since the prime costs are supposed to change from year to year, the effort to change all positions in the database would be extraordinary.[261] Therefore, it was

[260] Compare chapter 4.1.2

necessary to implement a table representing the percent changes of the prime costs each year.

Figure 4-32 shows the new input parameters in the yellow cells.

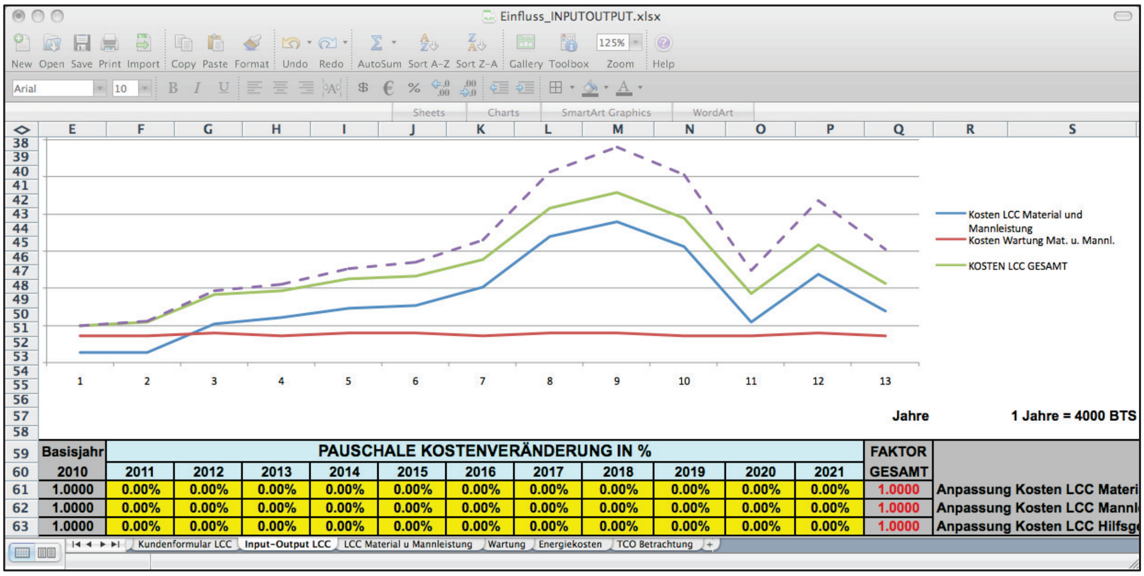


Figure 4-32 Possible Input Parameters for Adapting Kuenz Prime Costs

Specifically, the three rows represent the prime cost changes for material, personnel and AE. However, the functionality behind these three rows is the same.

All costs implemented in the maintenance sheets represent the values from the year 2010. The table, therefore, offers the possibility to enter an individual change in percent of material, personnel and AE costs for every year. The changes, executed at this table, directly influence the respective stored data.

Particularly, the factors, calculated from the basis 2010 (Figure 4-32 column E), and the changes in percent of each individual year, directly affect the calculation. Figure 4-32 shows the resulting factor, which is queried by the prime costs in the DBs, in the red font on the very right side (column Q).

In short, this additional input table ensures the utility and actuality of the calculation model in future, by avoiding maintenance effort of the costs in the databases.[262]

[261] Conversation, Artur Rauter – Head of Controlling, Kuenz (14/4/2010)

[262] Conversation, Artur Rauter – Head of Controlling, Kuenz (14/4/2010)

4.5.5 Data and Information Field

The last part of the I/O interface is simply an inserted table to specify the crane and the project. The information field is classified in two tables, representing basic data and technical data.

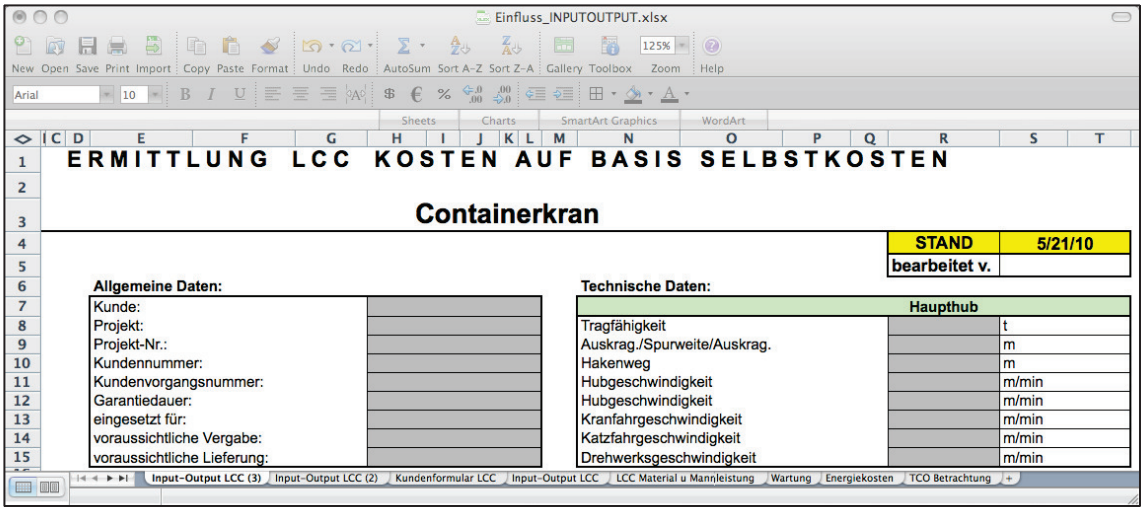


Figure 4-33 Data and Information Field

4.5.6 Final Input/Output (I/O) Interface

Finally, the last section of chapter 4.5 shall provide an overview of the sheet with it components. The following Figure 4-34 illustrates an overview of the whole user's interface.

Im Kran verbaute Elemente	
STROMZUFÜHRUNG PORTAL	
Motorleitungstrommel/ULV A oder	1
Motorleitungstrommel/ULV B	0
STROMZUFÜHRUNG KATZE	
Energiekette A oder	0
Kabelschlepp B	1
KRANFAHRWERK	
Anzahl Treiblaufsatz + Antriebe	12
Anzahl Mitlaufsatz	12
Anzahl Horizontalrollen	16
Laufrad 500 oder	0
Laufrad 630 oder	1
Laufrad 710	0
Antrieb A Größe 1 oder	0
Antrieb A Größe 2 oder	1
Antrieb A Größe 3 oder	0
Antrieb B Größe 1 oder	0
Antrieb B Größe 2	0
KATZFAHRWERK	
Anzahl Treiblaufsatz + Antriebe	4
Anzahl Mitlaufsatz	4
Anzahl Horizontalrollen	4
Laufrad Größe 1 oder	1
Laufrad Größe 2 oder	0
Laufrad Größe 3	0
Antrieb A Größe 1 oder	1
Antrieb A Größe 2 oder	0
Antrieb A Größe 3 oder	0
Antrieb B Größe 1 oder	0
Antrieb B Größe 2	0
SCHIENENZANGE	
A oder	1
B	0
HUBWERKSBREMSE (Betriebsbremse)	
A oder	1
B	0
HUBWERKSGETRIEBE	
A oder	0
B	1
KRANKABINE	
A oder	1
B	0
JA oder	1
NEIN	0
ANZAHL STUNDEN JÄHRLICH	2,080
ERSATZTEILPAKET	
JA oder	0
NEIN	1
WERT ERSATZTEILPAKET IN €	20,000

STAND	5/21/10

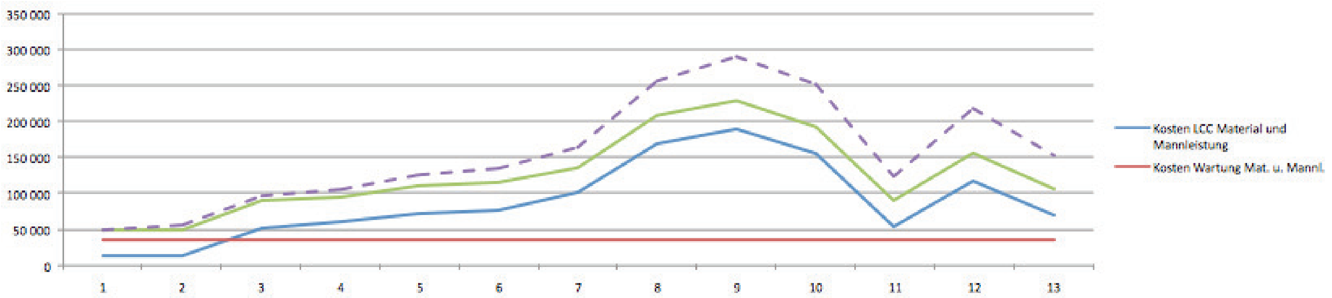
Allgemeine Daten:

