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Analysis Tool for Warehouse Material Handling Data

Bachelor’s Thesis in Computer Science and Engineering

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Abstract

Effective material handling plays a key role in cutting costs. Well-organized material handling can cut production cost by optimizing product transfer paths, decreasing the damage rate and by increasing the utilization of storage space. This report presents the development of an analysis system for StoraEnso Hylte’s paper reel database. The system extracts and classifies key points from the database which are related to material handling; like attributes related to the product (paper reel), forklift truck information and storage cell utilization. The analysis based on paper reels includes the damage rate and transfer paths of paper reels. A mathematical model is also presented, which tells us that the probability of damage per transport is more important than the number of transports for paper reels handling. The effect of decreasing non-optimal transportation (optimize the path) is very small.

Key words: Material Handling, Analysis System, Paper reel, Truck, Cell
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1. Introduction

Broadly speaking, all movements of material in a manufacturing plant can be lumped into material handling. Mechanical Engineers give the definition of material handling as the art and science involved in the moving, packing, and storing of substances in any form. [1]

This inclusive definition can include fluids, semi-fluids and all kinds of products. Effective material handling is significant in terms of costs. Well-organized material handling can cut cost by optimizing the product path, decreasing the damage rate and by increasing the utilization of storages. Therefore, material handling plays a key role both in production and marketing. This thesis focuses on handling of paper reels at warehouse of StoraEnso Hylte. The company produces on average about 2500 paper reels every day. Each reel is about $1300mm \times 1200mm$ (Diameter $\times$ Width). One paper reel weighs around 1200kg.

The work flow of paper reel is divided into three parts: production, wrapping and transportation. This paper focuses on transportation. The company has a huge database that keeps track of each paper reel from the time of production until it is shipped. Among other things, this database includes the trucks that transfer the paper reels and also the storage cells that are used to store the paper reels before they are shipped. It is expected to move a paper reel from the production area to one of the storage cells and then directly to the shipping area. But some of the paper reels are transferred several times from one storage cell to other storage cells before they are shipped. These extra movements (movement from one cell to another cell) of paper reels should be reduced as much as possible to improve the material handling. By analyzing the database, we can hope to find some crucial information, such as how to minimize the movements, what are the factors that influence the damage rate when paper reels are transferred, and which one is the dominating factor.

The analysis tool can use three main parameters: paper reel, storage cell and truck. By following a paper reel we can get statistics like the path of the paper reel in the warehouse and the number of transfers. These statistics can be used to analyze which factors that influence the probability of damaging a paper reel. Statistics like the total in/out number of paper reels and utilization of each storage cell can be generated from the survey of each storage cell.

The structure of the thesis is like this:

- Chapter 2 Background: - This chapter describes the basic information about material handling of StoraEnso Hylte and the database.

- Chapter 3 Methods: - This chapter describes the software design methods, programming tools and programming language we used in the project and the project plan.

- Chapter 4 Design and Implementation: - This chapter describes the data analysis method, implementation of designing graphical user interface and the distance matrix of the analysis system.
• Chapter 5 Testing: This chapter focuses on testing. The goal of testing is to find the problems of the data analysis system and fix them.

• Chapter 6 Result and Analysis: This chapter describes the results and the related analysis.

• Chapter 7 Conclusion: Conclusion for this paper.
2. Background

2.1 Hylte Warehouse

StoraEnso is a global paper, packaging and wood products company producing newsprint and book paper, magazine paper, fine paper, consumer board, industrial packaging and wood products [2]. The focus of this thesis is on the handling of newspaper reels in the warehouse. As shown in Figure 2.1, after the paper reels are produced and wrapped in the production area, they will come to the warehouse on two conveyor belts (A) (conveyor belt north and conveyor belt south). When the paper reels arrive to the warehouse, they are transported to a storage cell (B). From the storage cell, they may be later transported to another storage cell, or to the shipping area (C) (includes container, train, and lorry).

![Figure 2.1 The steps of the material handling. (conveyor belts (A), storage cell (B) and shipping area (C))](image)

Both conveyor belt north and conveyor belt south are used to transfer the paper reels from the production and packing area to the storage area. The conveyor belts are where the paper reels will come out after being packed, which means the trucks can only get the paper reels from the conveyor belts as the starting point. The two conveyor belts carry a total of about 2500 paper reels on average every day. These paper reels are placed in one of the 161 storage cells. The storage cells are grouped into eight sections: B (01-41), K (01-28), A (01-31), E (01-32), H (00-09), G (01-08), M (01-08) and F (01-03). In addition to the storage cells and conveyor belts has the warehouse 16 shipping areas. Large quantities of paper reels are shipped every day in three shipping areas: the rightmost part LU06-LU10, the bottom left part LU01-LU04 and top area KAJ01-KAJ08. Kasshog is an area in the warehouse where damaged paper reels are stored. Eight forklift trucks are involved in handling the transportation of the paper reels (one shown in Figure 2.2).
The layout of the warehouse of the paper mill is shown in Figure 2.3.

2.2 Database

StoraEnso Hylte has a database with more than 200 attributes recording the whole operations of the company. Twenty of these attributes keep track of the movements of the forklift truck and paper reels in the warehouse, such as unitcode (the ID of the paper reel), uby (truck name or employee’s name) and newwhloccode (new location code of the paper reel). The analysis tool is designed based on these attributes. Please see details in Chapter 4.
2.3 Problem Formulation

The aim is to analyze the material handling data related to paper reels in StoraEnso Hylte’s warehouse database, to see if information can be extracted that can be used to improve the operation. The first question that we ask is which attributes in the database that have direct or indirect influence on the handling of paper reels. The next question is to what extent these attributes affect material handling. The focus of our thesis is on paper reel handling at the warehouse and we extract all data that related to paper reels. The extracted data from StoraEnso’s database was about 150,000 lines of 20 attributes for one week. At the end of the project was a whole year’s data analyzed. The analysis tool is required to run fast besides generating accurate result.
3. Methods

This chapter describes the software design methods, programming tools and programming language we used in the project and the project plan.

3.1 Software Development Method

Normally a correct requirement analysis can reduce the task of designing a program. After general requirements are gathered, we clearly state an analysis of the scope of the development. Then the next is the implementation, testing and documentation. This development process can be described as a software development model. The most appropriate model for the project is incremental build model, because new requirements appeared during the development process.

