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Title: Renovation for Transfer Points in Dry Bulk Terminal

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Subject: Feasibility study of belt conveying system renovation on bulk material terminal

A dry bulk material handling company is interested in optimizing its terminal in coming years. The renovation of current material conveying systems plays the key role in future terminal operation. Due to the limitation of space and resource, transfer points are considered to be the parts where renovation will significantly benefit the company towards several aspects: energy use, maintenance cost, noise, spillage etc.

This assignment will be directed to the feasibility study of renovating the configuration and design of current belt conveying system. This assignment will comprise two phases:

Phase A:
- An overview of current belt conveying system in the terminal;
- Analysis of design characteristics for potential renovation of the transfer points within the terminal;
- Developing design criteria and key elements in the assessment of feasibility.

Phase B:
- A survey of the design requirements for the renovation;
- A conceptual design of a renovated belt conveying system, design alternatives will be recommended;
- An analysis of design alternatives and the renovated system.

As a result this assignment will present a primary estimate of CAPEX and OPEX for a renovated material conveying system.

Finally an assessment of the feasibility study shall be made, including recommendations for the conceptual design of such renovation.

The final report should be arranged in such a way that all data is structurally presented in graphs, tables, and lists with belonging descriptions and explanations in text.

The report should comply with the guidelines of the research section of TEL. Details can be found on the website.

The professor,

Prof. dr. ir. G. Lodewijks
Acknowledgment

After half year work, my thesis is now going to an end. During this period of time, I received so many helps from Transport Engineering and Logistics section of Mechanical, Maritime and Materials Engineering in Technology University of Delft, Europese Massagoed Overslagbedrijf bv., my families, my college students and my friends. Hereby, I would like to give my most sincere appreciation to all of them.

Firstly, prof. dr. ir. G. Lodewijks, as the initiator of my thesis project, offered me a lot of valuable suggestions in each meeting. With those suggestions, I am encouraged to seek better solutions towards series of problems. And even before the start of my thesis, I was inspired by the lecture given by prof. Lodewijks in the field of dry bulk. In this sense, prof. Lodewijks is truly the ‘initiator’ of my thesis, which I am very much appreciated.

At the same time, ir. Pang, who is my supervisor in university, offered me great help in the whole process of my graduation project. From every step of my progress, ir. Pang is highly involved and he devoted his time and effort to help me success with my thesis project.

And there are a lot of people from EMO, I would like to show my deepest grateful to them. Ing. Jan Verbaan, as my supervisor in EMO, contacts people from each department and brings me so much convenience during the process of my thesis. As I had my seat in maintenance office, there is no doubt that Ing. Jos van der Leer, Mr. Peter van Dijk, Mr. Jos de Kuyver and Mr. Hans Rijnsdorp from maintenance department gave me the great support not only for all my questions regarding maintenance issue in EMO but also instructions all over the operation in EMO. Mr. Harry Grashoff from technical inspection helped me so much with the introduction of mechanical components used in EMO, difference in impact materials, etc. Harry even sometime skips his lunch and has discussions with me for my questions. And Ing. Ton van der Leer, project manager, Ing. Jan de Wit, operation manager and Ing. J.Henk van TuijI, sourcing manager, all of them gave me expertise advices in their own area. I received so much help from EMO that I cannot list their name complete. But deeply thanks to all people from EMO. In the past six months, I enjoyed my thesis project in EMO all the time.

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In the end, my grateful is for my parents, who support me from Shanghai, faraway but firmly. And all my best friends in the Netherland exchange ideas and share it with me. Especially, Daniel who did his thesis project in EMO at the same time with me stimulates my ideas every time I had discussion with him. I really want to say thank you to him.
Without all those people I mentioned above, I could not possibly finish my last project in my master period successfully. Hereby, I would like to give them my sincere thanks to all of them!

Sincerely,

Lili Hong
Summary

This project focuses on the transfer point renovation topic in one dry bulk terminal. As in reality, a lot of manufacturers take great efforts in offering better transfer point solution, less academic research has been done especially for the transfer point itself. This makes transfer points a quite interesting topic for me. And the Kleinpolder plein which is one of the transfer points in EMO dry bulk terminal plays the key role in being the case study object. Although the research and design is done for the Kleinpolder plein, the methodology used and the designs developed in the project can be applied to other transfer points once adaption has been made.

The thesis paper begins with a general introduction on the reason of applying transfer points in dry bulk terminal. Then it is understood that the transfer point is an inevitable component for a terminal. Followed by that, a series of common problems in transfer points will be illustrated. Those general analyses can be applied to any transfer points.

The second part narrows the general introduction to exclusive focus on Kleinpolder plein. Based on the material – equipment – environment interaction relation study, the current situation for the target transfer point is known by now. With that information regarding performance of Kleinpolder plein, problems such as spillage, more energy consumption in transfer point are put on the table. And at the same time, key performance indicators are development especially under the circumstance what Kleinpolder plein is suffering from.

With the research result, design is made on the guideline of eliminating or at least improving the current problems in transfer point. Two main design directions: one is the technical design and the other is the operational design. The technical design mainly deals with the problems that can be solved by mechanical changes in the equipment or facility. And the operational design on the other hand offers a solution that reduces the function of transfer points. However, single design is not able to help forming a complete project which can help with EMO. Therefore, scenarios have been developed on the purpose of forming a complete new system, with which several improvements can be made in one adaption. The evaluation is followed by the scenario development. Matrix multiply is a core evaluation tool in this project. With the help of matrix, the connection between departments’ subject preferences and the scenario evaluation is built. In the end, two scenarios are much preferred. Based on five key performance indicators, their performances are again under evaluation. As a result, decision could be made by people from EMO freely based on their priority.

And the final part gives conclusion and recommendations with this project. Besides the recommendations given especially to EMO, suggestions regarding general transfer point renovation are also offered. Instead of just solving problems for one specific transfer point, the project is trying to conclude a complete system that can help with all transfer points in dry bulk terminals.
Samenvatting

Dit project richt zich op de transfer point renovatie onderwerp in een droge bulk terminal. Zoals in werkelijkheid een veel fabrikanten zich grote inspanningen in het aanbieden van betere overdracht punt oplossing, minder wetenschappelijk onderzoek is vooral gedaan voor de overdracht punt zelf. Dit maakt de transfer points een heel interessant onderwerp voor mij. En het Kleinpolder plein is een van de transfer points in EMO droge bulk terminal speelt de sleutelrol in dat de case study object. Hoewel het onderzoek en het ontwerp is gedaan voor de Kleinpolder plein, kan de gebruikte methodologie en de ontwerpen ontwikkeld in het project worden toegepast op andere overstappunten eenmaal aanpassing heeft plaatsgevonden.

Het thesis begint met een algemene inleiding over de reden van de toepassing van de transfer points in de droge bulk terminal. Dan is het duidelijk dat de overdracht punt is een onvermijdelijke onderdelen voor een terminal. Gevolgd door die, zal een reeks van gemeenschappelijke problemen in de transfer points worden ge?llustreerd. Deze algemene analyses kunnen worden toegepast op elke transfer points.

Het tweede deel versmalt de algemene inleiding van exclusieve focus op Kleinpolder plein. Op basis van het materiaal - uitrusting - omgeving interactie relatie studie, de huidige situatie voor de transfer point is bekend. Met die informatie over de prestaties van Kleinpolder plein, problemen, zoals morsen, meer energie verbruik in de overdracht punt worden gezet op de tafel. En op hetzelfde moment, key performance indicatoren zijn ontwikkeling onder de omstandigheid dat Kleinpolder plein lijdt.

Met het onderzoek leiden, is het ontwerp gemaakt op het richtsnoer van het elimineren of ten minste de verbetering van de huidige problemen in de overdracht punt. Twee belangrijke design richtingen: de ene is het technisch ontwerp en de andere is de operationele inrichting. Het technisch ontwerp voornamelijk bezig met de problemen die opgelost kunnen worden door mechanische aanpassingen aan de uitrusting of voorziening. En de operationele ontwerp aan de andere kant biedt een oplossing die de functie van de transfer points vermindert. Echter, enkel ontwerp is niet in staat om te helpen de vorming van een compleet project, die kan helpen bij EMO. Daarom zijn scenario's zijn ontwikkeld op het doel van de vorming van een compleet nieuw systeem, waarbij verschillende verbeteringen kunnen worden aangebracht in een aanpassing. De evaluatie wordt gevolgd door de scenario-ontwikkeling. vermenigvuldig Matrix is een kern-evaluatie-instrument in dit project. Met de hulp van de matrix, wordt de verbinding tussen de afdelingen 'onderwerp voorkeuren en het scenario evaluatie gebouwd. Op het einde, zijn twee scenario's veel liever. Gebaseerd op vijf belangrijke prestatie-indicatoren, hun prestaties zijn weer onder evaluatie. Als een reasult, kan worden besloten door mensen uit EMO vrij op basis van hun prioriteit.
En het laatste deel geeft conclusie en aanbevelingen met dit project. Naast welke aanbevelingen met name gegeven aan EMO, nog suggesties met betrekking tot algemene transferium renovatie worden aangeboden. In plaats van alleen het oplossen van problemen voor een specifieke transfer punt, is het project probeert om een compleet systeem dat kan helpen met alle transfer points in terminals voor droge bulk te sluiten.
Content

A. Introduction ......................................................................................................................... 12
  1. Background ........................................................................................................................ 12
     1.1 Transfer points in dry bulk terminal ........................................................................... 12
     1.2 Reference dry bulk terminal in the Netherlands .......................................................... 13
     1.3 Dilemma in transfer points design ............................................................................. 16
  2. Research questions ............................................................................................................. 17
     2.1 Sub questions regarding to research .......................................................................... 18
     2.2 Sub questions regarding to Design ........................................................................... 19
  3. Outline of project .............................................................................................................. 20

B. Research .............................................................................................................................. 22
  1. Klein Polder Plein: Transfer Point in EMO .................................................................. 22
     1.1 Background of EMO ............................................................................................... 22
     1.2 System scope ........................................................................................................... 23
     1.3 Kleinpolder Plein ...................................................................................................... 24
  2. System analysis in KleinPolder Plein ......................................................................... 25
     2.1 Material .................................................................................................................... 25
     2.2 Equipment ............................................................................................................... 29
     2.3 Environment ............................................................................................................ 31
  3. Key performance indicator developed for design ..................................................... 35
     3.1 Spillage (%) ............................................................................................................. 35
     3.2 Energy use (kw.h) .................................................................................................... 35
     3.3 Reliability of equipment .......................................................................................... 36
     3.4 Capital expenditure (million euro) ............................................................................. 36
     3.5 Operating expenditure (million euro) ......................................................................... 36
     3.6 Payback period ........................................................................................................ 36
  4. Research Conclusion ....................................................................................................... 37

C. Design ................................................................................................................................ 39
  1. Design Approach ............................................................................................................. 39
  2. Technical Design ............................................................................................................. 40
     2.1 Technical Issue ......................................................................................................... 40
     2.2 Technical Design ..................................................................................................... 46
  3. Operational Design ....................................................................................................... 53
     3.1 Dedicated route ....................................................................................................... 54
     3.2 Speed control ........................................................................................................... 60
  4. Scenario Development .................................................................................................... 62
     4.1 Zero-plus .................................................................................................................. 62
     4.2 Spillage free .............................................................................................................. 62
List of Figures

Figure 1 – Location of EMO (green square) and EECV (red square) .......................................................... 14
Figure 2 – Layout of EECV dry bulk terminal (Ertsoverslagbedrijf Eurooort C.V., 2010) ................................ 14
Figure 3 – Map of OBA (up) and the detail transfer point (down) .............................................................. 15
Figure 4 – Outline of report ....................................................................................................................... 21
Figure 5 – EMO bird view picture (left: year 1974, right: year 2009) ...................................................... 22
Figure 6 – Organization chart of EMO ...................................................................................................... 23
Figure 7 – Belt system Kleinpolder Plein area ............................................................................................ 24
Figure 8 – Current potential problems in Klein Polder Plein ................................................................. 25
Figure 9 – Illustration for calculation of material cross section with five rollers trough convey belt .......................................................... 27
Figure 10 – Material flow indication ....................................................................................................... 28
Figure 11 – Belt conveyer system in EMO (current situation, year 2011) ................................................ 29
Figure 12 – Enlargement map of the Kleinpolder plein area .................................................................... 30
Figure 13 – Road (extra space) along the Kleinpolder Plein ................................................................. 31
Figure 15 – Spillage percentage from 1995 to 2010 ................................................................................ 34
Figure 14 – Spillage problem in Kleinpolder Plein .................................................................................. 34
Figure 16 – Calculation of equipment availability .................................................................................... 36
Figure 17 – Connection between research and design ........................................................................... 38
Figure 18 – Diagram for the design procedure ......................................................................................... 39
Figure 19 – Problems in transfer points (Rozentals, 1991) .................................................................. 40
Figure 20 – A-shape plus U-shape .......................................................................................................... 41
Figure 21 – Rv-shape plus U-shape .......................................................................................................... 41
Figure 22 – The spillage percentage of EMO from 1995 to 2010 ........................................................... 42
Figure 23 – The watering system above belt 220 .................................................................................... 43
Figure 24 – Illustration for adjustable chutes design ............................................................................. 46
Figure 25 – Illustration for MARTIN® INERTIAL FLOW™ Transfer Chutes ....................................... 47
Figure 26 – ASGCO Flo-Control™ Chutes (ASGCO, 2008) ................................................................. 48
Figure 27 – Illustration for application of apron feeder ......................................................................... 49
Figure 28 – Apron feeder problem illustration ........................................................................................ 50
Figure 29 – Illustration for the apron feeder plus design ....................................................................... 50
Figure 31 – Demonstration of the flipped apron feeder ......................................................................... 51
Figure 30 – Illustration of the flipped apron feeder ................................................................................ 51
Figure 32 – Illustration of hydraulic cylinder application ....................................................................... 52
Figure 33 – Valve flow control application (Gunnewiek, 2008) ............................................................ 52
Figure 34 – Illustration of valve flow control ......................................................................................... 53
Figure 35 – Layout of belt connection in Kleinpolder Plein .................................................................. 54
Figure 36 – Lateral level of four groups of connections ....................................................................... 55
Figure 37 – Production group analysis toward connection to belt 220 ................................................ 56
Figure 38 – Production group analysis toward connection to belt 712 ................................................ 56
Figure 39 – Operational hour per month for transfer to 220 ............................................................... 57
Figure 40 – Operational hour per month for transfer to 220 ............................................................... 57
Figure 41 – Service area for connection 121 – 122 ........................................... 59
Figure 42 – Cross section indication for coal (left) and iron ore (right) .................. 61
Figure 43 – Coal spillage problem in EMO ......................................................... 61
Figure 44 – Speed control illustration .............................................................. 61
Figure 45 – Relation among KPI, EMO department and scenario ....................... 66
Figure 46 – Structure of part C research part .................................................. 73
Figure 47 – Relation between convey length L and coefficient C ...................... 104
List of Tables

Table 1 – Comparison among EMO EECV and OBA dry bulk terminal .........................16
Table 2 – Property of coal and iron ore.................................................................26
Table 3 – Average production hour per month.........................................................58
Table 4 – Scenarios developed .............................................................................64
Table 5 – Score for KPI from different departments in EMO.................................67
Table 7 – Score for scenarios based on criteria.......................................................67
Table 8 – Score for scenarios from different department in EMO .........................69
Table 9 – Preference of scenarios based on spillage indicator..................................69
Table 10 - Preference of scenarios based on energy use indicator.........................69
Table 11 - Preference of scenarios based on reliability indicator............................70
Table 12 - Preference of scenarios based on capital expenditure indicator .............70
Table 13 - Preference of scenarios based on operational expenditure indicator .......70
A. Introduction

Part A, which functions as a start of this project, unveils the background of transfer points and two references of dry bulk terminals followed by that offer an insight into different transfer point types in the Netherlands. With those backgrounds, the research problems can be found and the research questions will be formed to guide the later project undergoing. At the end of this part, an outline of this project will be illustrated in order to picturing a clear structure.

1. Background

The transportation of coal and iron ore plays a key role in large scale transportation nowadays. With the increasing demand for energy use and industrial production, the growing capacity required is an inevitable trend. Due to the limitation of space and resource, transfer points are the essential elements that each dry bulk terminals rely on. Because of the lateral level difference in transfer points, material faces an un-continuous flow problem, with which noise and dust are emitted. Also, in order to achieve the transferring of materials, more energy is consumed in transfer points to create more available connections. Therefore, the potential problems that are highly probable to happen in a dry bulk terminal concentrates in this specific area, transfer point.

In that way, this project is supposed to give a thorough look into the problems in one transfer point in real life, called Klein Polder Plein in Europees Massagoed Overslagbedrijf bv. To reduce or eliminate those aforementioned problems, a series of design alternatives regarding technical, maintenance and operational control will be included. And the final product will be one or more renovated systems for transfer point.

In this chapter, the background regarding a transfer point in dry bulk terminal will be fully discussed. Followed by that, are two reference dry bulk terminals in the Netherlands. The reason to take two reference cases in the Netherlands is to help with finding the common aspects for every transfer point and trying to distinguish what element might lead to various layout of transfer point.

1.1 Transfer points in dry bulk terminal

To reach a high service level with limited cost control in dry bulk transportation is always the ultimate goal of running a dry bulk terminal. As it functions as a buffer between either international or intercontinental transportation and inland or domestic transportation (G. Lodewijks, 2010), the storage area is quite crucial in one dry bulk terminal. Considering the limited area of one terminal and the fact that those precious lands will be divided both for transporting and storage, it would be nice if some components can make the full use of the current area and functions as a temporary storage place. Transfer points are the ones that...
may satisfy both two criteria.