Kunde:	
Projekt:	
Projekt-Nr.:	
Kundennummer:	
Kundenvorgangsnummer:	
Garantiedauer:	
eingesetzt für:	
voraussichtliche Vergabe:	
voraussichtliche Lieferung:	

Technische Daten:

	Haupthub	
Tragfähigkeit		t
Auskrag./Spurweite/Auskrag.		m
Hakenweg		m
Hubgeschwindigkeit		m/min
Hubgeschwindigkeit		m/min
Kranfahrgeschwindigkeit		m/min
Katzfahrgeschwindigkeit		m/min
Drehwerksgeschwindigkeit		m/min

BETRIEBSSTUNDEN HAUPTSCHUETZ BTS - ANZAHL GETAUSCHTER EINHEITEN													AUFSCHLAG 20.00%
0-4000	-8000	-12000	-16000	-20000	-24000	-28000	-32000	-36000	-40000	-44000	-48000	-52000	
13,565	15,261	40,576	50,804	54,428	57,676	90,830	152,943	156,781	123,754	32,276	90,783	18,747	Kosten LCC Material
65	358	8,984	9,230	13,634	15,386	10,850	12,415	22,601	22,588	8,434	23,349	28,340	Kosten LCC Mannleistung
0	0	1,830	380	4,392	3,770	0	3,512	10,440	9,856	13,460	4,150	22,380	Kosten LCC Hilfsgeräte
13,630	15,618	51,390	60,414	72,453	76,833	101,680	168,870	189,822	156,197	54,170	118,282	69,467	**Kosten LCC Material und Mannleistung**
3,960	5,698	7,101	3,961	6,556	6,253	3,960	6,549	6,288	4,836	5,698	6,254	4,842	Kosten Wartung Material
32,074	32,385	32,834	32,204	32,623	32,796	32,090	32,590	33,173	32,523	32,369	32,926	32,182	Kosten Wartung Mannleistung
36,034	38,083	39,935	36,164	39,179	39,050	36,050	39,139	39,461	37,358	38,066	39,180	37,024	**Kosten Wartung Mat. u. Mannl.**
49,664	53,701	91,325	96,578	111,632	115,883	137,730	208,010	229,283	193,555	92,236	157,462	106,491	**KOSTEN LCC GESAMT**
49,664	55,312	96,887	105,534	125,643	134,340	164,457	255,826	290,449	252,546	123,957	217,964	151,830	**KOSTEN LCC GESAMT VALORISIERT** 3.00%
49,664	104,976	201,862	307,396	433,039	567,379	731,836	987,662	1,278,111	1,530,657	1,654,615	1,872,579	2,024,409	**KOSTEN LCC GESAMT KUMULIERT**
49,664	52,488	67,287	76,849	86,608	94,563	104,548	123,458	142,012	153,066	150,420	156,048	155,724	**Ø Kosten pro 4000BTS bis zu entspr. Periode**



1 Jahre = 4000 BTS

Basisjahr	PAUSCHALE KOSTENVERÄNDERUNG IN %											FAKTOR	
2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	GESAMT	
1.0000	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.0000	**Anpassung Kosten LCC Material**
1.0000	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.0000	**Anpassung Kosten LCC Mannleistung**
1.0000	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.0000	**Anpassung Kosten LCC Hilfsgeräte**

Figure 4-34 Overview of the Final I/O Interface of the Calculation Model

The yellow boxes on the left side of Figure 4-34 show the characterization input of the crane.[263]

The result, as the output, is centrally outlined in the most turquoise rows inclusive the attached diagram.[264]

Further input parameters are at the bottom and implemented in the result section on the right side (yellow cells).[265]

Finally, the data and information field can be found on the very top.[266]

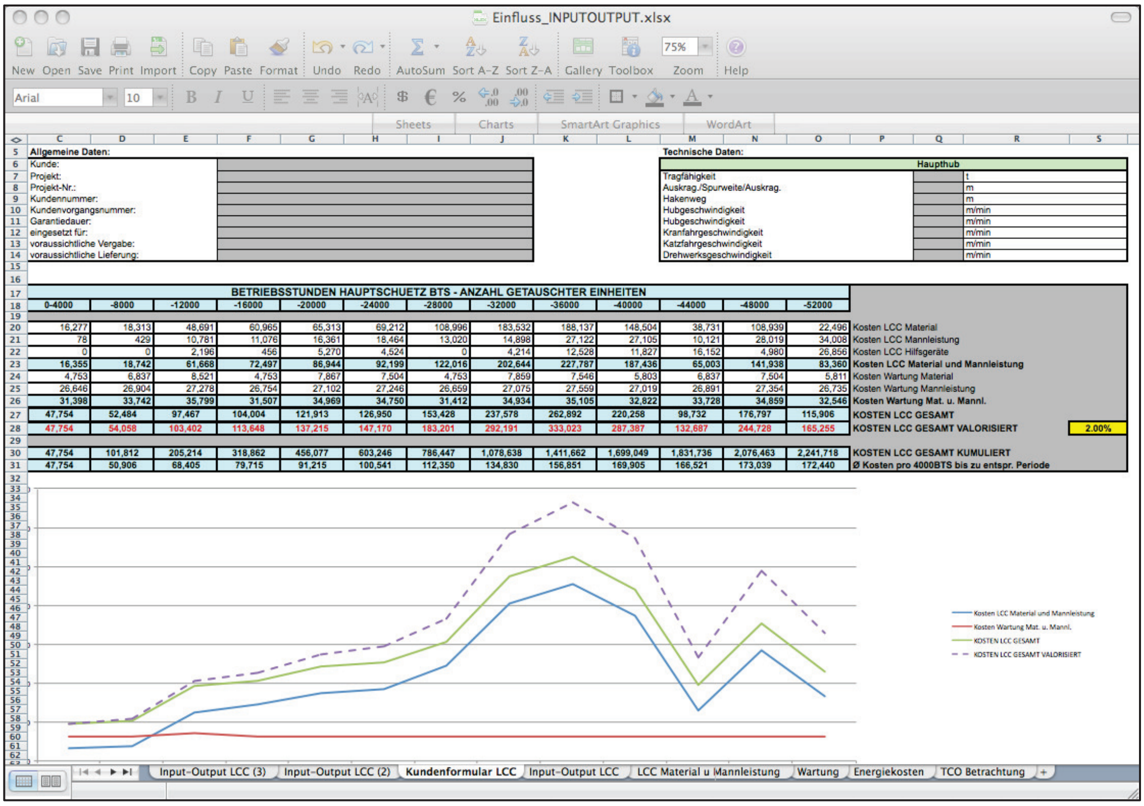
4.6 Customer Sheet

The customer sheet of the model is a printable form for the client. Basically, it displays the results without the input parameters.[267] However, the LCC result, displayed on the customer sheet, can be increased by a desired profit margin.

The basic idea for a separate customer sheet was to protect sensitive data, by copying only the necessary information for the client of the I/O interface. Moreover, as Figure 4-34 demonstrates, the I/O interface is quite complex.

Consequently, the I/O interface is the Kuenz user's environment, which allows to adapt the crane towards the wishes/circumstances of the customer, while the customer sheet is the result he finally gets.

[263] Compare chapter 4.5.2
[264] Compare chapter 4.5.3
[265] Compare chapter 4.5.4
[266] Compare chapter 4.5.5
[267] Compare chapter 4.5



Allgemeine Daten:
Kunde:
Projekt:
Projekt-Nr.:
Kundennummer:
Kundenvorgangsnummer:
Garantiedauer:
eingesetzt für:
voraussichtliche Vergabe:
voraussichtliche Lieferung:

Technische Daten:

		Haupthub
Tragfähigkeit		t
Auskrag./Spurweite/Auskrag.		m
Hakenweg		m
Hubgeschwindigkeit		m/min
Hubgeschwindigkeit		m/min
Kranfahrgeschwindigkeit		m/min
Katzfahrgeschwindigkeit		m/min
Drehwerksgeschwindigkeit		m/min