The incremental build model is a software development method which involves both development and maintenance, the product is designed, implemented and tested incrementally (Figure 3.1, a little more is added each time) until it satisfies all requirements, i.e. it’s finished. The model integrates the components of the waterfall model into the iterative philosophy of prototyping. We divide the product into several parts, and each part is designed and built individually (termed as builds). Each part is conveyed to the user after completed, which makes partial utilization of product possible. Moreover, it creates a large initial capital outlay without the subsequent long wait. This development model also reduces the side effect of suddenly releasing a totally new system. [3]

Figure 3.1 An incremental build model
3.2 Programming Tools and Language

The data provided by StoraEnso was stored in a txt file. The txt file was imported to the SQL Server 2005 and converted to a database. SQL Server 2005 provided us an easy way to manipulate and analyze the database in an effective way. In SQL Server writing and running queries is easy and user friendly. In addition to running SQL Queries we use Java for further analysis.

Java is designed to be object oriented, simple and platform-independent. Java offers us many advantages. For example, this programming language is designed to be easy to use and is therefore easier to write, compile, debug, and learn. Since it is easy language many people can understand and program in Java, so that many people can contribute and comment during the development of the software. Because java is portable the people who need to partake in the project can run and test the software in any platform. Besides, Microsoft provides a Java Database Connectivity driver which offers access to SQL Server from any Java application.

<table>
<thead>
<tr>
<th>Advantages</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Object-oriented</td>
<td></td>
</tr>
<tr>
<td>Platform-independent</td>
<td></td>
</tr>
<tr>
<td>Distributed</td>
<td></td>
</tr>
<tr>
<td>Secure</td>
<td></td>
</tr>
<tr>
<td>Robust</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.1

There are several Java integrated development environments (IDEs), such as Eclipse, Java Workshop and Netbeans. Netbeans, which provides a good graphic toolbar, can facilitate the interface development; we chose NetBeans as our platform to implement the program.

3.3 The Project Plan

This section describes the work packages of the project.

3.3.1 Data Analysis

StoraEnso, after extraction and validation, gave us raw data with 20 attributes. After understanding the data we extracted attributes relevant for further analysis. Figure 3.2 illustrates the process.
Figure 3.2 Interpretation and validation of each attribute in the database

Figure 3.3 Extraction of statistics
3.3.2 Extraction of Statistics from Database

This subsection describes the statistics, that the analysis tool should produce agreed upon by StoraEnso and the project members.

List of end results (function requirements):

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reel transferred flow</td>
<td>The details of transfer paths for each paper reel.</td>
</tr>
<tr>
<td>Reel transferred counts</td>
<td>The number of movements for each paper reel.</td>
</tr>
<tr>
<td>Reel transferred total distance</td>
<td>The total transfer distance for each paper reel.</td>
</tr>
<tr>
<td>The number of reels with different transferred counts</td>
<td></td>
</tr>
<tr>
<td>The number of reels transferred more than twice and not damaged</td>
<td>The number of all the paper reels whose transfer counts is greater than 2 and undamaged.</td>
</tr>
<tr>
<td>Truck</td>
<td>The route of truck</td>
</tr>
<tr>
<td>The total movement distance of each truck</td>
<td>The details of transfer paths for each truck.</td>
</tr>
<tr>
<td>Reel transferred count</td>
<td>How many paper reels has been moved by one particular truck.</td>
</tr>
<tr>
<td>Cell</td>
<td>Simple transfer matrix</td>
</tr>
<tr>
<td>Complicated transfer matrix</td>
<td>A matrix presenting the number of reels which are moved from one storage cell to another storage cell.</td>
</tr>
</tbody>
</table>

Table 3.2

3.3.3 Designing the Software

This includes a set of programs and queries required for extraction and analysis of data from the database. Section 3.2 describe software tools and programming languages that are used in the project and Chapter 4 will discuss more the implementation of the software starting from database creation to data analysis.

3.3.4 Analysis of the Output of the Program

After we got an output from the software the fourth work package was to analyze the result to see the material handling of the warehouse. The aim was to see the dominating factors on paper reel handling.
4. Design and Implementation

This chapter describes the data analysis method, the design of the graphical user interface and the computation of distance matrix used by the analysis system.

4.1 Data Analysis Steps

To be able to extract useful statistics from the database we need to clean the data and convert it to a format more suitable for further analysis. This is done in four steps. The following four sections discuss the details of the steps.

![Figure 4.1 The flow of data processing](image)

4.1.1 Import Original Data

The original data that we got from StoraEnso was a comma separated text file with 20 attributes in each new line. The first step was to convert this text file to a data format that could be extracted and analyzed, i.e. a database.

4.1.2 Clean Data by SQL Query

After creating the database the next step was to extract data related to handling of paper reels. After running a set of queries we got only 6 attributes that influence material handling of paper reels. Some of the queries are shown in section 4.2.
4.1.3 Clean Data by Program.

In this step we wrote a program that followed a paper reel in certain patterns and removed the data that did not match the patterns. To extract the patterns we checked the “Actcode”, “Oldwhloccode”, and “Newwhloccode” fields. See Figure 4.2 for sample data. Table 4.1 shows some of the procedures that are used by the program to clean redundant or unnecessary rows of data. In this table “ROBOT” denotes a big packing machine. ROBOT is expressed by a ten digit number where the first two digits are zeros (00 at the beginning). The program reads such kind of data and process the data as “ROBOT” according to the regular expression. OPL stand for unknown storage cell, which means the reel is being stored somewhere in the warehouse but the systems doesn’t know where it is.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Actcode = &quot;PROD&quot;</td>
<td>This kind of data is cleaned by the program.</td>
</tr>
<tr>
<td>B Actcode = &quot;WRAP&quot;</td>
<td>Insert conveyorRight (or conveyorLeft) and the cell name (H02) in the corresponding linear list.</td>
</tr>
<tr>
<td>C oldwhloccode= newwhloccode</td>
<td>The program filtered this kind of data and reads the next row. Because the condition (oldwhloccode = newwhloccode) means the reel is not moved.</td>
</tr>
<tr>
<td>D Cell --&gt; Truck, Truck --&gt; Cell</td>
<td>This kind of data is removed by the program. This reel hasn’t been moved.</td>
</tr>
<tr>
<td>(Same Unitcode and same cell.)</td>
<td></td>
</tr>
<tr>
<td>E Cell --&gt; Truck, Truck---&gt; Cell</td>
<td>Insert the cell names in the corresponding linear list and update the time.</td>
</tr>
<tr>
<td>(Same Unitcode, different cells.)</td>
<td></td>
</tr>
<tr>
<td>F &quot;Double Row&quot; data. (Same Unitcode)</td>
<td>The program just keeps the first row.</td>
</tr>
<tr>
<td>G Cell--&gt;Cell (different cells)</td>
<td>Insert the cell names in the corresponding linear list and update the time.</td>
</tr>
<tr>
<td>H oldwhloccode=&quot;ROBOT&quot; and newwhloccode=&quot;ROBOT&quot;</td>
<td>This kind of data is removed by the program.</td>
</tr>
<tr>
<td>I OPL --&gt; Cell</td>
<td>The data (oldwhloccode=&quot;OPL&quot;) are filtered and the data (newwhloccode=&quot;certain location&quot;) are processed by the program.</td>
</tr>
<tr>
<td>J OPL --&gt; Truck, Truck --&gt; OPL</td>
<td>This kind of data is filtered by the program.</td>
</tr>
<tr>
<td>K OPL --&gt; OPL</td>
<td>This kind of data is filtered by the program.</td>
</tr>
</tbody>
</table>