It is nature that at the very beginning, terminals can organize their land use freely and easily. But years after years, the growing capacity needs make the terminal struggle with the available land and equipment settlement. Transfer point is one of the choices that are made to sooth the land problem and moreover, it offers as an extra intermediate storage also. Due to those advantages of transfer points, they became the essential parts of a dry bulk terminal.

However, the transfer points will also bring some unique problems. Some of these problems have already been existing in dry bulk terminal but being much severe in transfer points and some of these problems are typical in transfer points. Spillage, for example, is one problem that confuses the entire terminal for years. And this is the very problem that becomes more serious in transfer points. Because of the height difference in the transfer point, material will bounce outside the belt or the chutes or the plates from all unexpected angles and places. Another terminal-wide problem is the wear issue. All over the terminals, equipments are suffering from different level of wear. Moreover, in transfer points, the wear problem comes up more than just with the troughed conveyor belt and related accessories, such as the wear to the impact or slide plate due to continuous impact from material flow is also a concern to terminal. Those impacts result in severe chute wear problem. On the other hand, some unique problems in transfer point are related especially to the structure of transfer points. Dust, internal build-up towards chute wall and etc are all problems happening especially within the transfer points. Those problems will be fully discussed in design part and corresponding solutions will also be applied.

1.2 Reference dry bulk terminal in the Netherlands

After some brief introduction of the transfer points in dry bulk terminal, it is necessary to see some real transfer points as vivid examples. As the fact that Europees Massaggioed-Overslagbedrijf (EMO) bv\(^1\) will be the case study object, it is interesting to see the dry bulk terminals which serve for similar material and also in the Netherlands. For those requirements, two typical dry bulk terminals, The Ertsoverslagbedrijf Europoort C.V. (EECV) next to EMO and OBA in Amsterdam will be studied as reference cases.

A. EECV

The Ertsoverslagbedrijf Europoort C.V. (EECV) locates in the Europoort area of Rotterdam (Ertsoverslagbedrijf Europoort C.V., 2010) and handles about 30 million tons of coal and iron ore every year. It began to operate from the year of 1970 for iron ore only and from 2004 EECV adds coal into handled bulk. The storage area for iron ore and coal is 3.5 million ton and 0.75 million ton respectively.

The relative geographically location of EECV compared to EMO is shown in Figure 1. As both of them serve as a terminal for coal and iron ore and they are quite close to each other,\(^1\)

\(^1\) In latter part of this thesis, the name of this dry bulk transportation company will be shortened as EMO.
inevitably there will be some competition between them. But interestingly, there also exist a cooperation relation between them. Considering the limit capacity for both unloading and storage, EMO and EECV both solve the problems from each other.²

The flexibility of EECV is relatively low compared to EMO dry bulk terminal as seen in Figure 2. The connection is quite dimply and direct, which reduces the movable parts and the maintenance difficulties. The cost of that is the flexibility and robustness of the whole transport system.

2 See Appendices 2 – Minutes of interview from Jos van der Leer
B. OBA

OBA is the dry bulk terminal, locating in Amsterdam port and operating with two terminals: “Main Terminal” and “Terminal North” in the port of Amsterdam. The total storage area is about 700,000 m². As there are six kinds of products handled in OBA, it is hard to divide the specific storage area for every kind of product. The main products handled are: coal, agriculture bulk, minerals and biomass. The total throughput of the dry bulk is 19 million ton per year (based on the statistics in 2010).

In Figure 3, it illustrates the general layout of the OBA dry bulk terminal. Similar as the layout of EECV, OBA follows a simple and clear transfer point design. The most complex transfer point as shown in Figure 3 includes two feeding belts towards two receiving belts. This is much easier connection compared to the transfer points in EMO. And by trading off between a high-flexible and a low maintenance cost transfer point, the concerns will be given based on the real throughput of the dry bulk terminal and the customer needs.

C. Comparison among EMO, EECV and OBA

After the introduction of EECV and OBA, it is better to make a comparison with important criteria for a bulk terminal among them. Below is the table lists the capacity, storage area, material type handled and the layout of one typical transfer points in those three bulk terminals.

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When closely looking into Table 1, there is no doubt that EMO is the largest dry bulk terminal among them and has the most complicated transfer points too. It might be easy to make a conclusion that there is a definite relation between the capacity and the complexity of the transfer points from the table made. However, the question is whether this relation is so solid that hardly improvements can be made there. To answer this question, it is better to give another look into the table again, and it can be found that the capacity of EMO is about 1.5 times to the capacity of EECV. But the complexity of the transfer points in EMO is almost 2 to 3 times compared to EECV dry bulk terminal. Therefore, this difference leaves me some room to consider the necessity of the complicated transfer points and intrigues me to find solutions towards this situation.

### 1.3 Dilemma in transfer points design

**A. Flexibility vs. Reliability**

The flexibility and reliability I am talking about here is exclusively meant for the transfer points in dry bulk terminal. Flexibility, on the one hand, indicates the possible connections one transfer point can provide. In operational point of view, flexibility is highly crucial to maintain the daily production without unexpected shut down. To create required numbers of possible connections, movable parts are critical for achieving alternative routes. The need of flexibility mainly is coming from customers who may require some specific time window for loading and unloading of their own products.

However, on the other hand, more movable parts, more potential problems. For example, movable parts increase the possibility of mechanical breakdown. In that way, the reliability is the indicator which oppositely the flexibility in transfer points case. When a transfer point is made reliable, it is meant that there are less movable parts in this transfer point. With higher reliability, the likelihood of failure for equipments is reduced. Therefore, as for terminal itself, the reliability of transfer points is more preferred.
And actually, the dilemma between flexibility and reliability reflects the tradeoff between service level one terminal wants to offer and the production cost it has to pay for. For some detailed explanation to the design dilemma – flexibility and reliability – the case carried on later in EMO can better illustrate it.

B. Cost vs. Penalty

The dilemma between cost and penalty in reflected from two aspects: investment and maintenance.

From investment point of view, cost indicates the initial cost a company can afford to pay at very early stage. And penalty indicates the follow-up investment, such as upgrade or renovation. Normally speaking, higher initial investment at beginning brings less follow up cost, that is, the penalty. However, as for a production company, cash flow should be controlled for each investment. When it faces with several projects undergoing at same time, it is better not to invest too much on one project. Instead of that, periodical payment for the investment is much more acceptable. To balance the initial investment (cost) and the follow up investment (penalty) is totally based on real cash flow situation in each company.

Another dilemma is in the maintenance arena. Penalty refers to the price which has to be paid for the future failure of equipment, in other words, the corrective maintenance cost. By literal meaning, it can be understood as the way to fix failure or worn out after it happens. This includes repair, replacement or restoration actions. And the cost here refers to the initial payment for preventing the potential failure, that is, the preventative maintenance cost. "Preventative maintenance is maintenance which is carried out to prevent an item failing or wearing out by providing systematic inspection, detection and prevention of incipient failure." By taking preventative maintenance measures, severe problem and unexpected shut down of the production can be hugely avoided. To achieve preventative maintenance, precaution measures such as regular inspection, monitoring systems have to be settled. Generally speaking, the higher cost put into at the early stage, the more preventative measures have been taken to avoid future failure. With different safety factor, the breaking point moves between the preventative cost and the aftermath penalty.

No matter for investment or maintenance point of view, to optimize the cost and benefit relation is always the pursuit of a company.

2. Research questions

Based on the background introduction and the design dilemma illustrated before, hereby the research question, including sub research questions, is stated below. Answers to those questions will be explored in the following chapter. Moreover, with this list of research

questions, it can easily guide the whole research under certain scope and focus the design onto the main target. In that way, the situation like lose focus in the middle can be avoided effectively.

The main research question of this project is decided as:

"How can the current transfer points be optimized by designing a new system which remains the same flexibility but increases the reliability of a dry bulk terminal?"

This main research question is the final goal of the whole project and it consists of several sub research questions below. And those questions are divided into two main parts: research and design part.

2.1 Sub questions regarding to research

A. System scope

➢ What can be learned from literature and other reference transfer points?
  - What are the main concerns for transfer points design?
  - Which aspects will be for and against each other?
  - What is the design dilemma for conducting a transfer point?

➢ What is the system boundary for this project based on the analysis before?
  - What will be the physical boundary for the project?
  - Why this scope is interested to be designed?
  - What is the current situation in this design scope?

B. Material

➢ What are the properties of the bulk solid material transported in EMO terminal?
  - How many types of material are transported and stored in EMO terminal?
  - What are the differences between or among those materials?

➢ How do those properties impact the transfer points?
  - How do those properties impact the design of equipment?
  - How do those properties interact with the environment?

➢ Will the material handled in the future be different from those now?
  - Will the transportation requirements be changed?
  - Will the properties of coal and iron ore be changed?
  - Will those changes make difference on current design?

➢ How is the material flow in EMO?
  - How does EMO monitor their material flow
  - Can the material flow be changed? To what extent?
C. Equipment

- What are the main transportation equipments in transfer points?
  - What are their functions?
  - How do they interact with each others?

- What is the physical layout of the current equipments in the transfer point?
  - What are the advantages and disadvantages of this layout?
  - With this current situation, which will be more proper idea for kleinpolder plein, the expansion or the renovation?

- How is the maintenance mechanism currently in EMO?
  - How the preventative and corrective maintenance be conducted in EMO?
  - What is the current maintenance situation?

D. Environment

- How many indicators are concerned to environment issues for a dry bulk terminal?
  - What are the current environment issue in EMO now?
  - What kinds of measurements have already been taken to obey the environment regulation and laws? And how is the effect now?

- In the future, with the growing restrictions to environment issue, are there still possibilities to reduce the pollution?
  - Is there any state of art measures to restrain the pollution within the limited quantity?
  - If not, how could EMO adapt to the new regulations?

E. Key Performance Indicators

- Based on the interaction among material, equipment and environment,
  - How many key performance indicators can be developed? What are they?
  - Can those KPIs be evaluated and in which way?
  - If consider the future developments, what other key performance indicator should be included?

2.2 Sub questions regarding to Design

A. Technical issue

- What are the problems in the studied transfer point?
- Those problems are related to some specific components of transfer point,
  - What are those components?
  - How can they be renovated?
  - Is there existing product for this kind of design?
  - Do those existing products need adaption to the current design?
B. Operational issue

➢ To think out of the box, is it possible to remove some of the transfer points?
  ➢ Which possible connection can be removed?
  ➢ Will the daily production be interfered?

➢ Is there any other existing operation design may help with the improvement in transfer point?

C. Design integration

➢ By integrating the technical and operational design, what kind(s) of problems can be improved by one specific scenario?

D. Design evaluation

➢ How can the scenarios be evaluated by Key Performance Indicators developed before?
➢ What is the preference from different departments in EMO towards the scenarios?
➢ What is the capital expenditure (CAPEX) and operational expenditure (OPEX) for the new design?
➢ Any other further modification to the design after the evaluation?

3. Outline of project

After understanding the background of transfer points in a dry bulk terminal and figuring out the research questions above, it is quite important to know the outline of the project in order to get a complete and clear view. With this outlines, it makes sure that those research questions mentioned above will be appropriately answered in a logical way.

This project is divided into four parts: introduction, research, design and conclusion. The project begins with a general introduction of transfer points in dry bulk terminal. And later it narrows down to a specific case study, which is the Kleinpolder plein area in EMO dry bulk terminal. With research from several aspects about the transfer points, it may bring problems into sight. Therefore, in the design part, it aims at searching for better solutions to those problems. The design is coming from two aspects: technical and operational. In that way, the choice made later on should be an integration alternative of both technical and operational design. And in the end, based on different criteria and different view from departments, choices can be made among those alternative scenarios. After all, conclusions and recommendations will be given, not only on the Kleinpolder Plein case study but also on general transfer points design. Below is the illustration for the project outline:
As illustrated in the outline of report, the transfer point is the key topic going through the whole project. The introduction starts with some general aspects for transfer points and in the end the conclusion is also given towards transfer point. And between them is the research and design specifically done for Kleinpolder plein. The reason is that each unique transfer point is probably showing different issues and problems, but with focus on one real case, down to earth design can be conducted and the performance can be better evaluated.
B. Research

1. Klein Polder Plein: Transfer Point in EMO

1.1 Background of EMO

EMO is the largest dry bulk transshipment terminal in east Europe, which was founded in 1973 in Maasvlakte I area of Rotterdam Port. It deals with coal and iron ore coming from all over the world. Currently, it has the maximum unloading capacity of 42 million ton per year and the storage area of 7 million ton. If assume the loading capacity is almost the same as unloading capacity, the storage area takes about 8.3% of the annual throughput tonnage.

Since 1973, EMO has grown from one stock pile until six stock piles now. The comparison of the expansion in EMO can be seen from Figure 5 below. From the very beginning, EMO generally only developed one to two stock piles operated by one combined stocking and reclaiming machine (kombi 1). And the kombi can be only fed from one way, which made the material flow quite simply at that time. With the growing number of incoming coal and iron ore, more stocking area is needed. In the right picture, it clearly shows the current situation of the whole belt conveyor network and the layout of stocking piles. And until 2012, the rest free land will be fully exploited for the last time expansion. After this expansion, all EMO land will be put into use and no more expansion is possible.

![Figure 5 - EMO bird view picture (left: year 1974, right: year 2009)](image)

The organizational chart is shown in Figure 6. The project undergone mainly is dealt by operational department. As there are two aspects in dry bulk terminal design and management, the logistic control is done by planning department and the physical layout and equipment are basically related to the technical department. To understand the organization structure of EMO helps to the information to be acquired in the future. At the same time, the information flow is crucial to the success of one project.

Another important thing should be paid attention too is that the organizational chart makes
it clear that this project is mainly related to the branch from the operations department. But still the technical and maintenance department may have different point of view towards one single project with regard to their different preference and priorities.

1.2 System scope

As the one of the oldest transfer points, Kleinpolder plein faces several problems during transportation with time passing by, such as the growing strict restrictions of environment issue from EU regulation, the aging of equipments and the emerging transportation demands. Therefore, this area is chosen as the project research object based on those considerations.

The project will be carried on mainly for the belt conveyor system in Kleinpolder plein, which is a typical transfer point in EMO. This includes the technical design of belts, chutes, apron feeder (if needed) and other related components critical to transferring and transporting materials. The technical design is limited into the conceptual design. After this feasibility research for different technical alternatives, further implementation or research for detailed design can be followed up.

Besides the mechanical changes, the layout of the Kleinpolder plein can also be altered within the capacity needs. The layout alteration is made in the aim of proficiently transferring material with current technical level. This change can be included as one aspect of the operational design. The other way of conducting operational design, such as optimizing the material flow or upgrading the handling efficiency will not be discussed in this
thesis. Some of those operational designs can be found in another project which is undergoing in EMO at the same time and focusing especially in operational control aspects.

The later evaluation comprises of capital and operational expenditure and also the payback period. With those commercial evaluation criteria, it is clear for the production company to decide which design is more preferred.

1.3 Kleinpolder Plein

Kleinpolder plein is the area functions as a critical transfer point, as shown in Figure 5 with the point of white arrow. The flexibility in this area is quite high due to five movable belt conveyors. Each of them can feed more than two following belts.

There are several reasons to build up transfer points. The most common reason is the space limitation. In most dry bulk terminals, material flow is always required to turn around at some corner to reach the stocking destination or a loading destination. If one continuous belt conveyor is used to achieve this turning material flow, a sufficient radiant is needed for the turning curve. This will definitely cause huge consumptions of spaces, which are quite precious for a terminal. In that sense, if two conveyor belts are arranged perpendicularly, not only the function of achieving the required material can be fulfilled, but also the influence from limited space has been minimized.

![Figure 7 - Belt system Kleinpolder Plein area](image)

Another function for the transfer point is that it creates an inter-mediate storage place. With long belts running over the terminal, they also offer some buffer with the capacity of the belts themselves. This can benefit a terminal especially when there are several assignments going on at the same time and the buffer created by transfer point make it possible for the unloading bridges or stacking and reclaiming machines to keep a continuous motion.

However, transfer points also bring a lot of problems to the terminal because of the movable belt conveyors.

Firstly, due to the transfer mechanism, material will be transported within different layers. In
other words, extra energy is needed to elevate the material. And also because of the transfer requirements, at least two belts are involved into one transfer assignment. Extra preparation and waiting time increases the energy consumption as well.

Also for the reason that material has to be lifted and then transported to other belts, the wear problem for both the belt and the chutes is critical. The impact plate is normally set up directly after the material coming out of the feeding belts. There is definitely a lot pressure on the chutes because of the continuous material hitting. As for the receiving belts, the vertical force due to the gravity from the falling of material will impact them also. But in this case, the slide chute, theoretically, may reduce the impact from the vertical force and make the outgoing material keeps the speed as close as the downwards receiving belts.

Besides the wear problem, spill problem is also caused in some extent by transferring. With the moving of material from one belt to another, no surprise there will be a lot spillage at the entrance of the receiving belt. Side skirt might be a solution to this kind of problem. But the tension between the side skirt and the belt conveyor is an issue. If the side skirt is set up too close to the belt, it will not only make the belt wear sooner but also increase the energy use because of the extra friction between them. And as for the case, side skirt is away from belt, then it may not function quite well to prevent the problem of spillage.

All those problems are the ones Kleinpolder Plein is facing with now. And the reason to make Kleinpolder plein as a design object is to try solving the problem or at least minimizing the effect from those problems. The next chapter will deeply analyze the problems in Kleinpolder plein from three aspects: material, equipment and environment. With those analyses, it could help to figure out clear solution to specific problems.