BETRIEBSSTUNDEN HAUPTSCHUETZ BTS - ANZAHL GETAUSCHTER EINHEITEN

0-4000	-8000	-12000	-16000	-20000	-24000	-28000	-32000	-36000	-40000	-44000	-48000	-52000		
16,277	18,313	48,691	60,965	65,313	69,212	108,996	183,532	188,137	148,504	38,731	108,939	22,496	Kosten LCC Material	
78	429	10,781	11,076	16,361	18,464	13,020	14,898	27,122	27,105	10,121	28,019	34,008	Kosten LCC Mannleistung	
0	0	2,196	456	5,270	4,524	0	4,214	12,528	11,827	16,152	4,980	26,856	Kosten LCC Hilfsgeräte	
16,355	18,742	61,668	72,497	86,944	92,199	122,016	202,644	227,787	187,436	65,003	141,938	83,360	Kosten LCC Material und Mannleistung	
4,753	6,837	8,521	4,753	7,867	7,504	4,753	7,859	7,546	5,803	6,837	7,504	5,811	Kosten Wartung Material	
26,646	26,904	27,278	26,754	27,102	27,246	26,659	27,075	27,559	27,019	26,891	27,354	26,735	Kosten Wartung Mannleistung	
31,398	33,742	35,799	31,507	34,969	34,750	31,412	34,934	35,105	32,822	33,728	34,859	32,546	Kosten Wartung Mat. u. Mannl.	
47,754	52,484	97,467	104,004	121,913	126,950	153,428	237,578	262,892	220,258	98,732	176,797	115,906	KOSTEN LCC GESAMT	
47,754	54,058	103,402	113,648	137,215	147,170	183,201	292,191	333,023	287,387	132,687	244,728	165,255	KOSTEN LCC GESAMT VALORISIERT	2.00%
47,754	101,812	205,214	318,862	456,077	603,246	786,447	1,078,638	1,411,662	1,699,049	1,831,736	2,076,463	2,241,718	KOSTEN LCC GESAMT KUMULIERT	
47,754	50,906	68,405	79,715	91,215	100,541	112,350	134,830	156,851	169,905	166,521	173,039	172,440	Ø Kosten pro 4000BTS bis zu entspr. Periode	

Figure 4-35 Overview of the Customer Sheet

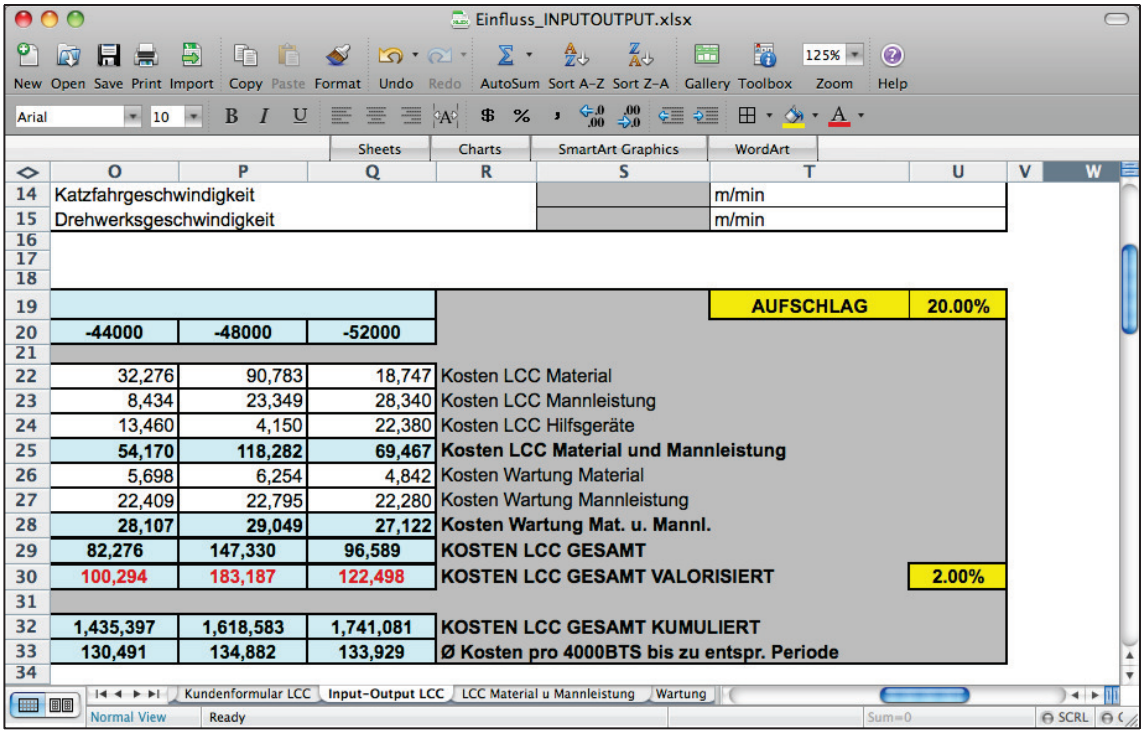
As the overview of Figure 4-35 illustrates, the sheet includes exactly the same LCC structure as the output of the I/O interface, introduced in chapter 4.5.3.

As previously mentioned, a defined profit margin in the I/O interface directly influences the whole table by increasing every cell of the result LCC by the defined percentage. Hence, the customer sheet represents a full costing basis, whereas the I/O interface remains on prime cost basis.[268] [269]

The following Figure 4-36 indicates the implemented profit percentage in the yellow box „AUFSCHLAG".

[268] Compare chapter 3.4.1 – "Full (Absorption) Costing"

[269] Conversation, Michael Geiger – Head of Sales, Kuenz (19/5/2010)



Einfluss_INPUTOUTPUT.xlsx

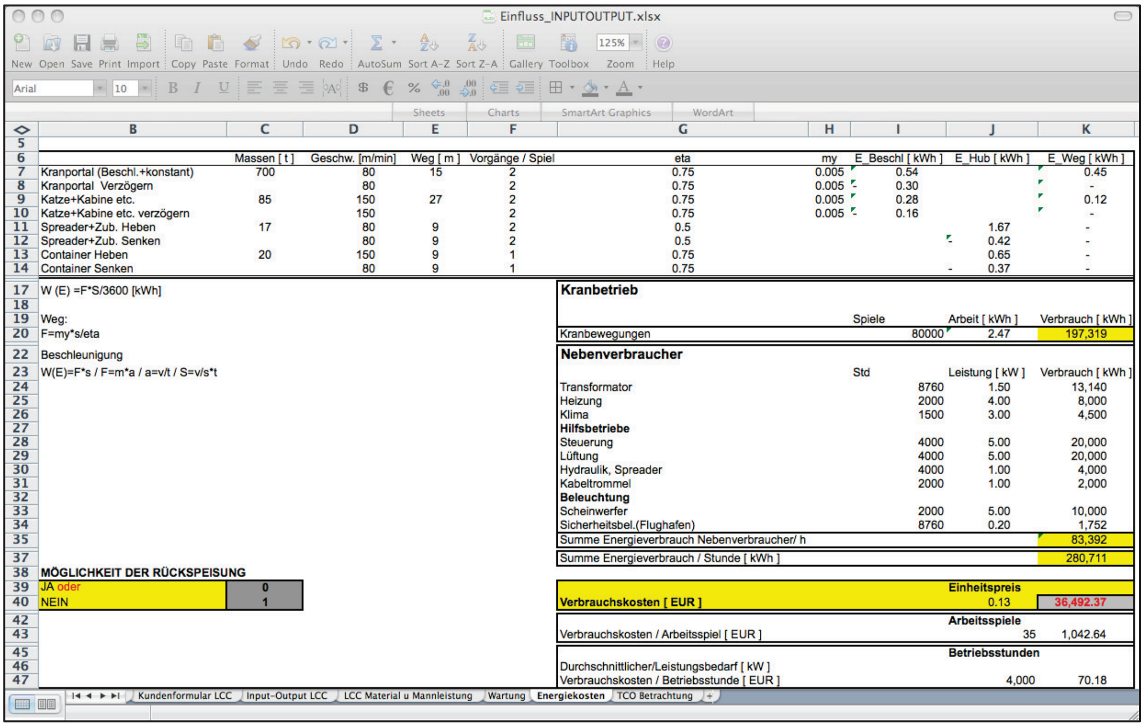
	O	P	Q	R	T	U
14	Katzfahrgeschwindigkeit				m/min	
15	Drehwerksgeschwindigkeit				m/min	
16						
17						
18						
19					AUFSCHLAG	20.00%
20	-44000	-48000	-52000			
21						
22	32,276	90,783	18,747	Kosten LCC Material		
23	8,434	23,349	28,340	Kosten LCC Mannleistung		
24	13,460	4,150	22,380	Kosten LCC Hilfsgeräte		
25	**54,170**	**118,282**	**69,467**	**Kosten LCC Material und Mannleistung**		
26	5,698	6,254	4,842	Kosten Wartung Material		
27	22,409	22,795	22,280	Kosten Wartung Mannleistung		
28	**28,107**	**29,049**	**27,122**	**Kosten Wartung Mat. u. Mannl.**		
29	**82,276**	**147,330**	**96,589**	**KOSTEN LCC GESAMT**		
30	**100,294**	**183,187**	**122,498**	**KOSTEN LCC GESAMT VALORISIERT**		**2.00%**
31						
32	**1,435,397**	**1,618,583**	**1,741,081**	**KOSTEN LCC GESAMT KUMULIERT**		
33	**130,491**	**134,882**	**133,929**	**Ø Kosten pro 4000BTS bis zu entspr. Periode**		
34						

Kundenformular LCC | Input-Output LCC | LCC Material u Mannleistung | Wartung

Figure 4-36 Input of the Profit Percentage

4.7 Energy Cost Sheet

The energy cost sheet is a calculation sheet to compute the annual energy costs of an RMG, based on the corresponding scheme of Kuenz.



