

**Development of a tool supporting the after sales
inbound logistics optimization under the
Renault - Nissan alliance**

By

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Submitted in partial fulfilment of the requirements for
the degree of

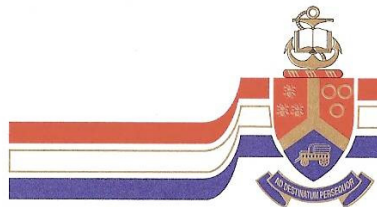
BACHELORS OF INDUSTRIAL ENGINEERING

In the

**FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION
TECHNOLOGY**

UNIVERSITY OF PRETORIA

November 2009



Universiteit van Pretoria
University of Pretoria

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Executive Summary

Nissans current procurement cost of their after sales parts is not at its lowest. Possible savings can be made by buying products at a higher unit cost but making use of cheaper transportation. Decisions need to be made regarding the vendor being sourced from as well as the mode of transportation being used.

A “decision making tool” has been developed. This “tool” makes use of existing database data and transportation costs to determine which vendor to source from and which transportation mode to use. It is a decision support tool; its results do not necessarily need to be employed. This “tool” is automated to make it user friendly. The tool consists of an Access database and a LINGO linear programming model.

1. Introduction and background

In 1911 Kwaishinsha Automotive Company was formed to produce the first Datsun cars in Japan. This company was later taken over and the Nissan motor company was registered. Nissan has been in South Africa for the last 40 years. Initially all parts were shipped in and only assembled in South Africa but a manufacturing facility was later established in Rosslyn. (Nissan South Africa, 2009)

In 1999 an alliance between Nissan and Renault was signed. Renault and Nissan are united for performance through a coherent strategy, common goals and principles, results-driven synergies and shared best practices. They respect and reinforce their respective identities and brands. (Nissan global, 2009)

The objective of this alliance is for the Nissan and Renault group to become the third best automotive group in the world. To achieve this objective both Nissan and Renault will have to reduce costs wherever possible.

Nissan is in need of a “decision making tool” that will be used to determine the minimum cost of the inbound logistics of after sales parts.

Parts are sourced from countries all around the world. The amount sources from each country can vary significantly. A large number of parts are sourced from Europe and Japan while very few are sourced from South America. When a small number of parts are sourced from a specific country it becomes more expensive to transport them to South Africa. Small shipments either need to be flown in which is more expensive than sea transport or be consolidated with shipments of other companies increasing the risk of damage and theft.

It may be more cost effective to buy the same product from another country at a higher unit price but save costs on transportation and reduce the risks. An illustration this concept appears in Appendix B.

2. Problem statement

Nissan and Renault are using the same parts for some of their vehicles. This is as a result of their alliance. These parts are currently ordered separately but delivered to warehouses relatively close to each other. This is highly inefficient as it leads to higher transportation costs and increased unit prices. By consolidating these shipments, transportation costs can be reduced.

When shipments are consolidated the order quantity of the parts are increased. The order quantity or demand has an effect on the transportation cost. The means by which products are transported need to be re-evaluated.

Even though Nissan and Renault may use the same part, they may order from different vendors. Therefore the choice of vendor needs to be re-evaluated.

3. Project Aim

As firms engage in global competition, logistic costs are becoming more and more significant. Parts are sourced from various vendors in different countries. The cost of sourcing from one country can vary significantly from the cost of sourcing from a different country.

The aim of the proposed project is to optimize the after sales inbound logistics by having the entire procurement process operating at the lowest possible cost without sacrificing on quality, reliability and security. The decision of which country to source a particular part from will need to be made.

In order to make this decision all possible procurement costs need to be considered.

These procurement costs include:

- the price of a unit
- the transaction cost
- transportation cost

The most cost effective systems do not always comprise of each component operating at the lowest possible cost. The total of all procurement costs need to be a minimum.