2. System analysis in KleinPolder Plein

2.1 Material

Coal and iron ore are the two products transshipped in EMO dry bulk terminal. Different products are of quite various qualities. And all those properties may influence the design of
Renovation for Transfer Points in Dry Bulk Terminal

Renovation for Transfer Points in Dry Bulk Terminal

belt conveyor and terminal layout. The basic characteristics which are important for bulk material are the shape, density, lump size, friction (motion and static), cohesion and adhesion. Among them, the particle size, the surface roughness and adhesion are characteristics interacting with the transportation equipment. The detailed statistics of the material transported in EMO dry bulk terminal can be checked in Appendices 1.

A. Coal

The average lump size of the coal transported in EMO is from 0 – 150 mm, while the maximum lump size can be up to 350 mm. The density varies from 0.5 – 2.6 t/m³. But most of the coal is with the density of 0.9 t/m³ and with the angle of repose of 38°. Humidity is around 2 – 10%.

As the density of coal is 0.9 t/m³ and the capacity for coal in EMO is 3500 t/h, as long as the belt speed is determined, the cross section of the coal can be calculated. In theory, the belt speed for carrying coal can reach up to 6 m/s. But in reality, the belt speed running in EMO is fixed at 4.5 m/s. Therefore, under those circumstances, the cross section of coal transported in EMO is 0.24 m².

B. Iron ore

The particle size for iron ore varies from 0 – 150 mm also. But the density is higher than coal. It ranges from 1.6 – 2.9 t/m³, which means the average density is 1.5 t/m³. But with regard to the weight of different iron ore transported, the expected density of iron ore is about 2 t/m³. As for the angle of repose, most of the iron ore is about 38 – 48 degree. Same as coal, the humidity is about 2% to 10%.

Similarly as the calculation for the coal, the cross section of iron ore can also be got. The density of iron ore is 2 t/m³ and the capacity for it in EMO is 5000 t/h with the same belt running speed, 4.5 m/s, which makes the cross section of iron ore 0.15 m².

C. Cross section

Now with the information gathered above, it is possible to calculation the cross section of coal and iron ore when they are transported on troughed belt conveyors as shown in Table 2.

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (avg.)</th>
<th>Capacity (avg.)</th>
<th>Cross section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>0.9 t/m³</td>
<td>3500 t/h</td>
<td>0.24 m²</td>
</tr>
<tr>
<td>Iron ore</td>
<td>2 t/m³</td>
<td>5000 t/h</td>
<td>0.15 m²</td>
</tr>
</tbody>
</table>

To calculate the cross section, it follows the formula below:
$A = \frac{Q_m}{p v_b}$

In which,

$A$ : the cross section area ($m^2$)

$Q_m$ : throughput ($t/h$)

$p$ : density of bulk material ($t/m^3$)

$v_b$ : belt speed ($m/s$)

With the result of cross sections, it is found that the coal is almost twice as the iron ore. Based on the observation in the terminal site, it is true that when the belt is transporting coal it is much fuller than the ones transporting iron ore. Due to that fullness, it might increase the possibilities of spillage of the coal. In that way, the belt speed may need some acceleration.

But only the cross section area is not enough for deciding whether the material is overloaded on the belt. Below is the algorithm for the five-roller belt calculating the maximum required cross section:

$$A = (l_1 + l_2 \cdot \cos \lambda_1) \cdot l_2 \cdot \sin \lambda_1 + [l_1 + 2l_2 \cdot \cos \lambda_1 + (\frac{b - l_1 - 2l_2}{2}) \cdot \cos \lambda_2] \cdot \frac{(b - l_1 - 2l_2) \cdot \sin \lambda_2}{2}$$

$$+ \left[ \frac{l_1}{2} + l_2 \cdot \cos \lambda_1 + (\frac{b - l_1 - 2l_2}{2}) \cdot \cos \lambda_2 \right]^2 \cdot \tan \beta$$

![Figure 9 - Illustration for calculation of material cross section with five rollers trough convey belt](image)

With angle of repose for 38° and belt width for 1800mm, the cross section can be got as 0.6645 $m^2$ for coal. Therefore the current 0.24 $m^2$ is about 36% of the required area, which is less lower than the regulation.

\[5\] Lecture note 2.2 from lecture WB3420, Prof. Lodewijks, Delft University of Technology
Therefore, actually the belt running speed in EMO can be reduced. It can still maintain the expected handling capacity and at the same time reduces the energy use for belt running. A simple way to solve this problem is that using speed control conveyor belts. In EMO, the speed control motors have already been built for years in the quay side long conveyor belts. But due to some unforeseen reasons, they have not been put into use. This could be a nice chance to apply those motors and most importantly reduce the energy use of EMO.

D. Material flow

The material flow in EMO is traced by the planning department. As shown in Figure 10, each color of the route indicates one material flow. This is a real-time trace system with the operation of belts all over the terminal. The belt group used for one material flow, the origin and destination of the material flow all can be found in this monitor screen. However it is not quantified. The exact running time and occupancy of conveyor belts should be looked for in the off-stage database.

Besides the real time exhibition of the usage for each conveys belts, the historical data are saved in the database of EMO. To record the transportation history, 'production group' is an efficient way to indicate the route of material flow. The production group indicates a group of conveyor belts which connect the original (such as the unloading bridge, the storage area, etc.) to the destination (such as the barge loading and train loading, etc.) Therefore, one production group actually gives one possible route for the material flow. In current EMO terminal, 985 production groups are available. Surely, in reality some of the routes are quite detour and not efficient in both technically and economically. It is 528 production groups that are indeed in use.
2.2 Equipment

One of the most critical equipments in EMO is the belt conveyor system. This part will fully discuss the current belt situation in Kleinpolder Plein area. In a microscope point of view, every separate belt will be examined based on their structure, dimension, availability through operation and energy usage. And in a macro scope, the whole layout of the system exposes the possibility of future expansion or renovation. Another very important issue in belt conveyor system is the maintenance mechanism. It is not only related to the maintenance cost also it can benefit the equipment itself by sending out precaution warnings and prevent problems before they happen.

A. Belt conveyor system

In Kleinpolder Plein area, there are ten conveyor belts involved, by which 14 connections are created. In Figure 11 and Figure 12, the arrangement of the belt conveyor system in Kleinpolder area and the connection of them can be seen.

Figure 11 – Belt conveyor system in EMO (current situation, year 2011)
Renovation for Transfer Points in Dry Bulk Terminal

To achieve those connections, five movable-head belt conveyors are set up. They are:

*Belt 112, Belt 121, Belt 131, Belt 711 and Belt 220*

With them, 14 transfer points are created, those are:

*Belt 112 -> Belt 712, Belt 220, Belt 113*

*Belt 121 -> Belt 712, Belt 220, Belt 122*

*Belt 131 -> Belt 712, Belt 220, Belt 132*

*Belt 711 -> Belt 712*

*Belt 220 -> Belt 132, Belt 122, Belt 113, Belt 410*

The detailed structure of those belts involved in Kleinpolder plein can be seen in Appendices 5.

B. Expansion possibilities

Before the renovation can be actually planned, the possibilities of whether the Kleinpolder plein is suitable for expansion should be taken care of. In Figure 13, it shows that beside the Kleinpolder plein area a road with 4.5 meter to 5 meter is used for commuting cars and small dossiers to pass by. This is already quite limit space for internal transportations. No further expansion should be considered due to the reality like this.

Therefore, the design later will focus on the changes within the current space taken, which means there can be changes merely in vertical direction. This includes both under and above ground construction.
C. Maintenance

Generally, maintenance is divided into preventative and corrective maintenance mechanism. The previous one gives regular inspection and precaution system in case terrifying aftermath of equipment failure. As for the corrective maintenance, it is a passive way of thinking which will wait until the real problem happens or about to happen then the problem will be fixed.

Those two kinds of maintenance both can be found in EMO nowadays. From the beginning of 2011, EMO began a pilot system called OPTIMIZER in order to upgrade the current maintenance situation. The on-site inspector will report existing failure as a corrective maintenance type into this system as well as report the substantial failure of the equipment as a preventative maintenance type. And the corrective maintenance can be also monitored in OPTIMIZER program, in which once the inspector finishes the examination of machine, the outcome and repair recommendations will be given. The advantage of using OPTIMIZER is to share the machine statue around all departments. The high efficient information flow keeps everyone in EMO informed about machine situation any time and avoids fatal shut down events.

2.3 Environment

The environmental issue is growing hotter and hotter these years regarding public health care and environment protection. In the case of a dry bulk terminal, the impact to the environment caused by the terminal is even more eye-catching due to the fine contained in bulk material and the continuous noise produced by large scale transportation equipment. There are a lot of environmental regulations set up aiming at the control of pollution in European Union. Two kinds of pollution to the environment are important to dry bulk
terminal: noise and air pollution. Besides them, the spillage issue is quite crucial to terminal itself. Not only will it affect the quantity of the transported or stored material but also the terminal has to suffer from the spillage causing blockage at the belt entrance or exit and the transfer points.

A. Noise emission

Some specific laws initialed exclusively for the noise pollution field. The Directive 2000/14/EC of the European Parliament and of the Council is made for the noise emission in the environment by equipment for use outdoors.6


Definition:
A temporarily installed machine suitable for transporting material by means of a power-driven belt.

Measurement:
Annex III, Part B, item 14 CONVEYOR BELTS
The geometrical centre of the engine shall be positioned above the centre of the hemisphere; the belt shall move without load and leave the hemisphere, if necessary, in the direction of point 1

Basic Noise Emission Standard
For the determination of the sound power level of equipment for use outdoors as defined by Article 2(1) the basic noise emission standards may generally be used subject to the following general supplements:

\[ L = A + B \cdot P \]

where \( L \) is the sound emission limit,
\( P \) is a power-related descriptor,
\( A \) and \( B \) are product-related constants.

And the upper limit of the noise emission is up to 80 dB according to the European Environment Agency.8 In EMO dry bulk terminal, the noise emitted by the belt conveyor is related to the running speed of the belt itself. One belt which is running at 4.5 m/s emits now around 90 db noise. But due to the distance from EMO to the closest neighborhood, the

Renovation for Transfer Points in Dry Bulk Terminal

Lili Hong

Impact of the noise has not been complained by the neighborhoods near the Maasvlakte I. But still, once the EU regulations become stricter towards industry field. It is better for EMO to upgrade related components, for example, the roller choice, the belt material, etc. But as for now, the issue regarding noise will not be included as one key performance indicator but only a back-up reference indicator for the future development suggestions.

B. Dust control

As discussed before, the lump size of either iron ore or coal is both from 0 to 350 mm. There is no doubt certain amount of bulk material is fine particles. With several transferring motion among equipments, fine particles are intended to be spray in the air and cause dust pollution. The very general way to reduce the dust percentage in the air is to spray water onto bulk material.

EMO has adapted three dust monitoring spots all over the terminal to ensure the dust will not float outside the EMO terminal board. To achieve this dust control goal, several measurements have been taken. Firstly, along the seaside, all those long belts for unloading are under the coverage of spraying. And due to severe problem of spillage in grab unloading spot, water is also added during the unloading procedure to prevent floating particles in the air. The water spraying system can be seen in every long belt now. And the target is to install water spray system for all belts in EMO terminal. Despite the spraying measurements, the dust curtain is in use also. As for the stocking piles, special glue is added to prevent the wind from blowing off the surface of stocked material.

The problem to those dust control measurements is that due to the additional water onto the material, the moisture percentage increases. This will affect the quality of the coal or iron ore transported obviously. The impact is hard to be quantified but can only be controlled by the operators with experience.

C. Spillage problem

Spillage is an inevitable problem once material has to be transferred from one equipment to another. Several areas are the most frequent place for spillage happening, such as the unloading area and the transfer point. The Kleinpolder Plein is the latter case. Being as a transfer points with 14 connections, Kleinpolder plein is an area where a large chance of spillage occurs. As for a dry bulk terminal, the problem is more than just loss some product during transportation. Spillage may block the current belt conveyor system without noticing.

To deal with the spillage, EMO firstly have to decide whether the spillage is contaminated or not. Once it has been contaminated by other material or sea water or other substance, it will no longer be useful. If it is 'clean' spillage, then it will be traced back to its original material piles. In reality, the latter case, that is the uncontaminated spillage, is really little.
The graphic above shows the spillage percentage compared to the total transported tonnage every year, from year 1995 to year 2010. It clearly shows that since 1997, the spillage percentage kept going down. And actually this the year EMO began to use the newly scrapers produced by Belle Banne. (see appendices 6) Also, the spillage plummets after 1999. During that time, the impact plate has been gradually replaced to a more sustained type, which prolongs the life time of the impact plate. After all the changes have been made, the spillage percentage goes into a stable level. To understand the historical situation for spillage problem in EMO helps for the future design to take some preventive measures into account.
3. Key performance indicator developed for design

Based on the analysis before, the key performance indicator which is important to belt conveyor system in EMO are shown below:

- **Spillage (%)**
- **Energy use (kw.h)**
- **Reliability of equipment**
- **Capital expenditure (million euro)**
- **Operational expenditure (million euro)**
- **Payback period**

The reason of why those aspects chosen as the key performance indicator and how they could be measured will be fully discussed below. Also as for the capital and operational expenditure, the components of them will be listed:

**3.1 Spillage (%)**
As mentioned before, spillage causes a lot of problem, like blockage and clearance issue. Therefore there are motivations to make changes in Kleinpolder plein area to soothe the problem. And the reason of causing spillage is various. Sometimes it is because EMO transports coal and iron ore with the same belt speed and it makes problem in transfer points due to different properties of those two materials. Also sometimes the material bounce a lot at the exit of the transfer chutes in that the design cannot fulfill the self-clean condition for both coal and iron ore.

The measurement for spillage issue in new design is quite hard. It can only based on the previous upgrade project on side skirt, impact chutes, etc and then the estimation of the spillage rate could be made.

**3.2 Energy use (kw.h)**
Sit in EMO's shoes, the energy use is no doubt a crucial indicator. It is definitely better if the energy use can be cut down as much as possible. But still the uncompromised condition is that the normal day transportation should be ensured.

To measure the energy use for the future design, it is mainly related to the engine chosen and availability of the equipment in the future. Basically the energy consumption is also the one needs to be estimated based on the information from historical statistics and the suppliers.

Besides that, the availability of equipment is important for the calculation of the energy use too. The calculation of the equipment availability is shown below based on Figure 16:

\[
\text{Availability} = \frac{\text{Running time}}{\text{Net operating time}} = \frac{\text{Total operating time} - \text{No scheduled production} - \text{failure} - \text{setup}}{\text{Total operating time} - \text{No scheduled production}}
\]
3.3 Reliability of equipment
The reliability of equipment is not a quantified criterion. However, it influences the decision maker much in that to guarantee the production of a dry bulk terminal is the most important goal. As it is hard to give a clear score or rank for the reliability, it would be wiser to use comparative way among design alternatives. Therefore, not like the other four indicators that are using quantified evaluation, the reliability of equipment due to its uniqueness, it uses a qualified way to evaluation the designs later on. The reliability will be considered from several aspects: the complexity of the equipment, the movable parts of the equipment and the difficulty in operation and maintenance.

3.4 Capital expenditure (million euro)
Funds used by a company to acquire or upgrade physical assets such as property, industrial buildings or equipment\(^9\) are called capital expenditure (CAPEX). Capital expenditure is essential for an engineering project, which may help the company to decide the future investment flow and plan the project construction period. The capital expenditure consists of the shut down time loss, the deconstruction of old facility cost and the new construction work cost. By evaluating them, information needed is from the historical project capital expenditure and suppliers available service cost.

3.5 Operating expenditure (million euro)
The reason of taking operating expenditure (OPEX) as a key performance indicator is pretty much same as the reason for capital expenditure. But the difference is that the operational expenditure functions as a continuous cost with time passing by. And the operational expenditure is comprised of personnel cost and maintenance cost. The actual expense should be estimated on the basis of maintenance engineer experience and historical operational and maintenance record.

3.6 Payback period
Payback period is quite important for an industrial company making choice among alternative projects. Therefore it is also listed as one indicator. But actually the payback

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\(^9\) http://elsmar.com/Forums/showthread.php?t=14499
\(^10\) http://www.investopedia.com/terms/c/capitalexpenditure.asp
period is calculated from the cost and benefit of one project. Cost includes capital and operational cost. As for profit here, it may include the reduction of energy use, the reduction of personnel involvement and the increase of material handled due to more efficient operation methods. Therefore, those cost and benefit can both be received from the previous five key performance indicators. To avoid overlapping evaluation, the payback period will not be taken as one evaluation indicator but only a final reference indicator for EMO to decide among alternatives with.

4. Research Conclusion

In research part, it starts with the background introduction of EMO. The capacity, material property, storage area are all important criteria for one dry bulk terminal. And most importantly, transfer points are influenced by those properties, such as the demanded number of connections, the required lay out, the minimal height difference. And followed by that is the research scope. It is not likely to include all problem-solved design. But the aim is to set up a new system, or scenarios, with which the most severe problem in Kleinpolder plein can be reduced effectively. And those problems that are not so obvious and interfering with daily productions will be kept watching and corresponding action will be taken after they bring troubles to the transfer point.

Then the Kleinpolder plein has been analyzed from three aspects: material, equipment and environment. The interaction among those three aspects pictures the whole current situation of Kleinpolder plein. Belt speed influences the cross section area of material, the fullness of material influences the dust in the environment and the environment limits the equipment construction. Those linkages build up a framework for the later development of key performance indicator.

So, after that is the key performance indicator forming chapter. Those indicators regardless the dust and noise, which do not threatened EMO in nowadays, but only take the most concerned criteria, like spillage and energy use. And the reliability criterion is the everlasting demands from production companies. As for one project, the capital and operational expenditure is a crucial indicator for the feasibility of the project.