Table 4.1 Some procedures that are used by the program to extract interesting patterns. Refer to Figure 4.2
Figure 4.2 Sample data

Numerous typical patterns have been concluded. The patterns in Figure 4.3 describe how the trucks transfer the paper reels inside the warehouse.

Figure 4.3 Typical patterns of material handling (right side from Figure 2.1 where conveyor belts (A), storage cell (B), and shipping area (C)) in Hylte warehouse (left side). (OPL means unknown storage cell.)

4.1.4 Data Presentation

The fourth step was to read and present the data to users in understandable format. The user should be able to export the data in Microsoft Excel format.

4.2 The Architecture of the Software

The analysis system processed a great deal of data and produced lots of data items, which were ordered when processing. List and Hash table are the basic and most frequently used data structures in the software design. Linear list is used as an intermediate storage for the data.
items or some temporary data produced by the system. Linked list is not used in the analysis system, because the analysis system ordered all the data to be processed by using SQL. Inserting and deleting operation are very limited.

Hash table is often used for matching in this analysis system. For example, matching the cell name and matching some existing data. It provides a very efficient way to do such kind of operations. Lists can also be used to do such operations but it cost more time than the hash table.

The details of implementing the system are shown below.

4.2.1 Thesis Database

We created a database named thesis with two tables; the "csvtest111" table that records the basic situation of reels of the factory and another table named “dist” that records the distances of each sub storage for the warehouse. The latter table was used for calculating the movement distance of the reel and truck.

How to create the table ------ "csvtest111":

```sql
create table csvtest111
(unitcode nvarchar (50), uby nvarchar (50), udate datetime,
oldwhcode nvarchar (50), newwhcode nvarchar (50),
oldwhlocode nvarchar (50), newwhlocode nvarchar (50),
actcode nvarchar (50), oldqualcat nvarchar (50),
newqualcat nvarchar (50), oldrsncode nvarchar (50),
ewrsncode nvarchar (50), oldordinode nvarchar (50),
newordecode nvarchar (50), extlabecode nvarchar (50),
whlocode nvarchar (50), unitdiam nvarchar (50),
unitwidth nvarchar (50), unitweig nvarchar (50))
go
```

Figure 4.4 Method for creating the table "CSVTEST111"

The method of creating the table------- "dist":

```sql
create table dist(id int not null primary key identity(1,1),d1 varchar(40),d2 varchar(40),distance decimal);
```

Figure 4.5 Method for creating the table "DIST"

In 4.2.4, we discuss the way to calculate the distance between two different cells.
4.2.2 Query Based On the Reel

In this section we describe how the analysis system works and how it is implemented when we query statistics based on paper reel. The traveling distance of paper reel can be analyzed from the distance matrix described in 4.2.4.

A) The graphical user interface:

The Graphical interface is shown in Figure 4.6. To do reel query you click on the ReelsGen button for activation.

![The Analysis System](image)

Figure 4.6 The graphic user interface based on the reel before query
When we got the result:

![Image of the graphic user interface based on the reel after the query](image)

**Figure 4.7 The graphic user interface based on the reel after the query**

B) Implementation

1) Query on ReelCode

Clicking the button "ReelsGen" queries all the different reels corresponding to the time span given and outputs it to the left drop-down box. Related SQL statement is as Listing 4.1:

```
select distinct unitcode from csvtest111 where udate between ? and ?
```

**Listing 4.1**

For more details please see the file MainFrame.java (function names are btnReelsGenActionPerformed and findAllReelsBetween).

2) Query on the specific ReelCode

Clicking the button “Query” queries all the data corresponding to the particular reel and outputs results to the left corresponding control.
Related SQL statement:

```sql
select uby, udate, oldwhloccode, newwhloccode, actcode, newordecode from csvtest111 where (uby like '%TRUCK%' or uby = 'tipseng') and unitcode = ? and udate between ? and ? order by udate
```

**Listing 4.2**

ReelDataModel is a model which expresses the reels’ features, the class diagram as follows:

![ReelDataModel class diagram](image)

3) Processing data of ReelDataModel linear list. Specific circumstances are as follows:

(1) The reel that comes off the assembly line generates two ReelDataModel data. The Actcode is “WRAP”.

A typical example:

<table>
<thead>
<tr>
<th>Uby</th>
<th>Udate</th>
<th>Oldwhloccode</th>
<th>Newwhloccode</th>
<th>Actcode</th>
<th>Newordecode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tipseng</td>
<td>2010-02-22 14:53:15</td>
<td>G03</td>
<td>G03</td>
<td>WRAP</td>
<td>HYDK-055172</td>
</tr>
</tbody>
</table>

**Table 4.2**

The processing program will generate a linear list as Figure 4.9. This linear list looks like a linked list; actually it’s a sequential list.
Figure 4.9 The linear list of ReelDataModel

Note: Usually, the paper reel will arrive at the first cell 15 minutes after it is put on the conveyor belt.

(2) The reel transferred from a certain location to a certain truck generates one ReelDataModel and appends it to the end of the linear list node.