	Massen [t]	Geschw. [m/min]	Weg [m]	Vorgänge / Spiel	eta	my	E_Beschl [kWh]	E_Hub [kWh]	E_Weg [kWh]
Kranportal (Beschl.+konstant)	700	80	15	2	0.75	0.005	0.54		0.45
Kranportal Verzögern		80		2	0.75	0.005	0.30		-
Katze+Kabine etc.	85	150	27	2	0.75	0.005	0.28		0.12
Katze+Kabine etc. verzögern		150		2	0.75	0.005	0.16		-
Spreader+Zub. Heben	17	80	9	2	0.5			1.67	-
Spreader+Zub. Senken		80	9	2	0.5			0.42	-
Container Heben	20	150	9	1	0.75			0.65	-
Container Senken		80	9	1	0.75			0.37	-

W (E) =F*S/3600 [kWh]

Weg:
F=my*s/eta

Beschleunigung
W(E)=F*s / F=m*a / a=v/t / S=v/s*t

MÖGLICHKEIT DER RÜCKSPEISUNG

JA oder	0
NEIN	1

Kranbetrieb

	Spiele	Arbeit [kWh]	Verbrauch [kWh]
Kranbewegungen	80000	2.47	197,319

Nebenverbraucher

	Std	Leistung [kW]	Verbrauch [kWh]
Transformator	8760	1.50	13,140
Heizung	2000	4.00	8,000
Klima	1500	3.00	4,500
Hilfsbetriebe			
Steuerung	4000	5.00	20,000
Lüftung	4000	5.00	20,000
Hydraulik, Spreader	4000	1.00	4,000
Kabeltrommel	2000	1.00	2,000
Beleuchtung			
Scheinwerfer	2000	5.00	10,000
Sicherheitsbel.(Flughafen)	8760	0.20	1,752
Summe Energieverbrauch Nebenverbraucher/ h			83,392
Summe Energieverbrauch / Stunde [kWh]			280,711
		Einheitspreis	
Verbrauchskosten [EUR]		0.13	36,492.37
		Arbeitsspiele	
Verbrauchskosten / Arbeitsspiel [EUR]		35	1,042.64
		Betriebsstunden	
Durchschnittlicher/Leistungsbedarf [kW]			
Verbrauchskosten / Betriebsstunde [EUR]		4,000	70.18

Figure 4-37 Energy Cost Sheet[270]

The energy costs are calculated as a function of the characteristics of the crane as well as its performance. Additionally, small standby energy consumers are considered as a lump sum.[271]

It follows that the necessary input for this sheet is crane specifications as well as the costs for a unit of energy.[272] Moreover, it can be selected whether the electricity provider supports an energy recover system or not. For example, „Électricité de France“ (EDF), the leading electricity provider in France,[273] does not support energy recovery, while it is supported in Austria and Germany.[274]

However, where applicable, energy costs can be decreased by 10% due to a kinetic energy recovery system integrated in the crane.[275]

270 Based on the scheme developed by Werner Buechele – Electronics, Kuenz

271 Conversation, Werner Buechele – Electronics, Kuenz (18/5/2010)

272 Measured in kWH

273 Compare www.edf.fr (8/11/2010)

274 Conversation, Michael Geiger – Head of Sales, Kuenz (19/5/2010)

275 Conversation, Werner Buechele – Electronics, Kuenz (19/5/2010)

4.8 Total Cost of Ownership (TCO) Sheet

According to the objectives of this thesis, introduced in chapter 1.3, the TCO investigation was the second main target, based on the LCC calculation. Consequently, the last MS Excel sheet offers also a kind of conclusion, by computing the total costs as well as by comparing the different cost types.

4.8.1 Introduction

Referring to the working definitions of LCC and TCO, introduced in chapter 3.5.3.2, the LCC calculated in the I/O interface, represent a part of the TCO. As a consequence and in accordance with the definition, TCO consists at least out of the following costs:[276]

- LCC
- Purchase Costs
- Personnel Costs
- Energy Costs
- Disposal Costs

4.8.2 Calculation

In accordance to the previous chapter, the TCO were fairly easy to calculate by summing up the individual cost positions. However, since the final aim of the objectives for this thesis was to calculate the total costs per twenty-foot equivalent unit (TEU),[277] it was necessary to introduce a time constraint.

4.8.2.1 Investigation Period of 10 Years

Because of the LCC results and the fact that container cranes face a technology leap every 10-15 years, a 10 years time horizon was implemented.

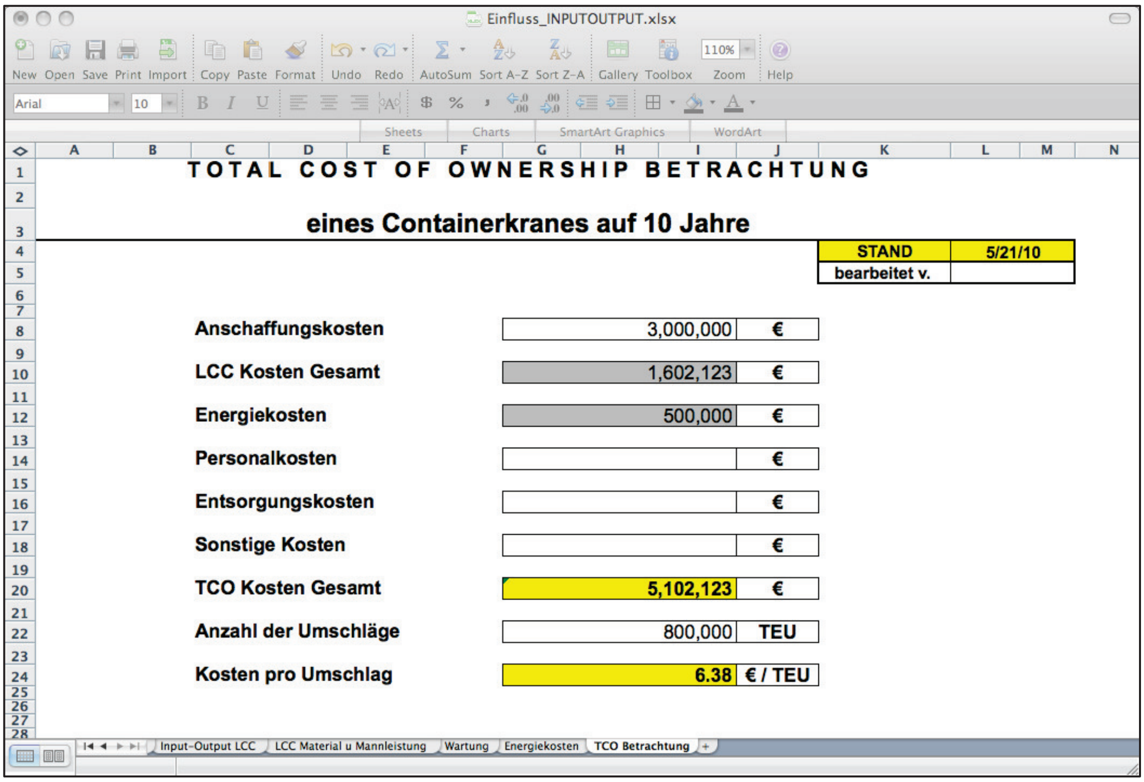
A longer time period could be also risky for major mechanical parts such as, big bolts and axis of the driving assembly.[278]

[276] Compare chapter 3.5.3.2
[277] Compare chapter 1.3
[278] Conversation, Peter Lerchmueller – Engineering, Kuenz (10/2/2010)

As a result, all cost positions as well as the TEUs had to be calculated on the basis of ten years. The assumption, hereby, was that an RMG handles in average 80.000 TEUs per year.[279]

4.8.2.2 Calculation Approach and Results

Basically, the calculation comprises a summing up of the TCO for 10 years. In order to get the requested costs per TEU, the total costs were then divided by the total TEUs for 10 years. Figure 4-38 shows the cost positions, the resulting TCO and, finally, the costs per TEU.