Now with all those research analysis done before, it is actually for the design part later. In Figure 17, it gives the relationship between the research part and the later design part:
This research part digs out the problem in Kleinpolder plein. Those problems are not only very important for later design part but also they help with the development of key performance indicators, with which the later design product can be evaluated. Now, with the problems discovered and the research done from all aspects in Kleinpolder plein, the key performance indicators are formed.
C. Design

1. Design Approach

In research part, the information regarding to EMO, especially in the kleinpolder plein area has been introduced thoroughly. In this chapter, the solution to those problems mentioned before will be illustrated. Before determine the final solution to specific problems, it is necessary to make a serious of decisions as shown in Figure 18.

For each specific problem in EMO, naturally it will be several solutions to that. For each solution, whether there exists a current product is the first concern. If no current product fulfills the demand to corresponding solution, a complete new design will be made. On the other hand, once a manufactured product is found suitable for the proposed solution, a following question is whether this product can be completely applied to the problem or it may need some adaption before the application. Therefore, the final product for the solution will be three types: the complete new design; the change in current product and directly application of one existing product.

Figure 18 - Diagram for the design procedure
2. Technical Design

2.1 Technical Issue

In terms of technical issue, the problems which originated from the technical part of the transfer points and can be solved by changing or renovating the mechanical parts. To distinguish from the operational issue that will be mentioned afterwards, it is the parts for chutes, side skirts and conveyer belts that are the ones indicated in technical issues.

A. Problems Specific in Transfer Points

To develop the problem in transfer points, it is very important to understand the process of material transferred in the transfer points. What will be happening there and what are the potential problems?

For each specific dry bulk terminal, unique problems in transfer points occur. Hereby, some general and common problems will firstly be introduced as below. In Rozentals’ paper, flow of bulk solid in chute design (Rozentals, 1991) states four potential problems in transfer point for dry bulk terminal: (see Figure 19)

- Carry back
- Dust from transfer point
- Internal buildup on chute walls
- Spillage and overflow

![Figure 19](image)

Figure 19 – Problems in transfer points (Rozentals, 1991)

The essential aim of good chute design is to successfully transfer as much of the incoming product as possible from one belt to the next. (Rozentals, 1991) In that way, the loss of material during transfer should be minimized as much as possible. Moreover, not only the internal loss should be controlled, but the impact towards the environment would also be
better if minimized.

Afterwards, those four problems will be deeply studied. The source of the problem and the possible solutions to eliminate or reduce the effect of the problem will also be introduced. Followed by that is the current treatment for specific problem in EMO and the outcome from them.

1) Carry back

Due to the adhesion of the dry bulk material, once the belt runs over the drum, some material will stick to the belt surface and be carried back towards the required transport direction. This will cause unforeseen material spillage on the way of transportation. In modern dry bulk terminal, scraper is the equipment specifically working on those problems.

There are variety shapes of scraper dedicated to different specification of belt and material. Using BELLE BANNE, the supplier for scraper of EMO as an example, different shape of scrapers serves different customer needs. There are three types of scrapers that are now being used in EMO: they are the A-shape, U-shape and Rv-shape scrapers. Two combinations are made to couple with each other for a high efficient belt cleaning job, that is the A-shape plus U-shape and the Rv-shape plus U-shape.

![Figure 20 - A-shape plus U-shape](image1)
![Figure 21 - Rv-shape plus U-shape](image2)

The A-shape is almost sharing the same configuration as the Rv-shape. But one unique property for the Rv-shape scrape is that it is able to serve a reverse conveyor belt. As in EMO, most long conveyor belts are functioning two directions. Then the Rv-shape and U-shape could do a lot help with that kind of belt.

As mentioned before, the scrapers have been gradually replaced after 1997. As shown in Figure 22, it indicates that the since 1998, the percentage of spillage kept decreasing and around 2007, it reaches a constant spillage percentage. And this is exactly the time EMO has finished all those replacement of scrappers. From the chart, it is clearly that, this scraper upgrade companion receives great outcome. It made the spillage reduced by about 0.20%. As for a dry bulk terminal which owns a capacity of 42 million ton per year, it is a quite considerable result.
Therefore, I will not make extra change in scrapers in this project. But with other design, I will still think of some improvements in spillage problem.

![Graph showing % Total Spillage in Year 1995-2010](image)

Figure 22 – The spillage percentage of EMO from 1995 to 2010

2) Dust from transfer point
Naturally, coal and iron ore bulk contains certain amount of fine particles. Those fine particles will float once they have been off the conveyor belt and about to be transferred to the following belt. Although this is a problem all over the dry bulk terminal, in transfer point due to the difference in level and the free falling material, more dust will come out of their supposed trajectory.

One efficient and simple way is to put watering system at the exit of transfer points. This is also what EMO does. Actually in every transfer point in EMO, it sets the spraying system as shown in Figure 23. Besides that, EMO has set up three dust detection spots. Once the dust is exceeded the regulation amount, extra movement will be taken to avoid that.
3) Internal buildup on chute walls
The third problem is the internal buildup on the chute walls. This will happen because all those dry bulk materials have certain level of moisture. With hitting the chute wall, some material will be adhesive at the wall due to the moisture. And later on, it keeps growing when material gradually dries and sticks to wall. Then days after days, more and more material builds up on the walls. Another reason is that, the material trajectory and the chute curve does not fit well with each other. This makes the material has higher impact which leads to higher adhesion to the walls.

To reduce this situation, two kinds of measurements can be taken. First is to make the chute adjustable. In that way, the material can be guided in such way that less impact will be made on chute wall and less material will loss due to the internal buildup. The second way is to use a much slipper wall material, such as the ceramic. In this case, it may cost extra investment, but ceramic scores better not only that it efficiently reduces the buildup but also that it has higher lifetime under high impact.

4) Spillage and overflow
The spillage and overflow at the exit of the transfer points are always the concerns. The reason of the spillage and overflow there is because of the transfer points' structure. The transfer point is always involved in height difference, and those differences are the roots of material bouncing. The bounce out of material creates not only the spillage but also the wear towards the receiving belt and the side skirt.

In about ten years ago, EMO was using rubber as the side skirt at the exit of the transfer point. But the falling material has quite force that pushes the rubber out of the belt and squeezes a slice of area to let the falling material spill to the ground. At the earlier stage, the rubber will go back to the initial position as it has been set. But when the rubber began to
become rigid, it sometimes stayed outside the belt and continuous material falling out
direct from the chutes to the ground. This imposes a lot loss. This loss is not only to EMO as
EMO has to assign extra personnel to clean the spillage but also the loss towards clients.
Therefore, around 2009, EMO began to use steel mounted side skirt. From that time, the
spillage due to the side skirt problem has been solved more or less. Extra attention will not
be paid on side skirt at least now.

Another improvement about the side skirt happened in year 2000. At that time, the
five-roller gearland has been changed into three-roller type and fixed relatively from each
other. Before that, the problem is the misalignment of the belt because the material
sometimes is not discharged in the center of the belt and gearland slipped to one side and
influence the function of side skirt. But with the relative fixed three roller type, the belt itself
guided the material to the center much better and this benefits the efficiency of the side
skirt. Therefore, this project will not discuss the development of the side skirt.

Another solution is the design of chute. Currently the chute using in EMO is a bunker with a
v-shape cone as an impact plate. The problem of this kind of chute is that once it has been
set up, it catches the material as a fixed position regardless the material density, the belt
speed, the conveyor inclination. Not to mention that in that case chute should be set up to
the closest situation of the material trajectory. And this is the reason why the chute wears so
quickly that it suffers a lot impact. An ideal design in industry is the hood and spoon chute, it
catches the material at a tangent position and guides the material to the following spoon
chute. With the spoon chute and self-cleaning condition, material will follow the spoon curve
and exit to the receiving belt with as much close speed as the belt is running with. To achieve
this mentioned scenario, one essential requirement is that the chute can be moved based on
different situation. This will be fully discussed in the following ‘Technical Design’ part with
some existing product and manufacturer information.

B. Problems not Specific in Transfer Points

Except for those problems mentioned above as specific ones in transfer points, there are
some problems that can be found all over the dry bulk terminal and it just becomes severe
especially in transfer points.

1) Wear Problem

The most nature thing in industry is the wear of equipment. It is inevitable and common. As
for a dry bulk terminal, it is also the case. But the thing is how to detect those wear and fix it
before the real problem happens and affects the daily production. And another concern is to
the suppliers that how to survive from heavy duty transportation assignment and extend the
life time of products.

In EMO dry bulk terminal, technical inspectors do the regular checks for all equipments and
register it in the maintenance system. The traditional inspection of conveyor belt is to drill a
small hole and measure the depth of the upper rubber cover part. With the improvement of
technology, there booms a lot laser inspection machines that can save the trouble of drilling
and measuring, but only to set up at one end of the conveyor belt and it can transmit the data to the information center. This method efficiently reduces the personnel involvement and increases the accuracy of the estimation of the life time and wear rate of the belt.

For Kleinpolder plein, extra wear happens on the transfer chutes. The continuous impact of the material shortens the life time of chute. The way of detection of the wear rate is observation. Once some of the transfer point is used at very high frequency, it can be imagined how fast those impact plates need to be replaced. Therefore, in EMO, a wear test has been carried out for choosing the most ideal product for both impact and slide chutes. Those products are:

- Ceramic
- VM-elements
- Arcoplate
- Vautid
- Castolin
- Triten
- Hardox
- Integra
- Sancic

The detailed test result can be found in appendices 7. The test procedure is not relevant to this project but the result is quite interested. For the impact plate, the VM-element is not only easy to use but also has a quite acceptable price with € 477- / m² (Europees Massagoed Overslagbedrijf (EMO) bv, 2003). And it stands for 14.5 million tons material transfer before it worn away. Although the ceramic also acts quite well with about 16.5 million tons but it has the price almost doubled, which is € 826- / m².

Consider the fact that EMO has already done much on the wear product choose to improve the wear problem all over the terminal, this project will focus much on the material flow treatment way of reliving the wear of equipments.

2) Energy consumption

To operate a dry bulk terminal, it is not surprise that quite a lot operational cost goes to the energy consumption. This is not a problem but an issue which has been put on the international table since the beginning of this century. How to efficiently use those energy is not only helping with the environment but also save a lot operational cost for EMO itself.

As for Kleinpolder plein, the complex structure definitely brings extra movable parts and much more energy use there. The simplest way of thinking is that reducing unnecessary movable parts is to reduce the energy use. There are several ways to achieve this: one is to reduce the start and stop of belt by creating much continuous flow to the belt; another is to control the belt speed under different load. The former solution can be made by optimized

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11 This can be found in Part C design, chapter 2.2, A adjustable chute, b. ASGCO, manufacturer information.
route and material flow control. And the latter one can be realized by setting up speed control motor for belts\textsuperscript{12}. (Hiltermann, 2008)

2.2 Technical Design

Based on the technical issues discussed above, there are three main designs carried out. Those designs are aiming at solving the current problems in Kleinpolder plein or at least upgrading the current facility for the purpose of less spillage, less energy, easy maintenance and high efficiency in the future transfer points.

Those three alternatives are: adjustable chutes, apron feeder and valve control. The adjustable chute is for creating a better material flow in which case the spillage can be highly reduced and the wear problem both for chute and receiving belt are eased at the same time. The apron feeder is a current application in EMO, but with some unsolved problem, some change will be made before it can be applied to the Kleinpolder plein area. And the last one, valve control is not a new design in industry, but actually it is a new design for the application in a transfer point. This will be shown in the latter passage with clear illustration and introduction.

A. Adjustable chutes

In EMO, two kinds of material, coal and iron ore are transported with same belt speed and transferred with the impact and slide chutes staying at the same position. No doubt the different properties of those two materials will result in two material trajectories when transferred between two belts. Therefore, to reduce the spillage and increase the life time of equipment, it is nature to consider the way of separate transporting the two materials. By using an adjustable hood, it is possible to fit the different trajectory of coal and iron ore. And at the same time, adjusting the corresponding spoon makes the full design complete.

To satisfy the required chute design for both coal and iron ore, the one simply way is to make a movable hood and spoon design. In that way, the hood chute can catch the material from feed belt at tangent point and correspondingly the spoon chute can pick up the material and feed it to the receiving belt. As shown in Figure 24, the conceptual design for movable chute is illustrated. And actually there exist real mature product as introduced below:

\begin{figure}[h!]
\centering
\includegraphics[width=0.5\textwidth]{adj chute.png}
\caption{Illustration for adjustable chutes design}
\end{figure}

\textbf{a. Martin Engineer}\textsuperscript{13}

Marin Engineer devotes to a lot of manufacture and maintenance of mechanical equipments in large scale

\textsuperscript{12} This can be found in Jan Hiltermann’s mater thesis paper, which introduces the speed control belt clearly and thoroughly.

\textsuperscript{13} The detail information of the transfer chutes can be found in annex.
Renovation for Transfer Points in Dry Bulk Terminal

transportation. Among all technologies developed in Martin Engineering, the transfer point technology is of the great interest for renovation of Kleinpolder Plein in EMO. As Martin Engineering is quite mature in this industry, they have complete different products dealing with various problems in transfer points. Seven aspects regarding transfer point are concerned:

- Belt Alignment
- Belt Support
- Chute Systems
- Dust Control
- Sealing Systems
- Tail Protection
- Transfer Point Accessories

Based on the current situation in Kleinpolder Plein analyzed before, the ‘Belt Alignment’, ‘Chute Systems’ and ‘Sealing Systems’ can be of great help to minimize or solve the spillage problem there. The other technologies like the scrapers, the side skirts from Martin Engineering will not be taken into account in that EMO has already renovated or going to renovate the side skirt and the scraper.

Among all of them, the MARTIN® INERTIAL FLOW™ Transfer Chutes is the product useful to the design of transfer points in EMO. The Martin Inertial Flow offers a hood and spoon design as shown in Figure 25. Compare to the current transfer bunkers used in Kleinpolder Plein of EMO, the Martin Inertial Flow prevails in the relative close system to the outside environment and the adjustable chutes can deal with materials with different properties.

And based on some reference terminals that have already put into use of adjustable chutes from Martin Engineering, below is the effect from them:

For the terminal in Alaska called Seward, they claim this MARTIN® INERTIAL FLOW™ Transfer Chutes increase their throughputs by 50% and it efficiently reduces the dust problems. As for another coal transshipment terminal, Superior, said the chutes increases their belt life up to

http://www.martin-eng.com/products/transfer-point-technologies
40% and spillage is largely reduced at the same time.

**b. ASGCO**

ASGCO offers quite similar service as Martin Engineering does. The overlapping part will not be further discussed. Two interesting products in ASGCO might be useful to belt conveyor system in Kleinpolder Plein a lot.

Firstly, the ASGCO Flo-Control™ Chutes (shown in Figure 26) suit the current layout of the belt conveyor system. It uses the discrete element methods (DEM) to simulate the material flow (Benjamin, 2000) and find the appropriate design of the chutes. The attractive part of this design is that, the Kleinpolder Plein is suitable for a hood and spoon design and the two materials transported in EMO, coal and iron ore now can be separated with the adjustment of the chutes.

Another one is the ASGCO laser alignment.\(^{16}\) It uses the laser equipment and digital processors to improve overall conveyor performance.\(^{17}\) By adapting the laser alignment detection, it may effectively increase the life year of convey belt system and reduce the energy consumption.

![Figure 26 - ASGCO Flo-Control™ Chutes](ASGCO, 2008)

**c. CMS**

Conveyor maintenance service (CMS) specializes in conveyor equipment and industrial

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\(^{16}\) As mentioned before in the 2.1 Technical issue, wear problem.

\(^{17}\) [http://www.asgco.com/Laser_Alignment_Services.shtml](http://www.asgco.com/Laser_Alignment_Services.shtml)
rubber sales, installation and repair. Impact beds, support rails, scrapers and side skirts are of the same function as the Martin Engineering and ASGCO. Therefore, it will not be fully discussed here. However, as for the tracking system, CMS offers Razer TunnelTrak™, which can ensure the correct alignment of belt conveyors. It is applicable for belt width from 450mm to 1800mm (in EMO, there are two kinds of belt width: 1600mm and 1800mm).

The products manufactured in CMS can be functioned as a comparison to the future design and a back up choices. Hence, no further research will be done for CMS product.

B. Apron feeder

Different from traditional troughed conveyor belt, apron feeder specialized in standing heavy impact from the material. The apron feeders can be found under the unloading bridge in EMO and they help to receive all the materials from the grab and transferring it to the following receiving belt. To use its specialties, I am thinking whether the apron feeder can be applied into catching the falling material in transfer point. As no doubt that lots of movable heads conveyor belts in Kleinpolder Plein. And with those movable parts, they bring the problems like consuming lot energy as well as spillage and reducing the reliability of the system. And with the introducing of apron feeder those movable heads can be fixed or removed. That is the initial thought to use the apron feeder in transfer point.

However, before making any application towards the apron feeder, there is one thing cannot be ignored, that is the deficit of the current apron feeder. As in EMO, all those apron feeders are running two directions (shown in Figure 27). In the quay side, each unloading bridge has an apron feeder downwards to receive tons of material unloaded from the grab everyday and divert them onto three quayside long belts. With the structure of the upper rubber part of the apron feeder, the material will get stuck if the apron feeder runs a wrong way as shown in Figure 28. If the apron feeder functions in a counter clockwise direction, even the material may get stuck a little bit at first when they travel through the drum, they may still fall out due to the gravity later. However, once it runs on a clockwise direction, because of the special structure of the apron feeder material will more or less stuck between to rubber pieces. This makes the apron feeder no longer a flat envelope. With this trouble, the apron feeder will get wear soon and reduce the quality of transportation with the problem of spilling material and loss of material.