A typical example:

<table>
<thead>
<tr>
<th>Uby</th>
<th>Udate</th>
<th>Oldwhloccode</th>
<th>Newwhloccode</th>
<th>Actcode</th>
<th>Newordecode</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYLTRUCK02</td>
<td>2010-02-25 04:25:41</td>
<td>E17</td>
<td>TRUCKPC02</td>
<td>CHANGE</td>
<td>HYDK-055172</td>
</tr>
</tbody>
</table>

Table 4.3

The refreshed linear list:

Figure 4.10 The linear list of ReelDataModel

(2) The reel transferred from a truck to a certain location generates one ReelDataModel and appends it to the end of the linear list node. For instance:
Table 4.4

<table>
<thead>
<tr>
<th>Uby</th>
<th>Udate</th>
<th>Oldwhloccode</th>
<th>Newwhloccode</th>
<th>Actcode</th>
<th>Newordecode</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYLTRUCK02</td>
<td>2010-02-25</td>
<td>04:26:39</td>
<td>TRUCKPC02</td>
<td>B13</td>
<td>CHANGE</td>
</tr>
<tr>
<td></td>
<td>03:54:43</td>
<td></td>
<td></td>
<td></td>
<td>HYDK-055172</td>
</tr>
</tbody>
</table>

The refreshed linear list:

Table 4.5

<table>
<thead>
<tr>
<th>Uby</th>
<th>Udate</th>
<th>Oldwhloccode</th>
<th>Newwhloccode</th>
<th>Actcode</th>
<th>Newordecode</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYLTRUCK02</td>
<td>2010-02-25</td>
<td>03:54:43</td>
<td>A01</td>
<td>KAJ01</td>
<td>CHANGE</td>
</tr>
<tr>
<td></td>
<td>03:54:43</td>
<td></td>
<td></td>
<td></td>
<td>HYDK-055172</td>
</tr>
</tbody>
</table>

The refreshed linear list:

Details are in the file MainFrame.java (function name is "btnReelQueryActionPerformed") and DataDAO.java (function names are "findReelDataBetween" and "reelProcess").
4.2.3 Query Based On the Truck

In this section we describe how the analysis system works and how it is implemented when we query statistics based on truck.

A) The Graphical Interface:

The Graphical interface is shown in Figure 4.13. To do truck query you click on TruckGen button for activation.

Figure 4.13 The graphic interface based on the truck before the query
When we got the result:

Figure 4.14 The graphic interface based on the truck after the query

B  Implementation

1) Clicking the button "TruckGen" queries all the different trucks corresponding to the time span and outputs it to the left drop-down box. Related SQL statement:

```sql
select distinct uby from csvtest111 where uby like '%TRUCK%' and udate between ? and ?
```

Listing 4.3

For details please see the file MainFrame.java (function name is btnTruckGenActionPerformed) and DataDAO.java (function name is findAllTrucksBetween).

2) Clicking the button "Query" queries all the data corresponding to the particular truck and outputs results to the left corresponding control.

Related SQL statement:

```sql
Select unitcode uby, udate, oldwhloccode, newwhloccode, actcode, newordecode from csvtest111 where uby = ? and udate between ? and ? order by udate
```

Listing 4.4
TruckDataModel is the model which expresses the data of Trucks, the class diagram as follows:

### Attribute:

```java
private List<String> reelCodes = new ArrayList<String>(1);
private Date arriveTime;
private Date leaveTime;
private String location;
private String state;
```

Listing 4.5

### Operation:

```java
public String getState()
public void setLocation(String location)
public String getLocation()
public void setLeaveTime(Date leaveTime)
public Date getLeaveTime()
public void setArriveTime(Date arriveTime)
public Date getArriveTime()
public boolean contains(String reelCode)
public void removeReelCode(String reelCode)
public void addReelCode(String reelCode)
public void setReelCodes(List<String> reelCodes)
public List<String> getReelCodes()
```

Listing 4.6

A lot of TruckDataModel form a linear list.

3) Processing data of TruckDataModel linear list. Specific situation is as follows:

(1) The reel shipped from a certain location to a certain truck. For instance,

<table>
<thead>
<tr>
<th>Unitcode</th>
<th>Udate</th>
<th>Oldwhloccode</th>
<th>Newwhloccode</th>
<th>Actcode</th>
<th>Newordecode</th>
</tr>
</thead>
<tbody>
<tr>
<td>091084920501</td>
<td>2010-02-22</td>
<td>B09</td>
<td>TRUCKPC01</td>
<td>CHANGE</td>
<td>HYCZ-054756</td>
</tr>
</tbody>
</table>

Table 4.6
The linear list of TruckDataModel:

![Linear List Diagram](image)

Figure 4.15 Linear list of the TruckDataModel

(2) The reel transferred from a certain location to a certain truck, it generates one TruckDataModel record and appends to the end of the linear list node.

<table>
<thead>
<tr>
<th>Unitcode</th>
<th>Udate</th>
<th>Oldwhloccode</th>
<th>Newwhloccode</th>
<th>Actcode</th>
<th>Newordecode</th>
</tr>
</thead>
<tbody>
<tr>
<td>091084920501</td>
<td>2010-02-23 22:04:22</td>
<td>B10</td>
<td>TRUCKPC01</td>
<td>CHANGE</td>
<td>HYCZ-054756</td>
</tr>
</tbody>
</table>

Table 4.7

It generates the linear list of TruckDataModel.

![Linear List Diagram](image)

Figure 4.16 Linear list of the TruckDataModel

(3) From the certain location to another location, it generates one TruckDataModel record and appends to the end of the linear list node.

<table>
<thead>
<tr>
<th>Unitcode</th>
<th>Udate</th>
<th>Oldwhloccode</th>
<th>Newwhloccode</th>
<th>Actcode</th>
<th>Newordecode</th>
</tr>
</thead>
<tbody>
<tr>
<td>091084920501</td>
<td>2010-02-23 22:04:22</td>
<td>B13</td>
<td>LU07</td>
<td>CHANGE</td>
<td>HYHU-952944</td>
</tr>
</tbody>
</table>

Table 4.8
It generates the linear list of TruckDataModel:

![Figure 4.17 The linear list of the TruckDataModel](image1)

Details please see the file MainFrame.java (function name is "btnTruckQueryActionPerformed"). Details please see the file DataDAO.java (function names are "findTruckDataBetween" and "truckProcess").

### 4.2.4 The Distance Matrix

A crucial preparatory work is to calculate the distance matrix, which describes the shortest driving distance between two cells. This distance matrix is used for the statistic for truck and reel. Figure 4.18 is the warehouse plan provided by StoraEnso.

The warehouse is divided into several cells and the shape of each cell is similar. Using this characteristic, we re-edit the warehouse plan. After discussing with the StoraEnso and the supervisors, we added main paths, bound and the "height" for each cell.

![Figure 4.18 The PDF File of the warehouse layout](image2)
Calculation Algorithm on Distance of the Location

To design an algorithm to calculate the distance between two locations we used the following ideas:

A) The distance definition of two cells: - The central point of the cell maps to the main path and the distance of two cells is the straight-line distance of two mapping central point plus two times the Height. Though the distance which the truck runs from one cell to another is not the same at different times, the deviation is little and tolerable, shown as in Figure 4.19.