Nissan and Renault source thousands of parts, it is therefore crucial to develop a “decision making tool” that will determine from which vendor a part should be sourced, to avoid this decision becoming a painstaking and time-consuming task. The “tool” should be flexible. The user must have full control over which parts to include in the decision making process.

4. Project scope

The “decision making tool” needs to provide Nissan with correct and meaningful information. It is therefore necessary to make the right decision as to what will be included in the scope and what will not. Some costs which have a minimal effect on the total price have not been included in the scope of this project.

The interface will be developed to facilitate decision making regarding:

- The supplier from which to source a product needs to be made.
- The mode of transport used to ship the parts also need to be determined.
- There will be a play of between supplier prices and the cost of transportation.

The following procurement costs will be investigated:

- The price of the product
 - This has long been the benchmark against which buyers measure cost but in a supply chain environment it is only one factor to evaluate and consider in the procurement process.
- Transaction cost
 - These are the costs of processing the material flow in order to acquire the products e.g. handling of shipping documents. Only costs which have a major affect on the total procurement price will be investigated.

- Transportation cost
 - The cost of shipping products from various different countries to South Africa. Different modes of transport and their associated costs will be investigated where applicable.
- Operations cost, quality control cost and supplier relationship cost will not be included in the scope of this project. The operations and quality cost are mostly incurred between the inbound transportation delivery of a part and its availability for use/ storage.
- The cost of salvage and waste disposal will also not be included in this project.

It is assumed that only full container loads will be used. Therefore all cost used will be for a full container.

5. Deliverables

The deliverables for this project will be the following:

- A tool to facilitate decision making as discussed in the project scope. This tool will have some sort of software interface. It should be as user friendly as possible.
- A user manual to assist users in the use of the tool.

6. Literature review and information gathering

As with all engineers, an industrial engineer needs to complete a literature review to fully prepare for the project. Reasons for performing a literature review include:

- The problem presented as well as available data needs to be studied and fully understood.
- All terminologies and concepts associated with the project need to be grasped.
- Possible tools and techniques for solving the problem need to be investigated and weighed against each other.

For this particular project it is important to determine which tools and techniques will be used to determine the optimal purchase and transportation strategy. Key concept regarding logistics need to be grasped. Further breakdown of procurement costs are essential to ensure that all costs are included in the total cost calculation.

6.1 Methods of information gathering

The following methods were used to gather information and to gain further insight into the project:

- **Similar projects**

The project “Development of a warehouse resource quantification tool to improve third party logistics services provided by Barloworld logistics” by Sandra Eelders (2007) was used as a foundation for possible concept designs of the required “decision making tool”.

- **Internet**

Various websites were consulted to assist in defining key concepts. The Nissan Global website as well as the SLA (strategic logistic Alliance, now part of Savino Del Bene) website was among the websites that were consulted.

- **Books**

Textbooks on logistics management, information system design etc were consulted.

- **People**

Information was sought from people in industry. This proved to be the method of most value.

6.2 Software

There are two parts to this “decision making tool”. Firstly there should be an interface through which data is entered, stored and manipulated. Secondly software will be required that is capable of using the data to determine the optimal solution. There are various software options available that can perform these functions.

6.2.1 Data input

6.2.1.1 Microsoft Excel

Excel is a powerful tool for creating spreadsheets. It is the most widely used spreadsheet in the world. Data is easy to analyse and manipulate up to a certain point. If the data is excessive, working with a spreadsheet can be overwhelming. Spreadsheets are also more suited for calculations rather than data storage.

6.2.1.2 Microsoft Access

Access is a data management system that can be designed to meet the needs of any individual/organisation. Access is more suited for storage of data. Large amounts of data can be handled with ease. Forms, queries and reports can be generated to input, isolate or produce output data. Entering calculations in Access can be a tedious task. Product information can be extracted from SAP into an Access database, allowing for easy transfer of data to the database.

Access also allows for the creation of a user friendly graphical user interface. Visual Basic is the programming language used to write Access. The visual basic code can be manipulated to add features that aren't already included in Access.