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18 http://www.conveyormaintenance.com.au
Renovation for Transfer Points In Dry Bulk Terminal

If this problem can be fixed in a short time or with a solution from the supplier (Stokman B.V.), the apron feeder could be a good existing design to reduce the number of moveable heads. In other words, it can reduce the chances of failure caused by moving the belts for transferring aims. As this project will propose an available solution at current stage, no expectation should be made to the future change in apron feeder. In that case, some improvements will be made to change the current apron feeder and make the newly improved apron feeder fit in the transfer points. Below are the two proposed designs: apron feeder plus and flipped apron feeder.

a. Apron feeder plus

Based on the analysis above of apron feeder application, it is clear that EMO is encountering some problems with the apron feeders. However, it is nature to think of an upgrade apron feeder design which may still handle the high impact in the transfer point and at the same time fulfill the requirements of reducing the moveable heads.

To meet the needs mentioned above, the first thought is to operate the apron feeder in one direction. As before the problem happens because of the two direction running situation. The second step is to set up a bi-directional troughed conveyor belt beneath. In that way, the apron feeder catches the material from such a height and stands for it with its strong structure and the troughed conveyor belt beneath on the other hand helps with the transporting between receiving belts.

This newly design based on apron feeder has some pros and cons. It solves the problems with current apron feeder, reduces the moveable heads and keeps the flexibility as before. However, it brings some extra problems into transfer points. Because of the use of second bi-directional troughed conveyor belt, the actually creates two times transferring. Therefore, the problem I
mentioned before such as spillage, dust, wear, etc, they all become doubled in this apron feeder plus design. This is a very fatal problem that may influence the later evaluation of this design quite a lot. But it will not be removed from the design part. It waits for the final decision.

b. Flipped apron feeder
The second design is called flipped apron feeder. This design is the most direct design to fix the problem of original apron feeder that it cannot be operated two directions due to its special structure that makes material stuck. So, as long as the above part can be flipped with the right running direction of the apron feeder, at least the material stuck problem can be solved.

The structure is showed right in Figure 30. If the apron feeder is operated counter-clockwise direction, then it needs to be flipped as the upper illustration with the direction of the purple arrow and vice versa. To realize this design, two chains which connect all those upper parts are applied. In Figure 31, a demonstration of how these chains flip the apron feeder is made. This demonstration is based on the two chain flip design. And the down edge of the plate stays at the same position in this situation.

However, this design also has a limitation that upon the apron feeder, there are two steel mounted rubbers which function as the side skirt for the apron feeder. To solve this problem, extra design would be added. Two hydraulic cylinders need to be used to control the lift and down of the side skirt. Once the apron feeder plates are required to flip, the hydraulic cylinder will be lifted. This motion can be connected with the flipped motion. Once the order is given, procedure will be followed as: lift the side skirt – flip the apron feeder plates – put down the side skirt. This extra design can be seen in Figure 32.
C. Valve flow control

Valve flow control is another design aiming at reducing the movable heads in Kleinpolder Plein. Valve is not a fresh design in the industry area. Actually, in EMO itself, there is a real case application of valve flow control. It is in the train loading number five as shown in Figure 33 (Sutton & Sjaus, 2000).

But in transfer point application, there is not so many case that can be referred to use valve control as another transfer method. The advantage to use the valve flow control is that it is a close system. That means the valve flow control design is indeed a dust-free solution. But on the other hand, there are still two main disadvantages: space limitation and maintenance difficulties.

a. Space limitation

If take the coal as the example, it has the cross section in the troughed conveyor belt as 0.24 m². It assumes that the pipe using in valve flow control design is a circle shape. Another assumption is that the pipe is 66% filled with material. As to accept pipe diameter output percentage fill must be less than 66%. (Pipe Conveyor Power and Tension Calculation)
With those two conditions, the minimal diameter of one branch of the valve control pipe conveyor can be calculated as below:

\[ S = \pi r^2 \]

In which,

- \( S \): the minimal required cross section of the pipe conveyor
- \( r \): the minimal radius of the pipe conveyor

As the actual cross section of coal is 0.24 m\(^2\) and the 66% fullness requirements of pipe conveyor:

\[
S_{\min} = \frac{0.24}{66\%} = 0.36 m^2
\]

\[
r_{\min} = \sqrt{\frac{S_{\min}}{\pi}} = \sqrt{\frac{0.36}{3.14}} = 0.34 m
\]

Therefore, the minimum diameter for one branch of the valve control design is 0.68m. As shown in Figure 34, between two branches there is still some space. In that way, the space need for one valve flow control design is at least larger than 1.5m. The current width of troughed conveyor belt is 1.8m. Therefore, if the valve control is put into use, it probably faces with the tight area for installation.

b. Maintenance difficulties

Based on the conceptual design shown in Figure 34, it is clear that the valve is in the pipe conveyor. Therefore, once there is problem with the valve rotation or the valve plate itself, to replace or repair the valve need to remove all the cover parts. This will result in extra down time for a transfer point. At the same time, the maintenance cost increases for this new design.

c. Material chosen

There are two crucial parts involved in the valve flow control design: one is the plate used as valves and the other is the bearing for it. The plate needs to take heavy duty application which can stand quite high wear. And the bearing needs to be strong as well as easy application under the circumstance that the valve is highly involved in each time of transferring. There are some manufacturer information regarding the material for plate and potential suppliers for the bearing as shown in appendix 10.

3. Operational Design

Apart from some technical issues in transfer point, there also exist issues regarding operation. By different operational methods, either the efficiency of handling material can be increased...
or some extra benefit, such as energy save, spillage free, is also interested to one transfer point design. In this chapter, efforts will be taken to seek the problems not belonging to technical area and then they can be solved in an operational way.

3.1 Dedicated route

In last chapter, all those designs are focusing on how to improve the transfer points. Now it is the time to think out of the box, that is, what if I remove one of the transfer point possibilities. Once the transfer does not exist, then the specific problems brought from transferring do no longer exist too. Then three questions should be answered for this design:

- Which route can be made dedicated?
- If this route has been changed, can the capacity still be satisfied?
- What will be the pros and cons of this design?

A. Which route can be made dedicated?

To begin with this design, it is necessary to take a first look into the layout of Kleinpolder Plein (Figure 35):

![Figure 35 - Layout of belt connection in Kleinpolder Plein](image-url)

From all those nine conveyor belts involved in Kleinpolder Plein, there are four critical movable belts: 112, 121, 131, 220. They take the great responsibility of achieving the different connections in Kleinpolder plein. With those four movable heads, four groups of transfer points can be illustrated:

- 112 to: 113, 712, 220
- 121 to: 122, 712, 220
- 131 to: 132, 712, 220
- 220 to: 113, 122, 132, 410
It is easy to find that belt 112, 121, 131 all feed same two belts: 712 and 220. And also from Figure 36, it can be seen that 112, 121 and 131 almost share the same structure of transferring. Whether all those connections are needed is the concern now.

Therefore, now the decision is narrowed down towards those three parallel belts (112, 121 and 131), that all feed belt 712 and 220. If one or more of those six connections (112-712, 121-712, 121-220, 131-712 and 131-220) can be removed or merged to other possible route, one dedicated route is made.

Before analyzing the possibility of removing one of those connections, one concept has to be introduced. In EMO, production group is assigned for one possible route, starting from unloading bridge, stacking area or silos and ending to barge loader, train loader, E-on, stacking area. There are about 1,000 production groups in EMO. In reality, half of them are never used, but function as a possible route. Therefore, it can be found in EMO database that all possible production groups that involve those six connections.
By getting the total possible production groups for six connections, the next step is to see how many production groups indeed are in production. By checking the work log in 2010, I find that actually less than half of those production groups are used. When seeing Figure 37 and Figure 38, it indicates quite clear that, the connection of 121 – 220, 121 – 712, 131 – 220 and 131 – 712 have low percentage in the actual used production group. This offers the first clue that, those four connections mentioned above have lower involvement into transferring to 220 and 712, compared to 112 belt connections. So, one step further is to see the real production hour for each connection.
As the statistics shown in Figure 39 and Figure 40, no doubt that 112 – 220 and 112 – 712 connections play a quite critical role in Kleinpolder plein as a transfer route. Therefore, now the choice has to be made between 121 and 131. This now requires the data of total production hour in one month for belt 121 and belt 131.
Table 3 - Average production hour per month

<table>
<thead>
<tr>
<th></th>
<th>121</th>
<th>131</th>
</tr>
</thead>
<tbody>
<tr>
<td>220</td>
<td>58.17 h</td>
<td>55.33 h</td>
</tr>
<tr>
<td>712</td>
<td>62.8 h</td>
<td>105.75 h</td>
</tr>
<tr>
<td>Sum</td>
<td>120.97 h</td>
<td>161.08 h</td>
</tr>
<tr>
<td>Total occupation</td>
<td>266.42 h</td>
<td>219.02 h</td>
</tr>
<tr>
<td>Percentage for 712 and 220</td>
<td>45.4%</td>
<td>73.5%</td>
</tr>
</tbody>
</table>

In Table 3, the average production hour for connection 121 – 220, 121 – 712, 131 – 220 and 131 – 712 are calculated. As the belt 121 and 131 are the two target belts. Their percentage of production occupancy for serving to 712 and 220 compared to their total average production hour per month is the basis of whether the route can be dedicated or not.

First, when looking at belt 121, it serves both belt 712 and 220 about 120.97 hours per month. And the whole operational hour for belt 121 is 266.42 hours. That makes the transport percentage of 121 – 220 and 121 – 712 connections less than half, that is, 45.4%. If we look back at Figure 35, it can be seen that, 121 has three connections, which means half of its production hour devotes to the transfer to 122. This transfer connection is quite important as it connects the following Kombi 3, 4, 5, 6, the train loaders, the E-on, the barge 2 and 3, the deep sea boat loading and silos (shown in Figure 41). Those yellow cubes indicate the possible destinations for only using the connection 121 to 122. The conclusion should be remembered before similar analysis done by belt 131.
Then, as belt 131, the situation is different from what I have observed from belt 121. Actually, in one month, most of the production time for belt 131 is devoted to the connection 131 – 220 and 131 – 712. Only less than 1/3 of the time (26.5%), the belt 131 is feeding the following belt, which is the belt 132. And the connection of 131 to 132 serves the same service area as the connection 121 to 122, as mentioned above.

This is a quite interesting discovery, which indicates that belt 121 has more preference in transferring the material to the following service area and the movable head of 121 is put above belt 122 much often. At the same time, conclusion can be made for belt 131 also. Belt 131 serves belt 220 and belt 712 much often, that results in less percentage of transferring material to the following belt 132. Now, here comes to one merge design. What if the connection between belt 121 to 220 and 712 has been removed and belt 121 can be more dedicated to serve the following service area, as indicated in Figure 41, and meanwhile, the belt 131 take the removed production tasks from belt 121 and being more dedicated to serve the connection towards belt 220 and 712. In that way, the belt 121 can function as a fixed head conveyor belt (relative to the ‘movable head’ definition) and belt 131 can focus much on connection to belt 220 and 712. With this change, the total movable parts reduced and the material flow can be much concentrate and even for each belt.

B. If this route has been changed, can the capacity still be satisfied?

Once the decision has been made to change belt 121 into a fixed head conveyor belt, one following question is whether the capacity through Kleinpolder plein can still be satisfied. The change in material flow affects two belts' production: belt 121 and belt 131.

As for the belt 121, the target modified belt, the reduction of production hour is the
connection of 121 to 220 and 121 to 712. And that is 120.97 hour. This assignment will be
taken by belt 131. It is assumed that no reduction of current production hour happens for
belt 131 after the change. Then it makes the total average operational hour per month of
belt 131 339.99 hours. If the belt availability is about 50 %, the production hour in average
should be 360 hours, which is definitely larger than the 339.99 hour.

In fact, those two assumptions made before are the worst situations. When belt 121 split its
origin task of transferring belt 220 and 712, belt 131 at the same time re-assign the task of
feeding the following service area to belt 121. By exchange of the production, both of them
can still satisfy the requirements from capacity needs. And the availability of equipment in
EMO is around 75 %, which makes the dedicated route design much reliable also.

C. What will be the pros and cons of this design?
After the analysis done for the dedicated route choice and the capacity issue, it is time to
think of the advantage and disadvantage of this design. By changing the movable head belt
121 into a fixed head belt and only feeding the following belt 122, the movable parts
definitely reduced. This results in the reduction of energy use and spillage problem. And with
this increase of the reliability, the flexibility in this transfer point has not been reduced based
on the analysis before.

The potential problem for this design is that the operational department may be still not
used to this change. As currently, those decisions are made from experienced operators
instead of automated control system. The personnel making route decisions mainly rely on
the transportation history (based on the interview from Mr. Jan de Wit, EMO, see appendices
3). With a new layout installed, changes take time to be fit in current production schedule. To
avoid this potential problem, there are two kinds of method. One is to develop an
automated operational route program, in that way, optimize material flow will be assigned
through all over the terminal intelligently. Another solution is to reduce the usage of
connection 121 to 220 and 121 to 712 gradually. This can be achieved by fix the belt 121
head above the belt 131 for about one year. Only if there is heavy duty transportation
demands, this fixed head will be moved. After one year, based on the data log, if the
utilization of those two connections is lower than 10 hours, it then is better to make the 121
to 122 connection as a one long belt solution.

3.2 Speed control
Speed control is no longer a brand new concept for industry area and even for EMO. In 2008,
one student from Delft University of Technology has already done a deep research on the
speed control issue. And EMO also set up the speed control related equipments for the three
quay side long belts since that time. However, it is not put into use until now. This thesis will
not focus much on the discussion of the speed control principal and the effects of using a
speed control motor, but it is very much important to me that to what extent the speed
control can help with the transfer point problems.
Renovation for Transfer Points in Dry Bulk Terminal

Remember in the previous part B, the research part, the material transported in EMO has been thoroughly studied. It mentioned that the coal transported in EMO has almost twice the cross section compared to iron ore (shown in Figure 42). This increases the possibility to spill the coal in the transportation process and even worse in transfer point. It is quite true based on what I have observed in EMO dry bulk terminal (shown in Figure 43). As the iron ore particles normally show the color of red, it is easy to conclude that the spillage from terminal that is black comes from coal transportation.

There are several reasons for the more spillage coming from coal instead of iron ore. For example, the coal has smaller density and lower average lump size, with which the percentage of fine particles increases. Or it has some reason regarding to the humidity. But those reasons of spillage have little to do with the handling method in dry bulk terminal, in other words, it is hard to change the property of the material in order to reduce spillage.

However, by changing the belt running speed to change the fullness of the bulk material status on the belt is a feasible way to reduce the spillage. This method is the one aforementioned, that is, the speed control. By using the speed control motor, the belt runs at the speed based on the real time capacity. This is not only very much helpful for the spillage problem but also reduce the energy consumption up to 11% to 15%.(Hiltermann, 2008)

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19 This can be found in Part B Research; Chapter 2 System analysis; 2.1 Material; C. cross section
So, based on the equation calculated in chapter 2.1, it can be calculated that once the belt increase its running speed from 4.5 m/s to 5 m/s, the cross section will be reduced to 0.216 m²; as for speeding up to 5.5 m/s, it makes the coal cross section to be 0.196 m² (as shown in Figure 44). And the belt designed speed is up to 6 m/s. Therefore, 5.5 m/s is still into a tolerant speed control range.

And what is even convenient for EMO to apply this design is that the facility has already been installed. The efforts only need to be taken in when and how to integrate this speed control operational way into current production. Therefore, this operational design actually means no capital expenditure but very propounding benefit.

4. Scenario Development

The design in the previous section is divided into two kinds: technical and operational. As for a complete feasible project in EMO, those designs have to be integrated to several alternative scenarios. The aim is to form every single scenario, with which one specific problem can be eliminated or at least relived. Hereby four scenarios have been developed below. Each of them has their unique specialty.

4.1 Zero-plus
The zero-plus scenario focuses on the least construction work based on the current situation. (In general, the current situation called zero solution and that is why this solution is named as zero-plus). The zero-plus solution includes the adjustable chutes design and the speed control design. As the adjustable chutes are the existing products, no further changes and adaption should be made to this design. And the manufacturer will help with the set up of the adjustable chutes in the dry bulk terminal. This brings fewer burdens for the changes to be made in Kleinpolder plein from EMO’s side. Also the speed control, as facilitated equipment, no extra working hours will be devoted to that. Therefore, those two designs make the least change to the current situation in transfer point but they ameliorate the spillage and energy use problem.

4.2 Spillage free
Work just as the name indicates, the spillage free scenario offers combination of series designs to reduce the spillage into a minimum percentage. This design involves adjustable chutes, valve flow control and the speed control. The valve flow control works as a close system, which uses pipe conveyors as the transportation tools. And it couples with adjustable chutes at the feeding entrance. Those two designs effectively reduce the possibility of spillage happening. Besides that, the speed control motor lowers the cross section of coal is another highly effective measures for spillage. All those three designs can make the spillage problem being lessened to a considerable low level.
4.3 Energy save
The third scenario is called the energy save situation. Flipped apron feeder, dedicated route and speed control are the three designs contribute a lot in saving energy. One flipped apron feeder can save at least feed two receiving belts. And with the cooperation from the suppliers, the test can be run on the current apron feeder also. As for the dedicated route design, as long as the transportation capacity can be met, the moving time for the conveyor belts in transfer point is dramatically reduced. With the growing concerns to the environment, the energy save topic grabs more and more attentions. And as for EMO itself, lower energy use indicates the lower operational expenditure. Energy save scenario is especially designed for this win-win situation.

4.4 Easy maintain
Easy maintain picks up the design that needs least maintain or has less difficulties in maintenance. In that way, this scenario includes the apron feeder plus design and the dedicated route. The reason for choosing the easiest maintenance design is to choose less movable parts and not a close system. For example, as for apron feeder plus, both the apron feeder and the troughed belt beneath it are open systems and they are only involved in traditional belt running instead of complex movements of belts themselves. Dedicated route is regarded as the easy maintain solution is because it helps to reduce frequent-to-maintain part, the movable head of belt 121.