B) Selection of the basic points: As mentioned before, the storage is divided into several cells and these cells have similar shape (same width and height, as shown in Figure 4.19). This provides an easy way to calculate the distance between two cells. First, we select a reference point for each storage. For instance, select "B01" as the reference point of the section "B". Likewise, select M01 as the reference point of section M. Based on basic points; we calculate the distance as shown in Figure 4.20.
The figure of the calculation method:

![Figure 4.20 Calculation method](image)

The base points:

<table>
<thead>
<tr>
<th>SECTION</th>
<th>BASE POINT</th>
</tr>
</thead>
<tbody>
<tr>
<td>KASSHOG</td>
<td>KASSHOG</td>
</tr>
<tr>
<td>CONVEYORLEFT</td>
<td>CONVEYORLEFT</td>
</tr>
<tr>
<td>CONVEYORRIGHT</td>
<td>CONVEYORRIGHT</td>
</tr>
<tr>
<td>SECTION A</td>
<td>A01</td>
</tr>
<tr>
<td>SECTION B</td>
<td>B01</td>
</tr>
<tr>
<td>SECTION E</td>
<td>E01</td>
</tr>
<tr>
<td>SECTION F</td>
<td>F01, F02, F03</td>
</tr>
<tr>
<td>SECTION G</td>
<td>G01</td>
</tr>
<tr>
<td>SECTION H</td>
<td>H00</td>
</tr>
<tr>
<td>SECTION K</td>
<td>K(6,7)</td>
</tr>
<tr>
<td>SECTION M</td>
<td>M01</td>
</tr>
<tr>
<td>LU</td>
<td>LU</td>
</tr>
<tr>
<td>KAJ</td>
<td>KAJ</td>
</tr>
<tr>
<td>ROBOT</td>
<td>ROBOT</td>
</tr>
</tbody>
</table>

Table 4.9 Basic point of the each section
4.2.5 Query Based On the Location

In this section we describe how the analysis system works and how it is implemented when we query statistics based on cell.

A) The Graphical Interface:

![The graphic interface based on the cell before the query](image1)

When we got the result:

![The graphic interface based on the cell after the query](image2)
B) Implementation

TimeSpan Setting: can set the time span.
Location Selection: can set the location. Two querying mode can be chosen: All location and single location.
   All location: query all information for all locations.
   Single location: query information for a specified location.

The SQL statement:

```sql
select unitcode, oldwhloccode, newwhloccode, actcode from csvtest111 where (uby like '%TRUCK%' or uby = 'tipseng') and (oldwhloccode = ? or newwhloccode = ?) and (udate between ? and ?) order by unitcode, udate ;
```

Listing 4.7

Data structure:

```java
LocationInOutNumMode
Listing 4.8
```

Attribute of the structure:

```java
private int inNum;
private int outNum;
Listing 4.9
```

Operation of the structure:

```java
public void addInNum()
public void reduceInNum()
public void addOutNum()
public void reduceOutNum()
public int getInNum()
public int getOutNum()
public void setInNum(int inNum)
public void setOutNum(int outNum)
Listing 4.10
```
Storage Method:

The map, which name is “result” is initialized by the constructor of the class DataDao. In the initialization process, all the cells’ names are set as the key of the map (“result”), and these cells are defined in file Util.java. For example:

```java
public static String[] locsA = 
{"A01","A02","A03","A04","A05","A06","A07","A08","A09","A10","A11","A12", 
"A13","A14","A15","A16","A17","A18","A19","A20","A21","A22","A23","A24", 
"A25","A26","A27","A28","A29","A30","A31"};

public static String[] locsB = 
{"B01","B02","B03","B04","B05","B06","B07","B08","B09","B10","B11","B12", 
"B13","B14","B15","B16","B17","B18","B19","B20","B21","B22","B23","B24", 
"B25","B26","B27","B28","B29","B30","B31","B32","B33","B34","B35","B36", 
"B37","B38","B39","B40","B41"};
```

Processing data is of LocationInOutNumModel linear list. Specific situation is as follows:

1. If the reel’s "actcode" is "wrap". The relevant location’s InNumber increase 1. For instance:

```plaintext
<table>
<thead>
<tr>
<th>Unitcode</th>
<th>Uby</th>
<th>Udate</th>
<th>Oldwhloccode</th>
<th>Newwhloccode</th>
<th>Actcode</th>
</tr>
</thead>
<tbody>
<tr>
<td>101105225022</td>
<td>Tipseng</td>
<td>2010-02-22 00:16:37</td>
<td>B12</td>
<td>B12</td>
<td>WRAP</td>
</tr>
</tbody>
</table>
```

The cell B12’s InNumber adds 1.
(2) The reel transferred from a certain location to a certain truck, the location’s OutNumber adds 1.

(3) The reel transferred from a certain truck to a certain location, the corresponding cell’s InNumber adds 1. Duplicated data are ignored.

(4) The reel transferred from location1 to location2, OutNumber of location1 increase 1 and InNumber of location2 increase 1. Duplicated data are ignored.
5. Testing

5.1 Distance Matrix

Testing for distance Matrix:

Test methodology: Choose a distance of two randomly selected points from the distance matrix, compare with the real distance; the deviation is acceptable if it is less than 0.2 m.

Testing results:

<table>
<thead>
<tr>
<th>Number of tests</th>
<th>Error Range</th>
<th>Incorrect distances before correcting the program (Ratio)</th>
<th>Incorrect distances after correcting the program (Ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>≤0.2</td>
<td>7/150 (4.7%)</td>
<td>0/150 (0%)</td>
</tr>
</tbody>
</table>

Table 5.1 Testing results

Two types of bugs were found:

1) Incorrect calculating logic, most of the logic problem comes from section LU, which includes several points but all points are mapped to one point.
2) Wrong distance of baseline, which is measured by hand.

5.2 Test of Queries

Testing for querying based on REEL and TRUCK:

Test methodology:

Step1: Randomly choose a time period.
Step2: Randomly choose a reel number or a truck from the database.
Step3: Query it by using The Analysis System.
Step4: Compare the result with the information in the database, check if the result is correct.
For example:

Figure 5.1 The results based on the reel.

Figure 5.2 The original data about the unitcode = '1010180106033' in the database

According to Figure 5.1 and Figure 5.2, the results are correct. The reel with the unitcode '1010180106033' is transferred from A03 and KAJ01.
According to Figure 5.3 and Figure 5.4, the results are correct. Truck01 started from K17, and then went to K11, finally returned to K17.