TOTAL COST OF OWNERSHIP BETRACHTUNG

eines Containerkranes auf 10 Jahre

STAND	5/21/10	
bearbeitet v.		
Anschaffungskosten	3,000,000	€
LCC Kosten Gesamt	1,602,123	€
Energiekosten	500,000	€
Personalkosten		€
Entsorgungskosten		€
Sonstige Kosten		€
TCO Kosten Gesamt	5,102,123	€
Anzahl der Umschläge	800,000	TEU
Kosten pro Umschlag	6.38	€ / TEU

Figure 4-38 TCO Sheet

The result of the LCC and the energy costs represent calculated values of the other sheets whereas the purchase, personnel, disposal and miscellaneous costs are cost positions, which can directly filled into the form.

As Figure 4-38 also indicates, the result of the TCO investigation is the costs of one handled TEU of the crane system. This represents an important key-value, which allows a comparison to other container handling equipment as well as to competitors in the RMG domain.

[279] Conversation, Wolfgang Fink – Head of Service, Kuenz (17/5/2010)

5 Calculation Model

According to chapter 1.3, the objectives of this thesis were to develop a calculation model for the maintenance costs of a container crane and, based on that, a TCO investigation. Chapter 4 implicated a chronologically and detailed discussion of how the targets were fulfilled. However, the following section will focus on a brief description of the final model.

5.1 Assumptions for the Calculation Model

First of all, to define the scope to an appropriated scale for an investigation, it was necessary to make assumptions. For example, the effect of environmental influences or the skills of the operator personnel on certain lifetime spans needed to be considered. Moreover, regarding the actual calculation, it was necessary to introduce constraints to get a significant result. The main issue was the difficulty to predict the costs occurring due to maintenance of unexpected exchange.[280]

To sum up, the assumptions that were considered are briefly listed:

1. The length of the investigation period is 52.000 OH for the LCC[281] and finally 10 years for the TCO investigation.[282]
2. The rails, on which the Rail Mounted Gantry Crane operates, are in perfect condition and are not within the responsibility of Kuenz.
3. The appropriated handling of the crane is assumed as well as excellent trained crane operators.
4. Significant unusual malfunctions and damages are not considered.
5. The steel-structure of the crane remains in perfect condition until the end of the investigated timeframe.[283]
6. Hourly wage-rates for maintenance, introduced in chapter 4.3.8, as well as the costs for may required AE[284] are based on average values of the geographical region of central Europe.

[280] Compare chapter 4.1.2.2
[281] 4000 OH = 1 year, compare chapter 4.3.5
[282] Compare chapter 4.8.2.1
[283] Compare chapter 4.3.3.1

7. The service personnel, in charge of performing the maintenance, are located directly at or nearby the terminal.[285]
8. Small wear and tear parts, in terms of monetary amount, are separately considered as a lump sum.[286]

5.2 Structure of the Model

As the development of the calculation model was already described in Chapter 4, this section introduces the resulting MS Excel sheets as well as their correlations.

The model consists out of the following six integrated MS Excel sheets:

- I/O Interface
- Customer Sheet
- Maintenance Costs due to Unexpected Replacement Sheet
- Scheduled Maintenance Cost Sheet
- Energy Cost Sheet
- TCO Sheet

Figure 5-1 shows the correlation of the MS Excel sheets:

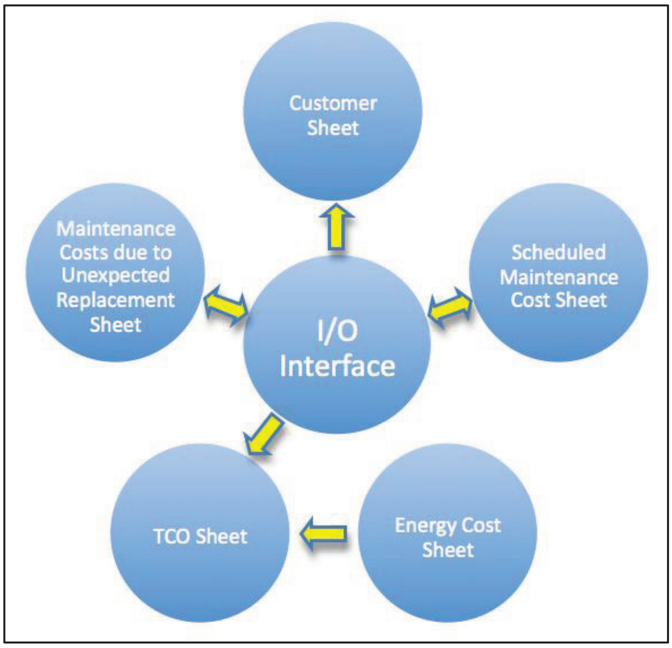


Figure 5-1 Correlations of the MS Excel Sheets[287]

[284] Mobil crane, lifting platform and forklift truck; compare chapter 4.3.8
[285] Compare chapter 4.3.6.2
[286] Compare chapter 4.3.3.1

The I/O interface is both, the central control unit of the calculation model as well as the output of the LCC, directly affected by the input. Specifically, the user can choose certain characterizations of the crane, which directly influence either the calculation or the data stored in the two maintenance cost sheets. Additionally, the results of both maintenance sheets, which can be also seen as databases with an enclosed calculation, are returned and summed up as the output on the I/O interface.

The customer sheet is simply a copy of the I/O interface's result without the input parameters. However, since the LCC on the I/O interface are calculated on a prime cost basis, the displayed result on the customer sheet can be margined by a percentage.[288]

As the LCC is a part of the TCO according to the working definition,[289] the TCO sheet queries the resulting LCC and also the result of the independent energy cost sheet.

5.2.1 Input/Output (I/O) Interface[290]

Basically, the I/O interface is the heart piece of the calculation model and intended for the interaction of the user. The aim of the MS Excel sheet is to provide a tool to calculate the LCC for an RMG, as a function of variable main characteristics.

5.2.1.1 Input Parameters

The input parameters are primarily connected with the stored data in the two maintenance sheets and, consequently, affect the resulting LCC.[291]

The following three categories of input parameter are implemented in the I/O interface:

1. Characterization of the Crane (and the Full-maintenance Contract)
2. Time Influence on Costs and Monetary Means
3. Percentage as the Marginal Profit

---

[287] Own illustration
[288] Compare chapter 4.6
[289] Compare chapter 3.5.3.2
[290] Compare chapter 4.5
[291] Compare chapter 4.3.1

Characterization of the Crane (and the Full-maintenance Contract):[292]

These input parameters work either in an ex-or fashion, choosing one out of two suppliers, or by entering a value, necessary for defining the number of wheels. The following characterization categories are implemented in the I/O interface:

- Power Supply of the Gantry
- Power Supply of the Trolley
- Gantry Carriage
- Trolley Carriage
- Rail Tongs
- Hoisting Gear Operation Brakes
- Hoisting Gearbox
- Crane Cabin
- Hotline
- Spare Part Kit

The last two input categories, referring to the options of a service hotline and an initial spare part kit, are rather related to the full-maintenance contract, than to the actual crane.[293]