4.5 Scenario summary
Different scenarios have been developed with different combination of designs. It is better to make a summary table for an overview towards those four scenarios. This is put in Table 4.
### Table 4 – Scenarios developed

<table>
<thead>
<tr>
<th>Alternative designs</th>
<th>Adjustable chutes</th>
<th>Flipped apron feeder</th>
<th>Apron feeder plus</th>
<th>Valve flow control</th>
<th>Dedicated route</th>
<th>Speed control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenarios</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero-plus</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Spillage free</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Energy save</td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Easy maintain</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
5. Scenario Evaluation

In this chapter, the scenarios developed in the former chapter will be evaluated here and in the end the preference of scenarios from different department in EMO will be listed. This chapter begins with an introduction of the methodology for evaluation. Afterwards, the calculation will be made to score each scenario.

5.1 Methodology

There are several methods involved in this evaluation procedure. To understand the reason for choosing those methods, it is better firstly to begin with what are the known conditions (Davidson, 2005) and what are the results expected.

A. Evaluation requirements

The scenarios developed are the outcome of this project, in other words, the to-be-evaluated object. EMO, as the customer of those design scenarios, definitely functions as the evaluators. As EMO is not aware of the expected outcome from those scenarios, how to evaluate those scenarios in the shoes of EMO is a problem to be solved. So, if the linkage cannot be built directly from EMO, the evaluators, towards scenarios, the object, one 'bridge' that can both link EMO and scenarios is needed.

And, five key performance indicators now make their entrance as the 'bridge.' On one hand, the key performance indicators are developed based on the user requirements from EMO, it is definitely can be used as a score card for evaluating the potential project to be undergoing in EMO. And on the other hand, different departments from EMO also have distinct priority towards key performance indicators. In that way, the 'bridge' has been built through those five key performance indicators20:

- Spillage (%)
- Energy use (kw.h)
- Reliability of equipment
- Capital expenditure (million euro)
- Operational expenditure (million euro)

20 Detail information can be checked in part B Research; Chapter 3 Key Performance Indicator
In Figure 45, it indicates the relation among EMO different departments, key performance indicators and four developed scenarios. The target relation I want to build up is between EMO different departments and the four scenarios. As no direct information can be retrieved for this relation, key performance indicator functions as an intermediate transition. Three departments in EMO can evaluate their priority towards KPI and at the same time, KPI can evaluate the scenarios. After those two relations have been set up, the final target relation between EMO and scenarios is retrieved.

B. EMO and KPI

The first linkage is made between different department in EMO and those five criteria. Here it uses the experts grading method and SAATY method. Based on different interviews from people in maintenance, technical and operational department, preference has been determined for those criteria.

The experts grading method rely on the subject grading from experts. Those scores are not merely indicator the general priority among criteria but at the same time it indicates the difference between those priorities. As a result the score for the key performance indicator s from the EMO is actually a quantified valued score with people’s preference. And based on the scores towards different optional choices, using sum or product of those scores can get a final grading system for all options. (Zhang & Ji, 2004)

Therefore, based on the preference to criteria from different departments in EMO, the table below gives a two-dimension matrix filled with expertise grades. Score 5 indicates the highest preference to one criterion and score 1 on the other hand indicates the lowest.
Table 5 - Score for KPI from different departments in EMO

<table>
<thead>
<tr>
<th></th>
<th>Spillage</th>
<th>Energy use</th>
<th>Reliability</th>
<th>CAPEX</th>
<th>OPEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td>0.7</td>
<td>0.2</td>
<td>0.9</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Operational</td>
<td>0.8</td>
<td>0.8</td>
<td>0.3</td>
<td>0.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Technical</td>
<td>0.6</td>
<td>0.5</td>
<td>0.7</td>
<td>0.7</td>
<td>0.6</td>
</tr>
</tbody>
</table>

C. KPI and scenarios

The relation between scenarios and criteria is done in the same way as I do for previously. First the score for scenarios based on criteria is made, and then normalization should be made with the same reason for comparable consider. Therefore, Table 6 below directly gives the table with normalized score.

Table 6 - Score for scenarios based on criteria

<table>
<thead>
<tr>
<th></th>
<th>Spillage</th>
<th>Energy use</th>
<th>Reliability</th>
<th>CAPEX</th>
<th>OPEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero-plus</td>
<td>0.7</td>
<td>0.2</td>
<td>0.9</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Spillage free</td>
<td>0.8</td>
<td>0.8</td>
<td>0.3</td>
<td>0.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Energy save</td>
<td>0.6</td>
<td>0.5</td>
<td>0.7</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Easy maintain</td>
<td>0.7</td>
<td>0.2</td>
<td>0.9</td>
<td>0.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>

D. EMO and scenarios

With all those preparation has been made, it is the time that relationship between EMO different departments and scenarios. With them, now I have two normalized matrixes. But, before the final outcome can be got, the meaning of matrix and multiply of matrix should be introduced now.

Let us assume there are two matrixes A and B. As for matrix A, it indicates the relationship between p and q:

\[ A = \begin{pmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{i1} & a_{i2} & \ldots & a_{in} \end{pmatrix} \]

And this value from the q and p relation makes up to the matrix A:
The same transformer can be realized for matrix B, indicating relation between q and r.

\[
\begin{align*}
& \begin{array}{cccc}
    r_1 & r_2 & \cdots & r_j \\
    q_1 & b_{11} & b_{12} & \cdots & b_{1j} \\
    q_2 & b_{21} & b_{22} & \cdots & b_{2j} \\
    \vdots & \vdots & \vdots & \ddots & \vdots \\
    q_m & b_{m1} & b_{m2} & \cdots & b_{mj} \\
\end{array}
\end{align*}
\]

And also the formation of matrix B:

\[
B = \begin{pmatrix}
b_{11} & b_{12} & \cdots & b_{1j} \\
b_{21} & b_{22} & \cdots & b_{2j} \\
\vdots & \vdots & \ddots & \vdots \\
b_{m1} & b_{m2} & \cdots & b_{mj} \\
\end{pmatrix}
\]

Then the target matrix, C, which needs the relation between p and r, requires the multiply production of matrix A and B. The mathematical meaning of multiply of matrix is illustrated below and the application meaning for that will be shown in our real evaluation case in next chapter:

As if

\[
C = A \times B
\]

Then,

\[
\begin{pmatrix}
    \cdots & \cdots & \cdots & \cdots \\
    \cdots & \cdots & \cdots & \cdots \\
    \cdots & c_{ij} & \cdots & \cdots \\
    \cdots & \cdots & \cdots & \cdots \\
\end{pmatrix}
= \begin{pmatrix}
    a_{11} & a_{12} & \cdots & a_{1n} \\
    \vdots & \vdots & \ddots & \vdots \\
    \vdots & \vdots & \ddots & \vdots \\
    a_{m1} & a_{m2} & \cdots & a_{mn} \\
\end{pmatrix}
\begin{pmatrix}
    b_{1j} \\
    b_{2j} \\
    \vdots \\
    b_{mj} \\
\end{pmatrix}
= a_{11}b_{1j} + a_{12}b_{2j} + \ldots + a_{mn}b_{mj}
\]

In that way, the matrix C has been formed and indicates the relation between p and r as I wished:

\[
\begin{align*}
& \begin{array}{cccc}
    r_1 & r_2 & \cdots & r_j \\
    p_1 & c_{11} & c_{12} & \cdots & c_{1j} \\
    p_2 & c_{21} & c_{22} & \cdots & c_{2j} \\
    \vdots & \vdots & \vdots & \ddots & \vdots \\
    p_l & c_{l1} & c_{l2} & \cdots & c_{lj} \\
\end{array}
\end{align*}
\]

And below is the matrix exactly needed for evaluation outcome.
5.2 Evaluation

Based on the methodology introduced in last chapter, hereby the application of the matrix knowledge is given and at the same time the real meaning of it.

After multiply the matrix made before (EMO – criteria and criteria – scenarios), the evaluation from EMO departments towards design scenarios is as below:

Table 7 - Score for scenarios from different department in EMO

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Maintenance</th>
<th>Operational</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero-plus</td>
<td>1.69</td>
<td>1.76</td>
<td>2.02</td>
</tr>
<tr>
<td>Spillage free</td>
<td>1.5</td>
<td>1.89</td>
<td>1.69</td>
</tr>
<tr>
<td>Energy save</td>
<td>1.63</td>
<td>2.07</td>
<td>2.07</td>
</tr>
<tr>
<td>Easy maintain</td>
<td>1.21</td>
<td>1.53</td>
<td>1.59</td>
</tr>
</tbody>
</table>

It is can be seen that both maintenance and technical department are fond of the energy save scenario. And the zero-plus scenario is much preferred by operational department. In last chapter, one step is quite crucial in multiply of matrix, that is, the sum of column a times row b forms the value of element in matrix C. Now in this evaluation application, it is exact offering the preference of different departments towards scenarios by each single criterion. This is so important that every stepwise calculation can be changed once the focus for EMO shifts or the EU regulation restricts.

Table 8 - Preference of scenarios based on spillage indicator

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Maintenance</th>
<th>Operational</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero-plus</td>
<td>0.42</td>
<td>0.48</td>
<td>0.36</td>
</tr>
<tr>
<td>Spillage free</td>
<td>0.7</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Energy save</td>
<td>0.28</td>
<td>0.32</td>
<td>0.24</td>
</tr>
<tr>
<td>Easy maintain</td>
<td>0.07</td>
<td>0.08</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Table 9 - Preference of scenarios based on energy use indicator

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Maintenance</th>
<th>Operational</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero-plus</td>
<td>0.12</td>
<td>0.48</td>
<td>0.3</td>
</tr>
<tr>
<td>Spillage free</td>
<td>0.12</td>
<td>0.48</td>
<td>0.3</td>
</tr>
<tr>
<td>Energy save</td>
<td>0.2</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Easy maintain</td>
<td>0.16</td>
<td>0.64</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Table 10 - Preference of scenarios based on reliability indicator

<table>
<thead>
<tr>
<th>Reliability</th>
<th>Maintenance</th>
<th>Operational</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero-plus</td>
<td>0.63</td>
<td>0.21</td>
<td>0.49</td>
</tr>
<tr>
<td>Spillage free</td>
<td>0.36</td>
<td>0.12</td>
<td>0.28</td>
</tr>
<tr>
<td>Energy save</td>
<td>0.63</td>
<td>0.21</td>
<td>0.49</td>
</tr>
<tr>
<td>Easy maintain</td>
<td>0.54</td>
<td>0.18</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Table 11 - Preference of scenarios based on capital expenditure indicator

<table>
<thead>
<tr>
<th>CAPEX</th>
<th>Maintenance</th>
<th>Operational</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero-plus</td>
<td>0.36</td>
<td>0.27</td>
<td>0.63</td>
</tr>
<tr>
<td>Spillage free</td>
<td>0.12</td>
<td>0.09</td>
<td>0.21</td>
</tr>
<tr>
<td>Energy save</td>
<td>0.24</td>
<td>0.18</td>
<td>0.42</td>
</tr>
<tr>
<td>Easy maintain</td>
<td>0.2</td>
<td>0.15</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Table 12 - Preference of scenarios based on operational expenditure indicator

<table>
<thead>
<tr>
<th>OPEX</th>
<th>Maintenance</th>
<th>Operational</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero-plus</td>
<td>0.16</td>
<td>0.32</td>
<td>0.24</td>
</tr>
<tr>
<td>Spillage free</td>
<td>0.2</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Energy save</td>
<td>0.28</td>
<td>0.56</td>
<td>0.42</td>
</tr>
<tr>
<td>Easy maintain</td>
<td>0.24</td>
<td>0.48</td>
<td>0.36</td>
</tr>
</tbody>
</table>

In this process, the meaning of the matrix multiply is obvious and convinced. Most importantly for this project and for EMO is that all those scores can be traced and monitored. Weight can be changed and new design or elements can be added. This flexible evaluation way makes life easier and much efficient once new project will be undergoing in EMO.

5.3 Evaluation conclusion

Now the two outstanding scenarios should be taken closer look now: zero-plus and energy save scenarios.

A. Zero-plus scenario

Firstly, the zero plus scenarios contains the adjustable chute and speed control design. Those two designs require least construction work in EMO. And the down time depends on the set up of chutes only. With an existing chute available, the down time can be estimated as less than one day. And the producer will take care of the installation. No extra construction or adaption needed for it any more. Below is its performance when examined by five key performance indicators and one reference indicator, payback period:

1) Spillage: Based on the history data and experience, the zero plus scenario can effectively reduce the current spillage level down by 0.05%, that is, around 0.20%. This reduction of
spillage is coming from the adjustable chutes reference: Martin Engineering. Obviously it is also related to the capacity of coal and iron ore going through on chute. Therefore, it is a general assumption reduction under the circumstance of 3500 ton / h coal transported and 5000 ton / h iron ore transported with 4.5 m/s belt running speed.

2) **Energy use:** The most contribution to energy use comes from the utilization of speed control. It can reduce the current energy use by 11% - 15% under the circumstance that all three long quay side belts are using the speed control motor. (Hiltermann, 2008)

3) **Reliability:** The reliability of zero-plus design will be considered as now change. Although there are extra movable parts involved, the adjustable chutes, they move not so often and within a very small range. Therefore, it has been considered as no obvious change in reliability compared with current situation.

4) **CAPEX**: The capital expenditure is mainly based on the investment of adjustable chutes produced by Martin Engineer. With estimation, the capital expenditure is about 3800 €.

5) **OPEX**: As there is energy reduction for this design, the energy cost will be reduced from operational expenditure. And the maintenance cost is around 5% of investment, added with the personnel cost, the final operational cost is up to 0.0013 € / ton.

6) **Payback period:** The payback period is calculated on the basis of the benefit earned from this design. As the spillage and energy use are the continuous benefit, it is about (converted to economical benefit) 0.0021 € / ton. That makes the payback period around six months.

B. **Energy save scenario**
And for the energy save scenarios, flipped apron feeder, speed control and dedicated route are the two designs involved in it. The flipped apron feeder is still under the conceptual design process. And the dedicated route includes two phases of construction: first is the one year test of fixing head operation and the second period is based on the result from last period, if the result is positive, it is much better to construct a long belt without transfer any more. Hereby is the evaluation for this scenario through five key performance indicators:

1) **Spillage:** The energy save scenario contributes nothing towards spillage problem, which means the spillage remains at current level, that is, 0.25%.

2) **Energy use:** The contribution to reduction of energy use comes from both the utilization of speed control and modification of dedicated route decision. It can reduce the current energy use by 13% - 19%. 11%-15% comes from the speed control application. And the other 2% - 4% is from the dedicated route. It reduces the movable heads of the original belt 121 and the energy use of belt 121 is calculated based on appendices 9.

---

21 The items in Capital expenditure can be seen in one reference project in appendices 8.
22 The items in Operational expenditure can be seen in one reference project in appendices 8.
3) **Reliability**: This design increases reliability as dedicated route and flipped apron feeder help a lot with eliminating movable head belts. One thing needs to be notice is that the flipped apron feeder may decrease the reliability under the circumstance that it is not a mature and existing product.

4) **CAPEX**: The capital expenditure is mainly based on the investment of research, experiments and production of flipped apron feeder. With estimation, the capital expenditure is about 6,000 – 12,000 €.

5) **OPEX**: As there is large energy reduction for this design, the energy cost will not be reduced largely from operational expenditure. And the maintenance cost is around 5% of investment, added with the personnel cost together, the final operational cost is up to 0.009 € / ton.

6) **Payback period**: As there is no contribution towards spillage, therefore the benefit comes only from the saving of energy, which makes the payback period about 2.5 – 3 years. It is due to the fact that construction for making dedicated route can be quite long and at the same time the cost for developing an upgraded product in industry is hard to estimate. (Horssen, 2003)

### 6. Design Conclusion

This is most ‘heavy’ part in this thesis paper. It starts with an introduction of the design methodology, which in short is a decision tree. And with the help of the decision tree, decisions have been made towards alternative solutions. All those solutions will not be eliminated at the very first stage but waiting to be evaluated in later evaluation period. However, the separate design alternatives losses the decision focus. Therefore, scenarios make its way in proposing an integrated project, with which more precise evaluation can be given. So, followed by that is the evaluation methodology and the outcome. The evaluation fails to use traditional multi criteria analysis or other evaluation methods due to the reason that it requires a relationship among three dimensions. In the end, the evaluation based on matrix calculation is done.
Four scenarios developed and in the end two of them make better performance under the current preference in EMO. The zero plus scenarios has very less duty on the EMO side, which might be quite interesting for the company and the energy save scenario will become much competitive if the EU regulations restrict harder on energy consumption of large scale industry or EMO suffers from the high operational cost.
D. Conclusions and Recommendations

In this part, the conclusion based what is proposed and evaluated before to EMO. Moreover, the general conclusion towards the design of transfer points will be given. And in the end, the recommendations for EMO in the future developments of renovation for transfer points are offered.

1. Conclusions on EMO case study

Two scenarios have been proposed to EMO finally, they are the zero-plus with least current change and the energy-save with least energy consumption scenarios. The zero-plus wins the maintenance department preference and the latter energy save scenario gets the operational and technical.

As a large scale transportation company, guaranteeing the production is the very first priority. This indicates that less down time for the equipments and facilities in the terminal, less loss for the company. Therefore, the zero-plus scenario proposes such a project that obtains the least potential construction time and at the same time brings benefit for the company from spillage and energy problem

The energy save scenario on the other hand focuses more on the profit point of view. The profit is not only purely the money earned from production, but also much profound and lasting effect in the future. With growing restrictions on energy issues from EU regulation and increasing price of energy, to seek the way of effectively and wisely using energy is an irresistible choice for a large scale industry.