One bug was found in the program:
The program doesn’t filter the following kind of data (same location to the same location):
Testing results of query based on reel:

<table>
<thead>
<tr>
<th>Number of tests</th>
<th>Mistakes before correcting the program (Ratio)</th>
<th>Mistakes after correcting the program (Ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>7/100 (7%)</td>
<td>0/100 (0%)</td>
</tr>
</tbody>
</table>

Table 5.2

Testing results of query based on truck:

<table>
<thead>
<tr>
<th>Number of tests</th>
<th>Mistakes before correcting the program (Ratio)</th>
<th>Mistakes after correcting the program (Ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>5/100 (5%)</td>
<td>0/100 (0%)</td>
</tr>
</tbody>
</table>

Table 5.3

Testing for querying based on CELL:

Test methodology:
- Step1: Randomly choose a time period.
- Step2: Split the time period into an arbitrary amount of time periods
- Step3: Manually compare the result with the information in the database, check if the result is correct.

For example:

*Figure 5.6 The results based on the cell*
According to Figure 5.6 and Figure 5.7, the results were correct. The grey parts means the location’s (A06) InNumber is 2.

Testing results of query based on cell:

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Mistakes before correcting the program (Ratio)</th>
<th>Mistakes after correcting the program (Ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>20/100 (20%)</td>
<td>0/100 (0%)</td>
</tr>
</tbody>
</table>

Table 5.4

5.3 Test of Time Consuming

There are 6,570,000 data lines for the whole year, it is very time consuming to process such a lot of data at once. In this case, it is necessary to separate the data into several parts and process them independently. We tested the time consuming for calculating based on reel with the data in different time period. Figure 5.8 and Figure 5.9 show the result.
Figure 5.8 Execution time for statistic based on reel

Figure 5.9 Execution time for statistic based on reel

Note:

<table>
<thead>
<tr>
<th>Data calculated by days</th>
<th>Data calculated by rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>7days’ data</td>
<td>It is about 140,000 rows.</td>
</tr>
<tr>
<td>14days’ data</td>
<td>It is about 300,000 rows.</td>
</tr>
<tr>
<td>21days’ data</td>
<td>It is about 460,000 rows.</td>
</tr>
<tr>
<td>31days’ data</td>
<td>It is about 690,000 rows.</td>
</tr>
<tr>
<td>45days’ data</td>
<td>It is about 1,040,000 rows.</td>
</tr>
</tbody>
</table>

Table 5.5 The data calculated by days corresponding to the rows
The software crashed when we run the whole year’s data with our own laptop. We therefore divided the one year’s database into 5 pieces. Each sub database has the data for 2 months. From the two figures above we can see it took 660 minutes to run 45 days’ data and the execution for the software occupied 2/3 the memory of our computer. The execution time grows like $T \sim O(l^2)$, where $l$ is the number of rows in the database.
6. Results and Analysis

6.1 Transfer Rate of Paper Reels

A paper reel is sometimes transferred more than two times before it reaches the shipping area. These are called extra transfers. These extra movements should be minimized to improve the material handling. Table 6.1 describes how many paper reels have been transferred how many times during a certain period. TransferCount shows how many times the paper reel has been transferred during a certain period. Number shows how many reels have been transferred for the specified TransferCount during the specified period. Count>2 and not damaged: is the number of paper reels that have been transferred more than twice but remain undamaged.

RatioA: The number of TransferCount=2 divided by the sum of column “Number” except TransferCount=0.
RatioB is the sum of TransferCout >2 divided by the sum of column “Number” except TransferCount=0.
RatioC is the sum of TransferCout =1 divided by the sum of column “Number” except TransferCount=0.

The average value of RatioA is around 70%. The average value of RatioB is around 10%.

<table>
<thead>
<tr>
<th>TransferCount</th>
<th>Jan-Feb</th>
<th>Mar-Apr</th>
<th>May-Jun</th>
<th>Jul-Aug</th>
<th>Sep-Oct</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17031</td>
<td>15396</td>
<td>28010</td>
<td>37295</td>
<td>28132</td>
</tr>
<tr>
<td>2</td>
<td>122215</td>
<td>119116</td>
<td>108725</td>
<td>99258</td>
<td>72022</td>
</tr>
<tr>
<td>3</td>
<td>12604</td>
<td>12144</td>
<td>14148</td>
<td>11434</td>
<td>10548</td>
</tr>
<tr>
<td>4</td>
<td>2487</td>
<td>2637</td>
<td>3488</td>
<td>2749</td>
<td>2644</td>
</tr>
<tr>
<td>5</td>
<td>822</td>
<td>758</td>
<td>1026</td>
<td>774</td>
<td>932</td>
</tr>
<tr>
<td>6</td>
<td>306</td>
<td>309</td>
<td>416</td>
<td>322</td>
<td>378</td>
</tr>
<tr>
<td>7</td>
<td>108</td>
<td>154</td>
<td>164</td>
<td>87</td>
<td>185</td>
</tr>
<tr>
<td>8</td>
<td>38</td>
<td>71</td>
<td>59</td>
<td>38</td>
<td>58</td>
</tr>
<tr>
<td>9</td>
<td>11</td>
<td>21</td>
<td>25</td>
<td>8</td>
<td>19</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>11</td>
<td>14</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>6</td>
<td>8</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TransferCount&gt;2 And not damaged</td>
<td>15696</td>
<td>15456</td>
<td>18926</td>
<td>15031</td>
<td>14482</td>
</tr>
<tr>
<td>Ratio A</td>
<td>78.53%</td>
<td>79.08%</td>
<td>69.66%</td>
<td>65.32%</td>
<td>62.66%</td>
</tr>
<tr>
<td>Ratio B</td>
<td>10.53%</td>
<td>10.70%</td>
<td>12.40%</td>
<td>10.14%</td>
<td>12.87%</td>
</tr>
<tr>
<td>Ratio C</td>
<td>10.94%</td>
<td>10.22%</td>
<td>17.94%</td>
<td>24.54%</td>
<td>24.47%</td>
</tr>
<tr>
<td>Total Ratio</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 6.1 Transfer rate of paper reels from January to October
From Table 6.1 we can see that Ratio A decreases from almost 80% to 60% during the year. Ratio B stays almost constant. Ratio C increases from 10.94% to 24.54%. The fact that Ratio C increases indicates that paper reels are staying longer in the warehouse.