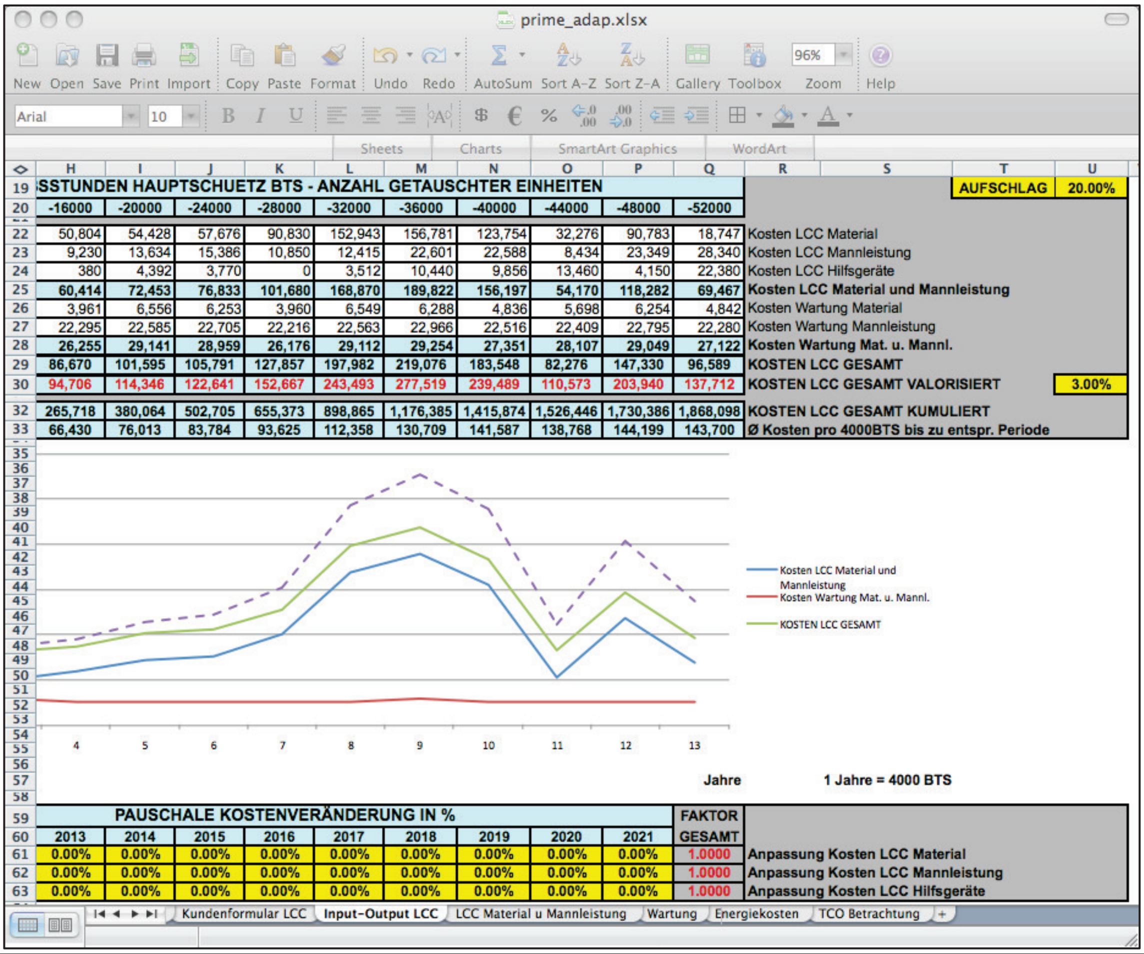
Time Influence on Costs and Monetary Means:[294]

Since the LCC investigation takes place over a timeframe of 52.000 OH, it was perfectly reasonable to also take the time influence on monetary means into consideration. Consequently, the I/O interface offers two different input options in this regard:

- A Discount Rate Referring to the Net-present Value Calculation[295]
- Yearly (Separate) Percent Changes of the Kuenz Prime Costs[296]

The following Figure 5-2 indicates the discount rate in the yellow box on the right side (column U, row 30), and the yearly changes of the prime costs on the bottom in the yellow boxes (underneath the diagram).

[292] Compare chapter 4.5.2
[293] Compare chapter 4.5.2.1
[294] Compare chapter 4.5.4
[295] Compare chapter 4.5.4.1
[296] Compare chapter 4.5.4.2



	H	I	J	K	L	M	N	O	P	Q	R
19	SSTUNDEN HAUPTSCHUETZ BTS - ANZAHL GETAUSCHTER EINHEITEN										AUFSCHLAG 20.00%
20	-16000	-20000	-24000	-28000	-32000	-36000	-40000	-44000	-48000	-52000	
22	50,804	54,428	57,676	90,830	152,943	156,781	123,754	32,276	90,783	18,747	Kosten LCC Material
23	9,230	13,634	15,386	10,850	12,415	22,601	22,588	8,434	23,349	28,340	Kosten LCC Mannleistung
24	380	4,392	3,770	0	3,512	10,440	9,856	13,460	4,150	22,380	Kosten LCC Hilfsgeräte
25	60,414	72,453	76,833	101,680	168,870	189,822	156,197	54,170	118,282	69,467	Kosten LCC Material und Mannleistung
26	3,961	6,556	6,253	3,960	6,549	6,288	4,836	5,698	6,254	4,842	Kosten Wartung Material
27	22,295	22,585	22,705	22,216	22,563	22,966	22,516	22,409	22,795	22,280	Kosten Wartung Mannleistung
28	26,255	29,141	28,959	26,176	29,112	29,254	27,351	28,107	29,049	27,122	Kosten Wartung Mat. u. Mannl.
29	86,670	101,595	105,791	127,857	197,982	219,076	183,548	82,276	147,330	96,589	KOSTEN LCC GESAMT
30	94,706	114,346	122,641	152,667	243,493	277,519	239,489	110,573	203,940	137,712	KOSTEN LCC GESAMT VALORISIERT 3.00%
32	265,718	380,064	502,705	655,373	898,865	1,176,385	1,415,874	1,526,446	1,730,386	1,868,098	KOSTEN LCC GESAMT KUMULIERT
33	66,430	76,013	83,784	93,625	112,358	130,709	141,587	138,768	144,199	143,700	Ø Kosten pro 4000BTS bis zu entspr. Periode

	PAUSCHALE KOSTENVERÄNDERUNG IN %									FAKTOR	
60	2013	2014	2015	2016	2017	2018	2019	2020	2021	GESAMT	
61	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.0000	Anpassung Kosten LCC Material
62	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.0000	Anpassung Kosten LCC Mannleistung
63	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.0000	Anpassung Kosten LCC Hilfsgeräte

Figure 5-2 Output Section of the I/O Interface

<u>Percentage as the Marginal Profit</u>:[297]

In contrast to all other input parameters, this percentage influences the result of the customer sheet only. Specifically, the percentage, visible at the very top right in Figure 5-2, affects every cell of the result section on the customer sheet.

5.2.1.2 Output

This chapter briefly explains the result of the LCC calculation. For more detailed information, however, please refer to chapter 4.5.3.

As visible in Figure 5-2 the result section in the most turquoise cells is classified in 4.000 OH-periods. The resulting maintenance costs of the two sheets, schedules maintenance costs and maintenance costs due to unexpected replacement, are displayed in numbers as well as in a diagram.

[297] Compare chapter 4.6

The resulting maintenance costs are further separated in personnel, material (and AE) costs, displayed in the white rows (Figure 5-2, row 22-24 and 26-27). The turquoise rows underneath the white blocks represent the sums, which are then further summed up to the LCC.

Furthermore, the LCC per period are affected by the PR, mentioned in chapter 5.2.1.1, resulting in the row in the red font, representing the valorized LCC (row 30).

The last two separated turquoise rows of the result section, however, represent an analysis explained in chapter 4.5.3.3.

5.2.2 Customer Sheet[298]

As previously mentioned, the customer sheet is basically a copy of the I/O interface without any input parameters. The result, however, can be affected by a marginal percentage to consider the profit of Kuenz. This form is dedicated to the customer to illustrate the LCC of a given RMG installation.

Consequently, the sheet tells the customer how much he has, or he would have, to pay yearly[299] for the maintenance of the crane. Moreover, since the annual maintenance costs highly vary, the result is also illustrated in a diagram.[300] As a consequence and referring to the motivation of this thesis,[301] the customer can now actively compare maintenance and purchase costs as well as he has knowledge when which maintenance costs occur.

5.2.3 Maintenance Costs due to Unexpected Replacement Sheet[302]

This MS Excel Sheet includes the data of all parts of a Kuenz RMG installation, which are not supposed to last longer than 52.000 OH of the main conductor. Moreover it provides information about the costs and the occurrence of the exchange of these parts. Additionally, and as a function of the data, an imple-

[298] Compare chapter 4.6
[299] 1 year = 4000 OH
[300] Compare Figure 4-35, p. 96
[301] Compare chapter 1.2
[302] Compare chapter 4.1.2.2 for the definition

mented formula computes in a two-step process the overall maintenance costs due to unexpected replacement per 4.000 OH-periods.[303]

In fact, this sheet was the most complex part of the calculation model and, consequently, the key for any total cost approach of an RMG. The process of developing it as well as an explanation of how it works, is explained in detail in chapter 4.3.

The following Figure 5-3 provides an overview of the sheet. The components are structured in a BOM tree on the left side, while the data is blocked in the same row on the right side (green cells).