2. Recommendations for EMO case study

For Kleinpolder Plein, enough studied has been done from its problems to possible solutions. There are several recommendations given to EMO Terminal. As I observed in past half year in EMO, the spillage is really a severe problem especially under each transfer point. I can see the dossier coming and going every day to prevent gradually growing spillage influencing the normal production work. I would suggest at least using one of the designs proposed in this project to reduce the spillage problem currently.

And as for the near future, there are two problems need to be taken great care of. First is the growing restriction on environmental issue from EU regulation. To face with that situation, by using aiding system such as spraying for dust and close system for noise can only help with some of the severe problems. To reduce the dust and noise from the origin which is the vibration of the belt, I would recommend to new industry products. During my project period, I find a lot of state-of-art products in reality. They focus on all those problems mentioned
above. Such as the intelligence roller, new belt surface material. With the help of scientific
development, environment problems in terminal can be eliminated at very early stage.

Another concern is about the maintenance technology. In EMO now, still belt drilling is the
way of detecting the thickness of belt. As a matter of fact, in industry, there exists laser
system set up at the head or tail of the belt which detects the thickness in real time without
damaging the belt itself. This kind of technology may help EMO increase the efficiency during
maintenance and fewer personnel will be involved.

And in the end, before any real changes will be made to the Kleinpolder plein, I would
suggest to do same research for the transfer points before and after Kleinpolder plein. The
reason is that with material flow being changed in one transfer point, unexpected changes
can happen all over the terminal and especially the transfer point. To prevent some
unforeseen factors influencing the success of the project, this will be recommended as one
necessary step.

3. Conclusion for general transfer points design

Kleinpolder plein as a real case helps a lot to build up a concrete view of transfer points in
dry bulk terminal. With one step back on this issue, I kept asking myself whether every
transfer point shares the same problems like Kleipolder plein does. What if each unique
transfer point owns its unique problem, and then what is the meaning of my project.

The answer comes from the reference terminals. No matter for which kinds of dry bulk
terminal, precious land usage is a continuous concern. With this limitation, transfer point has
to be built up to create different level of transportation for maximizing utilization of terminal
land. And below is the conclusion made for general transfer points:

- For those transfer points with simplified layout, technical improvements should be the
  first priority to be considered.
- For those transfer points with already complex layout, operational changes could be the
  first thought towards renovation.
- As I observed, the utilization of equipment in transfer points is lower than 50% and the
  storage area takes up 1/6 of the annual throughput. If possible, it is suggested to use
  internal logistic control to increase the utilization of equipment and efficient usage of
  land.
Reference


Renovation for Transfer Points in Dry Bulk Terminal


# Appendices

## 1. Appendices 1 Material Property

### iron ore

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<th>Angle of repose</th>
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<td>brasill ssf</td>
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<tr>
<td>car fijn</td>
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<tr>
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</tr>
<tr>
<td>fabrica sio</td>
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<td>guelbs</td>
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<td>sslo</td>
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### coal

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<td>inblaas kolen</td>
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<td>2-10%</td>
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| peakdown  | 0.8       | 38              |
| kolen     | 0.9       | 38              |
| pellets   | 2.2       | 26              |
| robr rf n | 2.6       | 38              |
| erts      | 2.6       | 38              |
| applachian| 0.9       | 38              |
2. Appendices 2 Minutes for Mr. Jos van der Leer

1. How often will the inspectors go outside to do a regular inspection and how about an irregular inspection?

It depends on the equipments needed to be inspected. And the frequency of a regular inspection will be altered also based on the historical statistics and experience. For instance, if a drum normally is checked once half year but as long as it is found that there is some potential failure in one drum, then the mandatory inspection of this drum may be shortened to twice one month.

As for the irregular inspection, it is determined by inspectors themselves. As long as they find some problems and report it in the system, it will be recorded and reflect on the following regular inspections.

2. You mentioned about 'the system', so what can this system achieve?

Before 2011, EMO used a $D7i$ system in which all kinds of equipments registered. It functions well in the past time, but as it lacks the warning mechanism with which the preventative maintenance measures can be enhanced. Therefore, from the beginning of 2011, brand-new maintenance software, OPTIMIZER, has been put into use. It adds a warning mechanism to help reduce the potential severe failure. It improves the information flow both in top-down and bottom-up hierarchy. For each equipment, corresponding expired or required inspection deadline will be issued in the system for them. Afterwards, the inspectors will reflect their examine result into the system and maintenance engineering will decide the follow up measurements, such as, keep monitoring, or replace or order new parts, etc.

3. Theoretically, there are two kinds of maintenance measures: preventative and corrective. What are the weights for those two maintenance actions in EMO? And in which way they are executed?

Corrective is the domain maintenance measures. But preventative is growing its percentage in our maintenance system in EMO now. At the beginning of 2011, one new maintenance system – OPTIMIZER – has been put into use in aid of the maintenance. In OPTIMIZER, all parts of the equipments in EMO have been listed, as well as their statuses and expire dates. With those information, the risk of unforeseen failure and shutdown can be reduced.

---

23 Mr. Jos van der Leer is the advanced maintenance engineer in EMO.
3. Appendices 3 Minutes for Mr. Jan de Wit\textsuperscript{24}

1. \textit{What is the function of operational department?}

The operational department in EMO takes care of two parts regarding production. One is the planning group, which undergoing and monitoring the on-site work and another is the technical department which is under supervision from Mr. Jan Verbaan. The regular inspection and maintenance is taken by maintenance and technical department. And the production schedule is arranged from the planning department.

2. \textit{As for the detailed material transporting, do operator realize them by pre-compiled programming system or by real time control from themselves?}

In EMO now, we are using operators for each route choice and material transportation. But we are keep seeking possible system or software with which optimized route choice can be made and better material flow can be supplied to our production.

3. \textit{You mentioned about the operators; so, what are the reasons for their decision making? History data or year after year experience?}

Mainly the operators in EMO do this route choice by their subjective decisions. We have a system with all those information about occupancy of equipment and available stacking area, with those information, operator can arrange alternative production group to fulfill the required transportation task.

\textsuperscript{24} Mr. Jan de wit is the operational manager in EMO
4. Appendices 4 Minutes for Mr. Ton van der Leer

1. What is the general function of the project department?

Generally speaking, there are two main parts regarding project group: the phasing period and the management period. As for the project department, both of the parts will be taken care of, from initial proposal until the after-construction evaluation.

2. From the initial period, there definitely are several proposed project, how to make decision among them? Is there any criteria helping with the priority of project?

For a proposed design, the standardization and utilization are the two concerns. For example, the newly built stack and reclaim seven is a cope of stack and reclaim five. The unloading bridge five is a copy of unloading bridge three. Based on the existing equipment and we make 40% - 50% improvements to achieve the future equipment.

3. What if the project is totally new and cannot find any reference in EMO terminal, then what key performance indicators will be given to the new project?

I will use an example here: several years ago we put a total automation management system in EMO terminal. It is a case which can hardly found a reference case from. Then aspects like investment cost, operational cost will be made to help with evaluating the project at the early tendering phase.

We are also facing same problem when we propose the project of building a new unloading bridge five. The supervision group asked whether it is possible to build a brand new bridge instead of a copy of unloading bridge three, or could it be a copy of other unloading bridge, for example, bridge two. Therefore, we did a comparison among 50 ton unloading bridge, 50 ton unloading tower, 85 ton unloading bridge and 85 ton unloading tower [see appendices 8]. The comparison will tell us the cost per ton and based on that primary judgment could be made from the tendering.

4. You mentioned about the investment and operational cost, as this is also very much important for my project, would you minding telling me the specification of those cost division and how to estimate those cost?

Actually there is no standard way to divide and estimate the cost. It really depends on specification of each equipment. Hereby I use the aforementioned case, the unloading bridge as an example (see appendices 8): The capital cost is calculated based on the investment, the depreciation, the interest rate and the total capacity.

---

Mr. Ton van der Leer is the project manager in EMO.
And the operational cost generally is divided into energy cost, maintenance cost and personnel cost. By using those estimations in each division, a final result of cost can be got. And by comparison, the difference among tendered projects can be checked. That will be the important evaluation and choice-making criteria.
5. Appendices 5 Belt structure for belts in Kleinpolder

Plein

Belt 112

Belt 121
### Renovation for Transfer Points in Dry Bulk Terminal

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#### Belt 131

![Belt 131 Diagram](image)

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#### Belt 711

![Belt 711 Diagram](image)
### Renovation for Transfer Points in Dry Bulk Terminal

#### Belt 712

- **Belt 712**

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- **Belt 220**

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6. Appendices 6 Belle Banne scrapers

A type scraper

Door het toepassen van de "Wet van Pascal" op de nieuwe Belle Banne A-type bandschraper, wordt het probleem van bandvervorming (zgn. trogvervorming) of slijtage gecompenseerd.

Bij transportbanden ontstaat soms het probleem van vervorming (door de trog) of slijtage van het oppervlak. Vele schrapers zijn ontworpen om dit probleem te verhelpen, echter het nooit gelukt om over de gehele bandbreedte goed te schrapen.

Onze nieuwe Belle Banne A-type bandschraper is hiertoe wel in staat door gebruik te maken van de "Wet van Pascal".

Het schraapblad bestaat uit segmenten (10 cm) die zich elk afzonderlijk in hoogte kunnen aanpassen aan het bandoppervlak. Hierdoor bereikt men een efficiënte schraapresultaten in het retourpart van de band.

Fig. 1

Een rubber buis, welke een vloeistof bevat, bevindt zich centraal in de steun van het schraapmes. Hierdoor worden alle elementen door vloeistof gedragen. Doordat de druk in de vloeistof zich in alle richtingen verplaatst, zetten de afzonderlijke elementen zich met gelijke druk tegen het bandoppervlak. Als bijvoorbeeld de buitenste messen (fig. 1) omlaag worden gedrukt, komt automatisch het middelste mes omhoog. Hierdoor wordt over de gehele bandbreedte een efficiënte schraapwerking verkregen.

De buffers waarop de messen bevestigd zijn, hebben een gegalvaneerde vorm.

De gegalvaniserde vorm van de rubber buffers ondersteunen de verticale beweging van de messen en absorberen schokkende druk in de richtingen A, B, en C (fig. 2), waardoor de schraper welig zijn werk blijft uitoefenen.

Messen van Wolfram Carbide en polyethyleen. Het mes dat in contact staat met de band is gemaakt van Wolfram-carbide, welke 3000 maal meer weerstand tegen slijtage bezit dan gewoon ijzer. De polyethyleen zijn gemaakt van een hoogwaardig polypropyleen, wat ongeveer een 15 maal hogere weerstand tegen slijtage heeft dan het conventionele polyethyleen.
Makkelijke montage en weinig ruimte nodig.
De Belle Bonne A-type bandschrapers wordt gemonteerd tus-
sen punten A en B zoals aangegeven in figuur 3. Bij een
lage band-spanning of bij trillingen in de band is een druk-
rol net na de schrapers nodig. De "vloeistofbuis" is uit één
stuk, en kan in zijn geheel vervangen worden.

Onderhoud
De schrapers hoeft slechts eens in de twee maanden gein-
specteerd te worden. De vervangingsperiode van de messen is afhankelijk van
diverse omstandigheden, echter als vuistregel geldt dat bij
pim. tweederdelige slijtage (ca. 7 mm) van het wolfram
carbide het betreffende mes vervangen dient te worden.

OPMERKINGEN
1. Dit type is niet geschikt voor steil olopende transportbanden.
2. Omgevingstemperatuur niet hoger dan 80 °C.
3. Bij afwijkende omstandigheden eerst uw leverancier raadplegen.
### BELLE BANNE® A & AF Type

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<th>Schraag-bredte</th>
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<th>Huis diameter</th>
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<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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<td>3100</td>
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</tr>
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</table>

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Renovation for Transfer Points in Dry Bulk Terminal

Rv type scraper

PROMATI R.v

De pionier in de schrapers met een hoog rendement, R.v-schraaper, is uitgerust met afzonderlijk in te stellen elementen die bestaan uit:
- een speciaal rubber segment dat trillingen en onevenheden absorbeert
- een schroopmes als hordmelool
- een anti-kleef polytheel

De hoogteregeving wordt verzorgd door een eenvoudig geleidingsysteem, en de spanning wordt geregeld door een veersysteem.

Het geheel is naar keuze behandeld met een anti-roest coating of warm verzinkt en alle bouten en moeren zijn in roestvast staal uitgevoerd.

De R.v-schraaper wordt toegepast op transportbanden met één draairichting; gecombineerd met een onder-schraper fungeert hij als voorschraaper.

Figuur 1

VOORRAADenziekte

<table>
<thead>
<tr>
<th>Referentie</th>
<th>Band breedte (mm)</th>
<th>Aantal messen</th>
<th>L (mm)</th>
<th>D (mm)</th>
<th>S (mm)</th>
<th>Gewicht (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.v 400 x 300</td>
<td>400</td>
<td>2</td>
<td>900</td>
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<td>300</td>
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<td>4</td>
<td>1150</td>
<td>48,6</td>
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<td>5</td>
<td>1300</td>
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<td>R.v 1000 x 900</td>
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<td>1500</td>
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<td>900</td>
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<td>R.v 1200 x 1300</td>
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<td>8</td>
<td>1700</td>
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<td>1200</td>
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<td>51</td>
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<td>R.v 1600 x 1500</td>
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<td>10</td>
<td>2100</td>
<td>60,5</td>
<td>1500</td>
<td>61</td>
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<tr>
<td>R.v 1800 x 1800</td>
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<td>12</td>
<td>2300</td>
<td>60,5</td>
<td>1800</td>
<td>68</td>
</tr>
<tr>
<td>R.v 2000 x 1950</td>
<td>2000</td>
<td>13</td>
<td>2500</td>
<td>76,3</td>
<td>1950</td>
<td>71</td>
</tr>
</tbody>
</table>

De schraapbreedte kan met stappen van 150 mm smaller worden uitgevoerd.

NOMENCLATUUR

De benaming omvat het type schraper (1), de bandbreedte (2), de werkelijke schraapbreedte (3), de polytheel (4) en het type schraampessen (5).

Voorbeeld: Rv 800-750 SP/M3

(1) (2) (3) (4) (5)

[5]: type schraampessen:
- M3: hordmetaal (ref. H 200 M3)
- IM3: RVS uitvoering (ref. IH 200 M3)
- P: keramiek (ref. H 200 P)
Keuze van de plaatsing

De schroopmessers van de Bandschrapper dienen in contact te zijn met de band tussen de punten A en B. Bij voorkeur zo dicht mogelijk naar punt B, want zich een minimum aan materiaal kan opbouwen op de dumper. Wals moet de schroor monteren (en.child loopt op de voorkant van de aanslag boven te draaien. Tevens dient man tevens te houden bij de schroefing van de schroop en steun.

Voorbereiding van de schroop

Controleer of alle buren en moeren van de rubber buffers waarden ter opf! De messen worden pas bij de afstelling vanwege.

Montage van de messen


Montage van het schreepframe

Breng het frame aan in het standpunt, en hang de kruisk in de luifels. Schuif de luifels over de kruisk en voeg de luifels aan. Schuif de deelschroop over de kruisk, en stel de luifels aan.

Montage van het luifelsysteem

Schuif de luifels over de kruisk en bepaal de plaats van de luifels. Bewaar de luifels van de constructie van het standpunt, breng de luifels aan en waal aan.

Afsluiting

Draai het frame zoals de schroopmessers de band geraken. Breng de luifels aan op de kruisk. Veelvoelige van de luifels over de kruisk. Druk de luifels door de aanslag van de schroop en schroop de luifels over de breedte van de luifels aan.

Bij de luifels op de aanslag van de band, en zet ze goed vast.

Bent de luifels op spanning tot er 0,5 mm speling tussen de luifels plaats en regel de luifels aan op de luifels. Bent de luifels aan op de luifels en zet ze goed vast.

Voorschriften en regels

- De bandopbouw die in goede staat is te zijn, zonder-innebeendeletende (zaad nemende) delen.
- De maximale bijlage van de band is 0,5 mm.
- De maximale aanslagtemperatuur is 80°C.
- Een regelmatige onderhoud bevoordert de levensduur en efficiëntie.
**U type scraper**

![Belle Banne U](image)

De hoge-rendementsschroper de **Belle Banne U** maakt gebruik van een gepatenteerde technologie.

Tegengesteld aan andere schrapers, bestaat hij uit een reeks schroapmessen die bestaan uit een hoge kwaliteits-hardmetaal dat bevestigd is op een flexibele metalen en rubberenhouder. Het complete schroapmes zit op zijn beurt gevat in een robuuste en gebogen schroapmeshouder.

De spanning wordt verzorgd door een veersysteem.

De universele bandschroper **Belle Banne U** heeft de volgende voordelen:

- de drukverdeling is geaccentueerd naar het midden van de transportband toe, dus daar waar de hoogste efficiëntie vereist is.
- eenvoudige montage en regeling.
- zeer weinig onderhoud is vereist.
- blijvende efficiëntie en zeer lange levensduur van het schroapmes, omdat de schroper en de transportband zich aanpassen aan elkaar gedurende de gehele levensduur van het schroapmes.
- uitstekende schraping, zonder gevaar voor obstructie.

Het geheel is behandeld met een anti-roest coating en alle bouten en moeren zijn in roestvrij staal.

De Belle Banne, U-schroper kan enkel toegepast worden op transportbanden met één draairichting.