6.2 Transfer Matrix

\[
\begin{align*}
\text{A01} & \quad \ldots \quad \text{B01} & \quad \ldots \quad \text{E26} & \quad \ldots \quad \text{G01} & \quad \ldots \quad \text{Robot} \\
\text{A01} & \quad 0 & \quad \ldots & \quad 0 & \quad \ldots & \quad 0 & \quad \ldots & \quad 0 & \quad \ldots \quad \ldots & \quad 0 \\
\vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots \quad \vdots \quad \vdots \\
\text{B01} & \quad 0 & \quad \ldots & \quad 0 & \quad \ldots & \quad 2 & \quad \ldots & \quad 0 & \quad \ldots & \quad \ldots & \quad 74 \\
\vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots \quad \vdots \quad \vdots \\
\text{E26} & \quad 19 & \quad \ldots & \quad 2 & \quad \ldots & \quad 0 & \quad \ldots & \quad 0 & \quad \ldots & \quad \ldots & \quad 1 \\
\vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots \quad \vdots \quad \vdots \\
\text{G01} & \quad 0 & \quad \ldots & \quad 0 & \quad \ldots & \quad 0 & \quad \ldots & \quad 0 & \quad \ldots & \quad \ldots & \quad 8 \\
\vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots \quad \vdots \quad \vdots \\
\text{Robot} & \quad 0 & \quad \ldots & \quad 0 & \quad \ldots & \quad 0 & \quad \ldots & \quad 0 & \quad \ldots & \quad \ldots & \quad 0
\end{align*}
\]
The transfer matrix is one of the outputs of our analysis tool which shows the number of paper reels transferred from one storage cell to another. This matrix can show us some facts like which storage cells have the highest exchange of paper reels. We have seen that storage cells which are neighbors exchange most of the time. There is also some exchange of paper reels between storage cells which are opposite each other in corridors (e.g. storage cell A and B). Figure 6.4 shows the transfer matrix from January to October. As can be seen from the figure there is a bright region across the diagonal which shows the transfer rate of neighbor storage cell. We can also see bright rectangle around the middle of the diagonal ("From" 73 "To" 73 and "From" 104 "To" 104 ) this shows that the neighbor storage cells of section E have more exchange of paper reels. There is also one bright region around the line which joins the two points "From" 65 "To" 0 and "From" 0 "To" 65. If we look at the map of the warehouse we can easily notice that the reason for this bright region is because storage cells in section A and B are in opposite of each other. With this matrix is it possible to draw a graphical illustration of the transport ways. Please see details in Appendix locationData_20100101000000_20100131235959.xls.

Figure 6.3 Transfer matrix

The histograms below (Figure 6.4) show the number of paper reels transferred from a few selected storage cells to all storage cells. If we look the first histogram around 95 paper reels have been transferred from A01 to A02. We also have more transfer from storage cell A01 to B section storage cells (around storage cell 60).
The other result which may be interesting to know is how many paper reels that were transferred into a storage cell and how many paper reels were moved out of the same storage cell in a certain time period. Table 6.2 shows an example for a few selected storage cells.

<table>
<thead>
<tr>
<th>Location</th>
<th>Start Time</th>
<th>End Time</th>
<th>In Number</th>
<th>Out Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A01</td>
<td>07-01-2010 00:00:00</td>
<td>08-31-2010 23:59:59</td>
<td>1107</td>
<td>1159</td>
</tr>
<tr>
<td>A02</td>
<td>07-01-2010 00:00:00</td>
<td>08-31-2010 23:59:59</td>
<td>796</td>
<td>659</td>
</tr>
<tr>
<td>A03</td>
<td>07-01-2010 00:00:00</td>
<td>08-31-2010 23:59:59</td>
<td>2048</td>
<td>2066</td>
</tr>
<tr>
<td>Robot</td>
<td>07-01-2010 00:00:00</td>
<td>08-31-2010 23:59:59</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 6.2 The results based on storage cells
6.4 Model of Paper Reel Handling

6.4.1 Fault Probabilities

We assume that the probability for damaging a paper reel is the same for every transport of the paper reel. We call this probability $\alpha$. The probability for making $k$ transports of a paper reel without damaging it is then

$$(1 - \alpha)^k$$

Let us also assume that the minimum (optimal) number of transports for a single paper reel is 3 before it reaches the customer: from conveyor belt to storage cell; from storage cell to shipping pier (“lastkaj”); from shipping pier (“lastkaj”) into shipping unit (container, train, lorry, etc...).

The total number of produced paper reels during a time period is $N$. We denote by $N(k)$ the number of paper reels that are transported $k$ times before they reach the customer, where $k \geq 3$. We have that

$$\sum_{k=3}^{\infty} N(k) = N$$

The total number of non-damaged reels during this period is

$$\sum_{k=3}^{\infty} (1 - \alpha)^k N(k) = N_{\text{ok}}$$

If $N(k) = Cb^{(k-3)}$ then the ratio between successive numbers of transported reels is constant, i.e. $N(k + 1) = bN(k)$. From Table 6.1 we see that $b$ is approximately $1/3$. Then we have:

$$\sum_{k=3}^{\infty} (1 - \alpha)^k Cb^{(k-3)} = N(1 - b) \sum_{k=3}^{\infty} (1 - \alpha)^k b^{k-3} = \frac{N(1 - b)(1 - \alpha)^3}{(1 - b + b \alpha)}$$

$$\sum_{k=3}^{\infty} (1 - \alpha)^k Cb^{(k-3)} = N_{\text{ok}}(\alpha, b)$$

The constant $C= N(1 - b)$. 

Figure 6.5 shows the usage of storage cells from Jan-Feb.
Hence, \[ N_{\text{ok}}(\alpha, b) = \frac{N(1-b)(1-\alpha)^3}{(1-b+b\alpha)} \]

The number of damaged paper reels is less than 1%.

With \( b = \frac{1}{3} \) and \( \frac{N_{\text{ok}}(\alpha, b)}{N} = \frac{2500 \times 30 - 500}{2500 \times 30} = 99.3\% \)

This leads us to \( \alpha \approx 0.5\% \).

### 6.4.2 Efficiency of Decreasing Fault Probabilities and Transports

#### Decreasing number of transports

What happens if we are able to decrease the number of non-optimal transports, i.e. if \( b \) is decreased?

\[
N_{\text{ok}}(\alpha, b - \varepsilon) = \frac{N(1-b+\varepsilon)(1-\alpha)^3}{(1-b+\varepsilon+(b-\varepsilon)\alpha)} \\
= \frac{N(1-b)(1-\alpha)^3}{(1-b+\varepsilon+(b-\varepsilon)\alpha)} + \frac{N\varepsilon(1-\alpha)^3}{(1-b+\varepsilon+(b-\varepsilon)\alpha)} \\
\approx \left[ 1 + \varepsilon \frac{\alpha}{(1-b)+(1-b+b\alpha)} \right] N_{\text{ok}}(\alpha, b) + O(\varepsilon^2)
\]

This means that, to first order, the gain (the improvement in number of undamaged reels) is proportional to \( \varepsilon \alpha \) if we decrease the number of non-optimal transports (the factor \( b \)).