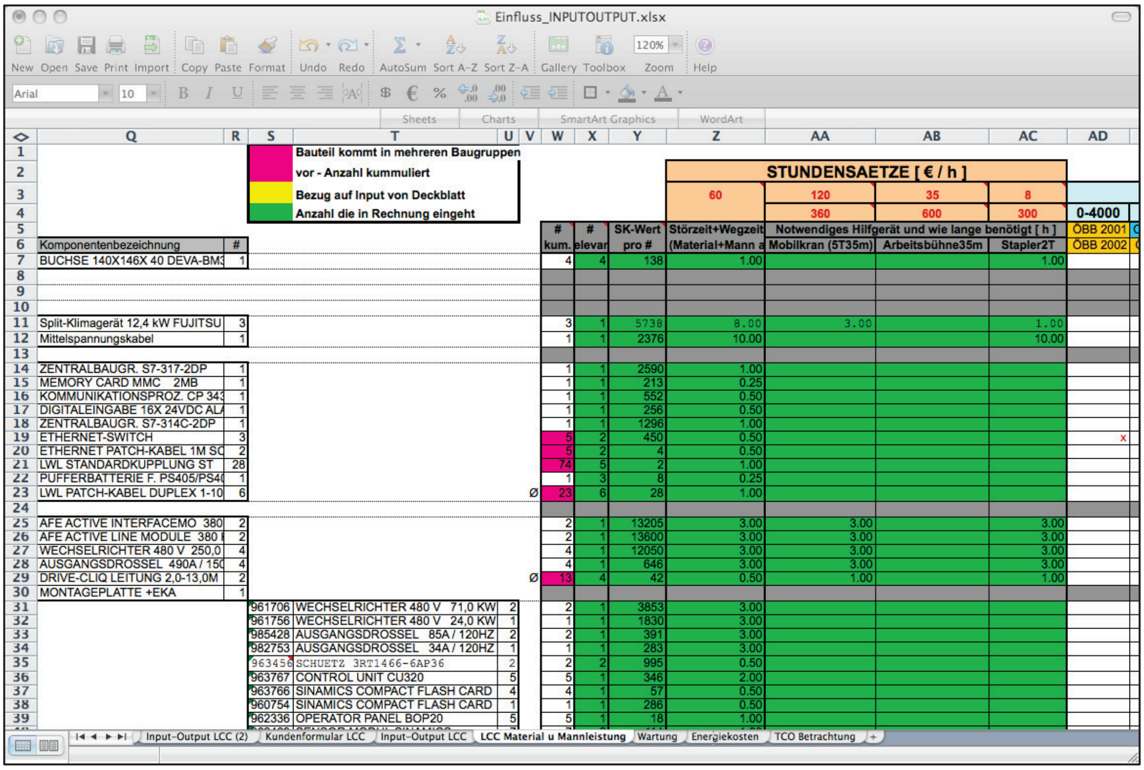


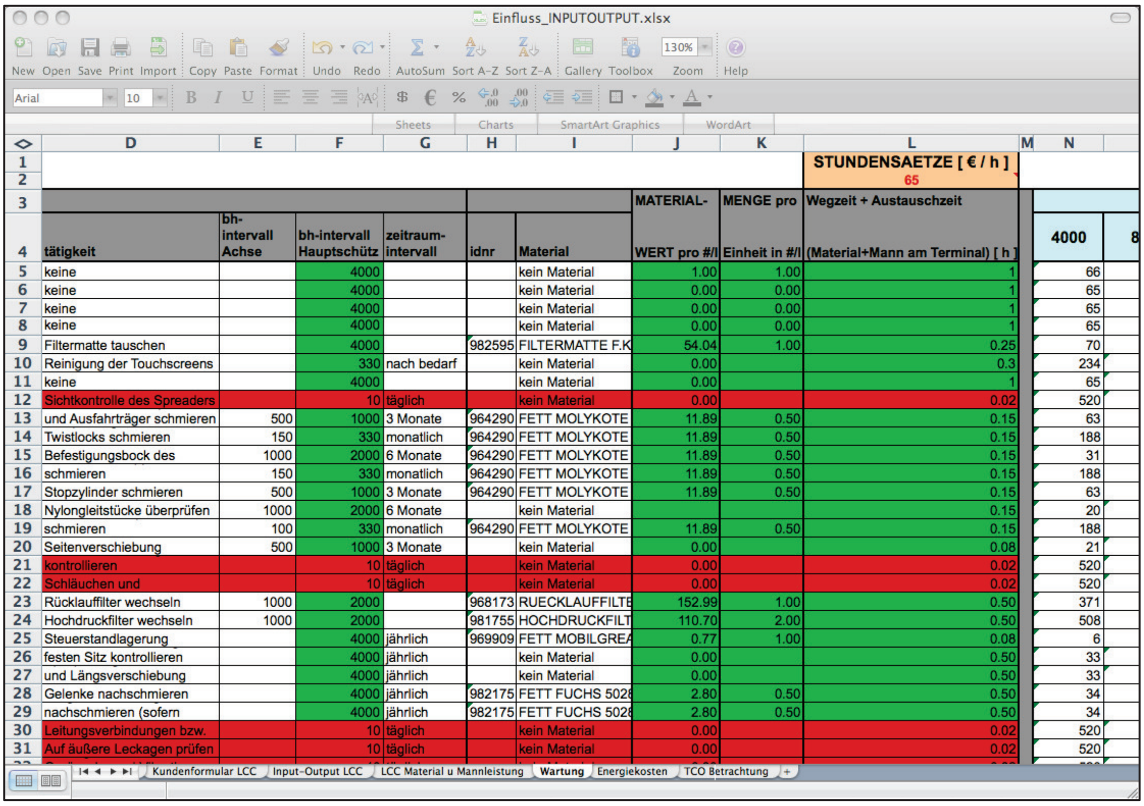
Figure 5-3 Overview of the Maintenance Costs due to Unexpected Replacement Sheet

5.2.4 Scheduled Maintenance Cost Sheet

Scheduled maintenance of parts means the known regular maintenance of parts, dictated by the respective manufacturers. Likewise to the other maintenance sheet, the purpose of this sheet is to calculate the involving costs of the scheduled maintenance per 4.000 OH-periods.

303 Compare chapter 4.3.11

The following Figure 5-4 provides also just an overall impression, since the sheet is explicitly explained in chapter 4.4.



	D	E	F	G	H	I	J	K	L	N
1–2									STUNDENSAETZE [€ / h] 65	
3							MATERIAL-	MENGE pro	Wegzeit + Austauschzeit	
4	tätigkeit	bh-intervall Achse	bh-intervall Hauptschütz	zeitraum-intervall	idnr	Material	WERT pro #/l	Einheit in #/l	(Material+Mann am Terminal) [h]	4000
5	keine		4000			kein Material	1.00	1.00	1	66
6	keine		4000			kein Material	0.00	0.00	1	65
7	keine		4000			kein Material	0.00	0.00	1	65
8	keine		4000			kein Material	0.00	0.00	1	65
9	Filtermatte tauschen		4000		982595	FILTERMATTE F.K	54.04	1.00	0.25	70
10	Reinigung der Touchscreens		330	nach bedarf		kein Material	0.00		0.3	234
11	keine		4000			kein Material	0.00		1	65
12	Sichtkontrolle des Spreaders		10	täglich		kein Material	0.00		0.02	520
13	und Ausfahrträger schmieren	500	1000	3 Monate	964290	FETT MOLYKOTE	11.89	0.50	0.15	63
14	Twistlocks schmieren	150	330	monatlich	964290	FETT MOLYKOTE	11.89	0.50	0.15	188
15	Befestigungsbock des	1000	2000	6 Monate	964290	FETT MOLYKOTE	11.89	0.50	0.15	31
16	schmieren	150	330	monatlich	964290	FETT MOLYKOTE	11.89	0.50	0.15	188
17	Stopzylinder schmieren	500	1000	3 Monate	964290	FETT MOLYKOTE	11.89	0.50	0.15	63
18	Nylongleitstücke überprüfen	1000	2000	6 Monate		kein Material			0.15	20
19	schmieren	100	330	monatlich	964290	FETT MOLYKOTE	11.89	0.50	0.15	188
20	Seitenverschiebung	500	1000	3 Monate		kein Material	0.00		0.08	21
21	kontrollieren		10	täglich		kein Material	0.00		0.02	520
22	Schläuchen und		10	täglich		kein Material	0.00		0.02	520
23	Rücklauffilter wechseln	1000	2000		968173	RUECKLAUFFILTE	152.99	1.00	0.50	371
24	Hochdruckfilter wechseln	1000	2000		981755	HOCHDRUCKFILT	110.70	2.00	0.50	508
25	Steuerstandlagerung		4000	jährlich	969909	FETT MOBILGREA	0.77	1.00	0.08	6
26	festen Sitz kontrollieren		4000	jährlich		kein Material	0.00		0.50	33
27	und Längsverschiebung		4000	jährlich		kein Material	0.00		0.50	33
28	Gelenke nachschmieren		4000	jährlich	982175	FETT FUCHS 5028	2.80	0.50	0.50	34
29	nachschmieren (sofern		4000	jährlich	982175	FETT FUCHS 5028	2.80	0.50	0.50	34
30	Leitungsverbindungen bzw.		10	täglich		kein Material	0.00		0.02	520
31	Auf äußere Leckagen prüfen		10	täglich		kein Material	0.00		0.02	520

Figure 5-4 Overview of the Scheduled Maintenance Cost Sheet

5.2.5 Energy Cost Sheet

The energy cost sheet calculates the energy costs for an RMG as a function of the performance and characteristic of the crane. The approach is based on Werner Buechele's energy cost calculation scheme.[304]

The yearly resulting summed up energy costs are, comparable to the LCC, a direct position in the TCO calculation.