---

### Leveringspakket

<table>
<thead>
<tr>
<th>Referentie</th>
<th>Breedte</th>
<th>Breedte (totale)</th>
<th>D</th>
<th>W</th>
<th>X</th>
<th>E</th>
<th>F</th>
<th>G gewicht</th>
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<td>1300</td>
<td>48.6</td>
<td>70</td>
<td>60</td>
<td>38</td>
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<td>237</td>
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<td>48.6</td>
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<td>1600</td>
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<td>105</td>
<td>38</td>
<td>184</td>
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</tr>
<tr>
<td>U 1000</td>
<td>1000</td>
<td>1800</td>
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<td>62</td>
<td>120</td>
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<td>215</td>
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<td>46</td>
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<td>357</td>
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</tbody>
</table>
BANDSCHRAPER
MET EEN HOOG RENDEMENT

Promati

Keuze van de plaatsing
In het algemeen dient men rekening te houden met de
afmetingen van de schrapers en te zorgen voor een
good doorgang voor het afgescheurde materiaal.
De schrapers mag niet te dicht bij de kranen geplaatst
worden (niet dichter dan lijn a op figuur 1). Zodat het
mogelijk blijft om voldoende spanning op de schraper
te plaatsen.

Voorbereiding van de schraper.
Bevestig de schrapers in het midden van de kranen
e draai de 2 bevestigingsborden aan.

Montage van de 2 laterale
bevestigingssteunen.
Maak indien nodig 2 rechthoekige openingen in het
frame van de transband volgens fig. 2
Pontraverse de lagerblokken in het midden van de 2
steunen en draai ze goed vast. Draai alle bouten van
de steunen goed vast.
Build the supports on the chassis of the trans-
portband, zodat het midden van de lagerblokken 85
mm onder de transportband komt.

Montage van de schraapbuis.
Houd de schraapbuis in de lagerblokken.
Schuif de lagerblokken in de lager- en de lager-
blokken en vergrendel ze met de spitstenten. Schuif de
ontmoetingsblokken over de buis. Elk aan 1 zide van
het anti-leugelgat. Regel nu de buis zodat het
schraapbuis contact maakt met de band (zie fig. 2).

Montage van het
spanningssysteem.
Schuif de spanningssysteem over de buis en zorg dat
zowel de buisvasten op de lagerblokken geplaatst zijn
en zodat de buisvasten een goede leugelvorm vormen
Met de spanningssysteem die aan de band bevest-
gd zijn op de buis liggen.

Drukregeeling
Breng het spanningssysteem aan op de schrapers en draai
de 2 anti-leugelgaten vast. Zodat enkele mm spen-
ing tussen steunen en buis bestaat.
Zorg ervoor dat het schraapvlak goed parallel soor
is met de transportband en dat het schrapers goed
aansluit aan de band.

Voorsprongsmetingen
- De bandopvoerplaat dient in goede staat te zijn
- De maximum toegelaten bandafmeting is 6 m/s
- De maximale omgevingstemperatuur is 80°C
- Een regelingsgereedschap dat de leugelvorm van de
scherper verlengen en verhoogt zijn efficiency
7. Appendices 7 Wear test result

_Ceramics_ in transfer chute 020 – 120.

This material has lasted for 16.5 million tons on the impact plate in the transfer chute. Wear capacitance of this material is very large at this application. With passing the millions tons the wear passed wavelike over the surface. A hole on the impact spot formed slowly. There came frayed edges to the flags and some small cracks in the surface. The reject condition is 35 mm wear, then the bolt comes in the bulk flow and the wear rises very fast.

Halfway  

[worn out image]


This material has been for 14.5 million tons in the transfer chute. Wear capacitance of this material in this application is very large. Wear goes very even. After the profile has been worn away, still a rubber layer of approx. 20 mm with still 5 mm steel plate remains to plan replacement. Reject condition are: The profile worn, then plan for to replacement.
Arcoplate in transfer chute 010 – 181

Concerning this material 5.5 million tons has passed before the wear resistant layer had been worn out.
Wear went very even.
Using an ultrasonic thickness measurement instrument regularly wear has been checked measuring the thickness.
Reject condition: The wear resistant layer worn out.

Vautid 100 in transfer chute 161 – 240

Over this material 800,000 tons has passed and then was the plate was worn out.
Wear went very fast, in this case in 2.5 months.
In-between 1 time thickness has been measured with the ultrasonic thickness measurement instrument.
The estimate with regard to life span was afterwards already immediately that the material would not come above the 1 million tons.
Reject condition: in this case worn out plate, but would have been: wear resistant overlay worn low

![New](image1.png) ![Worn out](image2.png)

**Castolin CDP 4666** in transfer chute 010 - 111

Concerning this material 2.3 million tons of bulk has passed before the wear resistant layer had been worn low. Also, at this material wear has been evenly. Performed with the ultrasonic thickness measurement instrument regularly cross-section measurements. Reject condition: Wear resistant overlay worn out.

![50% worn away](image3.png) ![Worn out](image4.png)
Triten T200X en T237X in transfer chute 080 - ZBB

In this transfer chute not the impact plate has been covered with the wear product, but the wall under the impact plate slanting to the belt.
For the material T200X 1.5 million has passed tons before the material was worn out.
For the material T237X 2.1 million has passed tons before the material was worn out.
The impact load in this specific transfer chute arise because the material that slides down the impact plate falls on slanting, underlying wall and then on the be supply belt of the ZBB.
The extreme large wear on this point arises by the slanting angle among which the bulk material falls on the wear plates.
The wear product has his wear resistance by chromium carbide needles which stand in a matrix of austenitic stee. By the slanting angle of the bulk material the austenitic steel is worn out around the chromium carbide needle and is the needle falls out. Because the needles must give the wear resistance, this way no wear product is left and the wear plate will be worn out in very little time.

Triten T200X in the cells of stacker-reclaimer KB1

Over the wear plates in the cells 1.3 million tons bulk material has flowed before the wear resistant layer had worn out.
Wear has gone very evenly.
Reject condition: Wear resistant overlay worn out.
Hardox 500 in the cells of stacker-reclaimer KB1

Over the wear plates in the cells 1.3 million tons bulk material has flowed. The Hardox has been worn out for 49%.
Wear has gone very evenly.
Reject condition: Not yet obtained, would be 2 – 3 mm Hardox left.

Integra 100 in the cells of stacker-reclaimer KB1

Over the wear plates in the cells 1.3 million tons bulk material has flowed before the wear resistant layer had worn out 100%.
Wear has gone very evenly.
Reject condition: Wear resistant overlay worn out.
Sancic on the guide plate (saddle) of load installation nr.1 for railway carriages.

Approx. 16 million tons has flown over the plates. Wear is very little and very even. The granules of tungsten carbide are more clearly visible than at the beginning of the test because the cast iron wears out little by little. The estimate is that at least the same amount of ore can pass the plates go before the wear resistant layer will been worn out.

Supplement: Approx. 22.5 million tons have passed and now wear spots become visible where a reduction of tungsten carbide granules in the surface is visible. This indicates that the base of the wear resistant overlay approaches. The wear covering is still completely present.

Supplement: The situation in relation to the previous supplement has not changed virtually.
8. Appendices 8 CAPEX and OPEX table example

<table>
<thead>
<tr>
<th>Capital &amp; Operational Costs / $/ton Ship-Unlocker</th>
<th>Costs per ton at capacity level</th>
<th>Unit</th>
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<tbody>
<tr>
<td></td>
<td>50 ton</td>
<td>80 ton</td>
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<tr>
<td><strong>Capital costs</strong></td>
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<td>Annual costs</td>
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<td>Interest rate</td>
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<td>Total</td>
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<td>Production – max. capacity</td>
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<td>Capital costs per ton</td>
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<tr>
<td>Subtotal I</td>
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<td><strong>Operational costs</strong></td>
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<td><strong>Total I + II</strong></td>
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</tbody>
</table>

**Recalls**

1. In this calculation the effects on other equipment such as B/E capacity and occupancy have not been taken into account. This leads to additional advantages when utilizing a 95 ton unlocking.
2. Investment of $85 ton based on budgetary tender. Range 75-85% for 50 ton vs 75 ton.
3. Total for unlocking process
   a. Operations unlocking
   b. Operators as per
   c. Other operators incl. overhead and 25% wks.

101
9. Appendices 9 Belt Conveyor Related Calculation

(Source: DIN 22101)

1. Operating power required

\[ P = \frac{F_V}{\eta} \]

In which,

- \( F \): Total motion resistance
- \( V \): Belt speed
- \( \eta \): Power factor

The total motion resistance is a complex part to calculate. It is composed of following resistance:

\[ F = F_H + F_N + \phi \]

In which,

- \( F_H \): main or primary resistance
- \( F_N \): side or secondary resistance
- \( \phi \): gradient resistance
- \( \psi \): special resistance

All those components will be fully discussed below:

A. \( F_H \)

\[ F_H = \mu M g \]

In which,

- \( M = L [ m_R + (2 m_G + m_L)] \cos \delta \)

Also,

- \( L \): belt length
- \( m_R \): mass of rotating rolls
- \( m_G \): mass of belt
- \( m_L \): mass of bulk solid material
- \( \delta \): inclination angle

(1) \[ m_R' = \frac{m_{RG} + m_{RR}}{l_C + l_R} \]
In which,

\( m_{c}' \): mass of carry idler

\( m_{r}' \): mass of return idler

\( l_c \): carry idler spacing

\( l_r \): return idler spacing

\[
(2) \quad m_{c}' = (m_{r}'' + m_D)B
\]

In which,

\( m_D'' = \rho_r (t_r + t_b) \)

\( \rho_r \): density of rubber

\( t_r \): thickness of top cover

\( t_b \): thickness of bottom cover

\( B \): belt width

And \( m_{z}'' \) is determined by the figure below. It is related to the type of belt material.

\[
(3) \quad m_{z}' = \rho A_b = \frac{Q}{3.6v}
\]

In which,

\( Q \): belt capacity

\( v \): belt speed
Once the main resistance is calculated, the side resistance or secondary resistance could be
got with a coefficient C. And this coefficient C is based on different conveyor length. (see
Figure 47.)

\[ F_N = (C - 1) F_H \]

![Length coefficient](image)

Figure 47 – Relation between convey length L and coefficient C
Source: Slides from WB 3420, 3me, TU Delft

C. \( F_M \)

\[ F_M = H m_L \cdot g \]

In which

- \( H \): height elevated
- \( m_L \): mass of bulk solid material

And the way to calculate mass of bulk solid material is illustrated above in calculating the
main resistance part.

D. \( F_s \)

\( F_s \) exists when there are extra or special resistance included in transportation. Then it is
determined based on different situations, therefore there is no general way to calculate it.
10. Appendices 10 Valve flow control design

Plate material choice

Sandvik Scowc is made up of two different materials. The type and proportion of nodular iron and cemented carbide determine the wear resistance of the material.

A tailored wear material for heavy-duty applications

Scowc is a unique wear material combining the wear resistance of cemented carbide with the shock resistance, ductility and forming capability of nodular cast iron. Scowc is used in a wide range of applications in the mining and mineral handling industries, steel works, concrete plants and in road maintenance. It has found use most notably in crushing, fragmentation and grinding operations. In such applications, Scowc can replace conventional wear-resistant steels, castings and hardfacing on wear parts subjected to severe stress. By much higher wear resistance makes Scowc an economical valuable material.

The different materials to withstand the heavy duty

Scowc is produced in the form of composite or clad material. The casting method used in both cases provides a metallurgical bond between the cemented carbide in the wear zone and the base material.

Composite with the basest iron hard and fast

In the Scowc composite material, the wear-resistant zone consists of cemented carbide granules of some 1 to 6 mm, depending on the application, cast together with nodular iron. The cemented carbide granules account for approximately half of the volume of the wear zone. This composite material is the best choice when wear is excessive due to heavy impacts.

Clad for abrasive wear and tear

Scowc clad materials consist of cemented carbide tiles embossed in the base material. The tiles can be of various shapes and sizes, they are usually rectangular with a length and width of 10 to 50 mm, and thickness of 2 to 10 mm. The tiles form an almost continuous surface and provide the best protection against abrasive and erosive wear and moderate impacts.
Life comparison

A material with unlimited potential

Since Sacci is made up of two different materials, its hardness cannot be measured as easily as that of conventional wear materials. The type and proportion of modular iron and cemented carbide govern the wear resistance of the material chosen for the application.

In general, the following hardness values apply: Cemented carbides 950-1500 HV3 (about 85-94 HRA), modular iron 200-450 HB.

An optimally designed Sacci product has a wear resistance approaching that of cemented carbides. Where special wear problems are encountered, for example locally concentrated wear, preferred inserts of cemented carbide can be incorporated. In some cases, the best solution may be a combination of Sacci composite and clad forms.

DIMENSIONS
Sacci: products with large wear surfaces require a certain material thickness. The minimum is generally 15 mm. The following are some examples of typical dimensions of Sacci components:

- Length, mm: 200, 300, 400
- Width, mm: 200, 300, 400
- Minimum thickness, mm: 50

It is preferable to divide larger wear surfaces into smaller units.

GEOMETRIES
Sacci wear materials can be cast to the same shapes and tolerances as other cast metals. They cannot, however, be manufactured with wear surfaces on opposite faces of large areas. Recessed corners are recommended, but if sharp corners are required, performed inserts can be incorporated.

WEIGHS
Sacci: products are available in weights from about 0.5 kg up to around 1000 kg. However, the majority of Sacci products are in weights from 5 to 100 kg.

MACHINING
Sacci: material should preferably be used directly, as cast. It can, however, be machined using the normally accepted respective methods for modular cast iron and cemented carbide. Carbide-free sections can be drilled and milled, and sections containing cemented carbide can be ground and shot-peened.

Sacci: components may be retained by means of bolt or screws. Through bolt holes are cast, or the part may be provided with tapped holes on the backside. Alternatively, bolts, threaded bushings or other fasteners may be incorporated. Sacci: can also be welded to most types of steels. Specific Sacci welding instructions are available.

THE RESULTS ARE CONSTANTLY IMPROVING
We have shown you examples of some applications where Sacci is already being used with excellent results. But the possibilities have only begun to be explored. There are scores of areas where Sacci would be the better choice. And that is where you come into the picture - to improve your performance results by exploiting the unique features of Sacci.

Sacci: gives you a wear-resistant material in which the composition can be optimized to meet your specific application requirements. Designs with rounded corners are recommended. However, if sharp corners are required, performed inserts can be incorporated.

Prefared insert

Sacci: gives you a wear-resistant material in which the composition can be optimized to meet your specific application requirements. Designs with rounded corners are recommended. However, if sharp corners are required, performed inserts can be incorporated.
**Bearing material choice**

**Bearing Types**

**Retained Type Bearings (BR)**
This bearing has integral lips on the outer race to provide a surface for axial feed. This axial load is accommodated on the inner race via the hardened clamp rings which both align the inner race hubs and provide roller guidance. In larger bearings the inner race is manufactured with integral lips for roller guidance and axial load.

**Expansion Type Bearings (BX)**
This bearing is designed for radial loads only. As in the retained type bearing, the rollers are guided on the inner race by the hardened shoulders of the clamp rings.

During expansion or contraction of the shaft, rollers are free to move across the plain outer race allowing virtually no resistance to axial movement. Limits for the amount of axial movement are given in the Assembly and Maintenance section.

**Support Types**

**Support Units**
SRB bearings and housings may be mounted in a variety of support units according to the application and bearing constraints. A number of options are available as standard types with other units available on request. SRB can also offer a design and manufacturing facility to produce bespoke units to cover more specialised applications.

**Pillow Block Type**
This is by far the most popular method for mounting SRB units. These supports are manufactured from high strength grade 250 (BS 973:1975) cast iron. This, combined with the robust design, provides a stable, rigid base, allowing the split bearing fixed to give optimum performance.

**Flange Units**
In applications where bearings need to be mounted against horizontal or vertical faces, SRB flange units provide a simple means of achieving this goal. Again, the use of Grade 250 cast iron ensures a durable unit.

**Hanger Units**
A compact unit commonly used for supporting screw conveyors or similar equipment.

**Take-up Units**
These sliding units can be used to effectively tension conveyors and elevator systems. Both pull and push types are available.
**Range Comparison**

**Bearing Series**

**Light Series:**
The most commonly applied series offering good load and speed capabilities with the smallest sections within the range.

**Heavy Series:**
A more specialized series used in the most heavily loaded applications, generally operating at relatively low speeds.

**Medium Series:**
An increased section offers additional load carrying capacity. This series is typically used in ambushing, heavily loaded applications where shock load and vibration may be present.

**Bearing Selection**

**Dynamic Loading**

Selection of 300 series roller bearings must be considered separately for both initial and radial loads. Initial loads must be considered independently.

**Radial Load Considerations**

The basic bearing life of a bearing can be derived from the formula:

\[ L = \frac{C}{P} \times \left( 10^6 \right) \text{ (10^6 Revolutions)} \]

In the majority of cases where the speed remains constant, the life can be expressed in hours from the formula:

\[ L_{h} = \frac{10^6 \times C}{60 \times n} \]

Substituting – (i)

\[ L_{h} = \frac{10^6}{60 \times n} \times \left( \frac{C}{P} \right)^{1/3} \]

Under the influence of the above conditions

\[ P = F_{r} \times F_{i} \]

The required theoretical bearing life is based upon a number of factors, including reliability, availability, and service conditions. Generally, life values should be as follows:

**Load Categories**

- Machine fitted intermittently: 500 to 2,000 hours
- Occasional use: 5,000 to 10,000 hours
- Normal operation: 20,000 to 30,000 hours
- Continuous operation: 75,000 to 100,000 hours
- High Reliability: > 100,000 hours
Renovation for Transfer Points in Dry Bulk Terminal

Lili Hong