It is required that \( b \) is different from 0. Of course, if no suboptimal transports are made, then there is nothing to be gained from decreasing suboptimal transports.

#### Decreasing probabilities for damage

What happens if we decrease \( \alpha \)? The probability for damaging the reel will be

\[
N_{\text{ok}}(\alpha - \varepsilon, b) = \frac{N(1-b)(1-\alpha + \varepsilon)^3}{(1-b+b\alpha - b\varepsilon)} \\
= \frac{N(1-b)[(1-\alpha)^3 + 3\varepsilon(1-\alpha)^2 + O(\varepsilon^2)]}{(1-b+b\alpha - b\varepsilon)} \\
= \frac{N(1-b)[(1-\alpha)^3 + 3\varepsilon(1-\alpha)^2]}{(1-b+b\alpha)} \left[ 1 + \frac{\varepsilon b}{(1-b+b\alpha)} \right] + O(\varepsilon^2) \\
= N_{\text{ok}}(\alpha, b) \left[ 1 + \frac{\varepsilon(3-2b(1-\alpha))}{(1-\alpha)(1-b+b\alpha)} \right] + O(\varepsilon^2)
\]

This means that, to first order, the gain (the improvement in number of undamaged reels) is proportional to \( 3\varepsilon \) if we decrease the probability for damaging the reel in a transport (the factor \( \alpha \)).
7. Conclusion

We have seen the material handling of the warehouse is quite good. In Table 6.1 it is shown that almost 71.1\% (average of Ratio A) of the paper reels have been transferred without extra moves, which is from conveyor belt to storage cell and then from storage cell directly to shipping area during the year. The percentage of paper reels with extra moves where only 11.3\% on average. The “efficiency” (Ratio A) goes down from almost 80\% to 60\% during the year. The main reason is that the percentage of paper reels that are transferred once (Ratio C) increases from 10.94\% to 24.54\% during the year. This is because the paper reels stored in the warehouse that haven’t been shipped to customer increases during these ten months.

The percentage of damaged paper reels is below 1\%. About 500 damaged paper reels per month with about 2500 produced reels per day. From the mathematical model we see that the probability of damage is more important than the number of transports for paper reel handling. The effect of decreasing non-optimal transportation is small.

One more thing we want to mention is the software development method which is named incremental building model. This model is appropriate for the project with undetermined requirements, i.e. the new requirements appeared during the development process.
References


Appendix A - The Overall Warehouse Drawing

The overall warehouse drawing:
Appendix B - Preparation and Importing the TXT Format File into the Database

Preparation:

We are supposed to add two library files into the [Library]. One is sqljdbc.jar file and another one is jxl.jar file. The sqljdbc.jar file is the driver for connecting Microsoft SQL Server 2005 Database. The jxl.jar is the driver for exporting the data to excel.
How can the customer use the software normally?

Step 1:

Create the database [thesis].

1. Click the right mouse on the [Database] to select the [New Database].

2. Click the button [OK].
3. Check the database [thesis] in the left box which named [Object Explorer].
Step 2:

How to import the txt format file (csvtest111) into sqlserver2005?

1. Click the right mouse on the database [thesis] , [Tasks] -> [Import Data]

2. [Data Source] -> [Flat File Source] and other options are default.
3. Click the button [Browse] and select the txt format file which should be imported.

4. Click the button [Next]
5. Click the button [Next]

1. Click the button [Next] and make sure the database name is correct.
7. Click the button [Preview] and check the preview data.

8. Click the button [Edit Mappings] if you want to edit the attributes and the types of the file. Click the button [Next]
9. Click the button [Next].

10. Click the button [Finish].
Step3:

How to import the txt format file (dist) into sqlserver2005?

1. Click the right mouse on the database [thesis], [Tasks] -> [Import Data]

2. [Data Source] -> [Flat File Source] and other options are default.
3. Click the button [Browse] and select the txt format file which you need.

4. Click the button [Next]
5. Click the button [Next]

7. Click the button [Edit Mappings] and select the [Enable identity insert]. Click the button [Next].

8. Click the button [Preview] and check the preview data. Click the button [Next].
9. Click the button [Next].

10. Click the button [Finish].
Appendix C - Manual

MANUAL

How to operate the analysis software which we design?

1. About the Query on the Reel

I: [Time Span] text field

II: The Drop-Menu: Showing all the reelcodes in a certain time span

III: The [ReelGen] button

IV: The button [Query]: Query a single reelcode's details according to the time span

V: The button [QueryAll]: Query all reelcodes' details according to the time span.

VI: The table [Path] shows the transferred path of the reelcode.

VII: The table [Total Distances] shows the total transferred distances of the reels.

VIII: The table [Transfer Count] shows the transfer count of the reels.

IX: The table [Details] shows the details about Location, TruckName, ArriveTime, LeaveTime, SpanDistance.
X: The table [Details of All Reels] shows the details about ReelCode, TransferCount, Distance, Path, CountToKashog, LastLocation.

XI: The table [TransferCount] shows the details about TransferCount, Number.

XII: The table [Distance of All Reels] shows the distances of the all reels.

XIII: The table [Count>2 & Not Damaged] shows the number of the reel which is not damaged and the transfer count greater than 2 times.

XIV: The button [ExportToExcel]: export the result to excel [ExportToExcel].

2. About the Query Based on Truck

The button [TruckGen]: It generates all the trucks names.

The button [Query]: Query details of a single Truck.

The button [QueryAll]: Query all details of all Trucks

The table [Path] the path of the track has moved

The table [Total Distances] shows the total distances of the trucks.

The table [Moving Count] shows the moving count of the trucks.
The table [Details] shows the details about Location, ReelCodes, ArriveTime, LeaveTime, SpanDistance.

The table [Details of All Trucks] shows the details about TruckName, ReelTransferCount, Distance, and Path.

The button [ExportToExcel]: Export the result to excel [ExportToExcel].

3. About the Query on the Location

1. Time Span Setting
   The Radio button [Manual Setting]: The time period is divided by manual operation.
   The Radio button [Auto Split Setting]: The time period is divided automatically by the software.

2. Location Setting
   The Radio button [All Locations]: Query locations’ InNumber and OutNumber.
   The Radio button [Single Location]: Query a certain location’s InNumber and OutNumber.

   The button [Query]: Start query.

   The button [ExportToExcel]: Export the result to excel [ExportToExcel].