5.2.6 Total Cost of Ownership (TCO) Sheet

As the final step of the calculation, the TCO sheet firstly computes the total costs of the crane for 10 years[305] and secondly, the requested key-value of costs per TEU.[306] Therefore, besides the already given LCC and energy costs, I inserted fields for the following variable cost positions:

---

[304] Compare chapter 4.7

[305] Compare chapter 4.8.2.1

[306] Compare chapter 1.3

- Purchase Costs
- General Personnel Costs
- Disposal Costs
- Miscellaneous Costs

The sheet calculates the total costs as the sum of all cost positions. The resulting sum, subsequently divided by the total number of handled TEUs of the crane, equals the previously mentioned key-value.

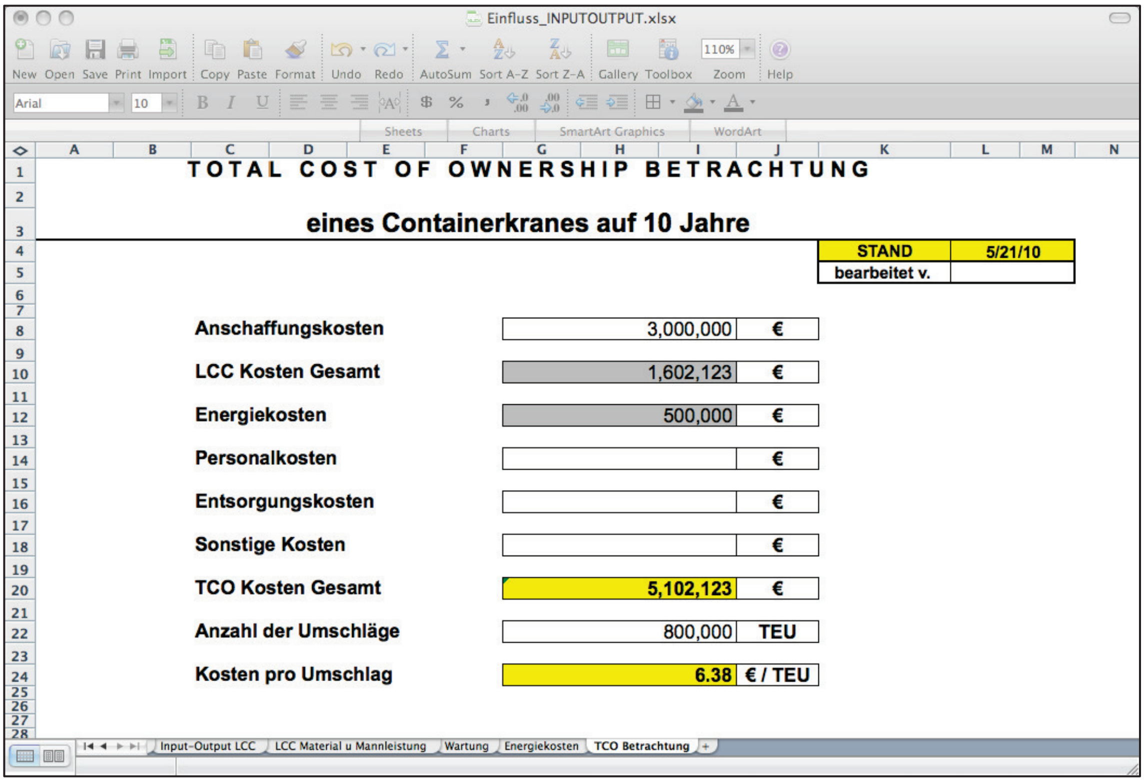


Figure 5-5 TCO Calculation

For a more detailed information of the TCO sheet of the calculation model, please also refer to the corresponding section of the chapter: 4.8.

6 Summary

Since container cranes require a huge maintenance effort and, consequently, high maintenance costs, it is perfectly reasonable to compare running costs and purchase costs. Especially for Kuenz it is interesting to investigate the total costs of their cranes with higher initial costs but also excellent quality over a longer timeframe.

The key element for creating the demanded total cost calculation of a container crane was definitely the determination of the maintenance costs due to unexpected emplacement, since the lifetime of the components as well as their probability of causing a malfunction varies. After the selection of the cranes on which the calculation model is based on, a general BOM of all occurring elements was therefore created. However, only the components, which are supposed to not remain fully functional over the investigation period, were considered. The next step towards the result of the determination of the maintenance costs due to unexpected replacement was then the obtainment of the necessary information for the calculation. Chronologically, data regarding the material costs, lifetime, necessary exchange time and exchange costs as well as the considered quantity of the parts were gathered before the actual calculation could have been carried out. Ultimately, the resulting maintenance costs added by the costs of scheduled maintenance, resulted in the LCC, which represents a cost position in the final TCO calculation.

Referring to the objectives of this thesis, introduced in chapter 1.3, both, the adaptable LCC calculation and the resulting TCO investigation were implemented in a MS Excel sheet until the end of May 2010.

Due to the successful implementation of the calculation model, Kuenz will now be able to take advantage of the initial ideas behind this thesis.[307] Consequently, the Kuenz service department will take the model as a basis for the calculation of full-maintenance contracts. Thus, Kuenz can offer potential customers transparent full-maintenance contracts as an additional incentive for cooperation.

[307] Compare chapter 4.1.1

Furthermore, the LCC result of the calculation model also indicates the maximum economic feasible duration of a full-maintenance contract, since it can be concluded that the peak, visible in the LCC diagram, occurs periodically.

The model will also support the purchase price argumentation with customers, since the following costs are well known and comparable to the initial costs. Moreover, the MS Excel customer sheet of the model explicitly splits the LCC in terms of the occurring nature – personnel, material, AE – as well as provides an illustrative diagram of the results. Consequently, the customer sheet tells the client exactly the necessary costs per year to keep the container crane system in a ready-to-operate state.

The TCO calculation offers, ultimately, the key-value costs per TEU, which allows a comparison to competitors as well as among alternative container handling equipment.

7 Outlook

The calculation model is designed in a way that improvements and adaptations can easily be implemented. Particularly, since the calculation is mostly based on practical experiences, it is only logical to add data, if new experiences are made. Future experiences are especially important for the lifetime values concerning maintenance due to unexpected replacement,[308] as the lifetime of components, in praxis, varies. Additional practical experiences will, therefore, help getting a more realistic mean value for the calculation.

Consequently, the DBs of the calculation model can be seen as a data and knowledge pool, dedicated to continuously improve the results.

An additional implementation of the existing model, however, could be the integration of the energy sheet, by connecting it with the characteristics of the I/O interface. Basically, also new sheets could be added for the other cost positions of the TCO calculation. Referring to Figure 5-5, it may also make sense to set up and integrate a calculation sheet for personnel, disposal and miscellaneous costs. Moreover, a connection to the already existing crane calculation, which is also based on MS Excel, could be a useful idea as well.

[308] Compare chapter 4.3 and 5.2.3

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List of Abbreviations

AE	**A**uxiliary **E**quipment
BOM	**B**ill **o**f **M**aterial
CEO	**C**hief **E**xecutive **O**fficer
CTO	**C**hief **T**echnology **O**fficer
CCG	**C**argo **C**enter **G**raz
DB	**D**ata**b**ase
E-housing	**E**lectronics **housing**
EDF	“**É**lectricité **d**e **F**rance”
ERP	**E**nterprise **R**esource **P**lanning
Ex-or	**Ex**clusive-**or** (logic operator)
FAQs	**F**requently **A**sked **Q**uestion**s**
I/O	**I**nput/**O**utput
IP	**I**nternal **P**rocesses
ISO	**I**nternational **S**tandard **O**rganization
kWH	**k**ilo-**W**att **H**ours
LCC	**L**ife **C**ycle **C**ost
MRO	**M**aintenance, **R**epair and **O**peration
MS	**M**icro**s**oft
OH	**O**peration **H**ours
RMG	**R**ail **M**ounted **G**antry Crane
RTG	**R**ubber **T**ired **G**antry Crane
STLB	“**St**eiermaerkische **L**andes**b**ahnen”
TCO	**T**otal **C**ost of **O**wnership