6.2.1 Optimization

6.2.1.1 Matlab

Matlab is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. (www.mathworks.com)

Matlab can be used for optimization but it is not as efficient as other software packages that were specifically designed for linear programming. Matlab has a function called Linprog which solves linear programming models. It also has a database toolbox that can be used to import and export data from and to Access.

6.2.1.2 LINGO

LINGO is a comprehensive tool designed to make building and solving linear, nonlinear and integer optimization models faster, easier and more efficient.

(www.lindo.com)

LINGO has the following benefits:

- Easy formulation of expressions by the use of standard mathematical operators.
- LINGO can receive data from a database or a spreadsheet. It can also send information to a database or spreadsheet. There is an easy transfer of information.
- Contains a wide-range of solvers from which LINGO automatically selects one appropriate for your formulation.
- There is a user manual and help file available.
- It has a function called @ODBC which allows data to be imported and exported from and to Access.

The only problem with LINGO is that it may not be available to Nissan.

6.2.1.3 GAMS

The General Algebraic Modelling System (GAMS) is specifically designed for modelling linear, nonlinear and mixed integer optimization problems and is especially useful with large, complex problems. (www.gams.com)

GAMS has the same benefits as LINGO. GAMS is also not widely available.

The only advantage of GAMS over LINGO is the fact that GAMS represents the output in a report which is much more user friendly than LINGO output.

There are also tools available to import and export data from and to Access but they are more complex than those of Matlab and LINGO.

6.2.1.4 Excel Solver

Solver is an add-in available in all Excel packages since 2003. Cells on your worksheet can be assigned as one of three types of cells:

- **The target cell**
This is the cell that contains the value of your objective function. For this project it would contain the total procurement cost of a product.
- **The changing cell**

These cells represent your variables i.e. the values that can be changed to obtain the optimal solution. For this project these variables will be:

- ◆ Which vendor is selected
- ◆ What form of transport is made use of
- **The constraints**

These cells represent restrictions placed on your problem. A product can only be bought from one supplier is an examples of a constraint related to this project.

The solver uses the simplex and branch-and-bound method to solve linear and integer problems.

One very important advantage of using Excel Solver is that it interfaces easily with Access. Most computer literate users have basic Excel skills which will allow them to easily operate Excel Solver while other software application may be intimidating. And disadvantage of Excel Solver is that it is limited in the number of variables it can handle.

Excel is readily available but will not have enough processing power to handle the large amount of variable this “decision tool” requires. Matlab, LINGO and GAMS will be capable of handling large amounts of variables. *LINGO was chosen to develop the “decision making tool” as its interface with Access is the most user friendly.*

6.3 Methods, tools and techniques

6.3.1 Tools for building an information system

An information system (IS) is an arrangement of people, data, processes and information technology that interact to collect, process, store and provide as output the information needed to support an organization. (Whitten J.L. & Bentley L.D.) In this case the information system would be a decision support system (DSS) that provides information to make decisions.

Knowledge asset management is one of the business drivers for today's information systems. It is important to realise that data, information and knowledge are critical resources. (Whitten J.L. & Bentley L.D) By simply managing these resources correctly a competitive advantage can be gained. This is exactly what this project aims to do. By accurately utilizing the available data and information inbound logistics can be minimized.

Currently Nissan uses SAP AG an enterprise resource planning application (ERP). An ERP is a software application that fully integrates information systems that span most or all of the basic, core business function. (Whitten J.L. & Bentley L.D) All of the data concerning the after sales products can be acquired from SAP. Data like the demand, dimensions, weight etc can be extracted from SAP into an Access database or Excel file.

The following process can be followed to develop an information system as prescribed by (Whitten J.L. & Bentley L.D):

- **System initiation**
This includes defining the scope, aim, schedule and budget of the IS. This has to some extent been done in the first few chapters of this document.
- **System analysis**
The business requirements and specifications for the IS need to be established. This will be determined by the client.
- **System design**
A computer based solution for the identified requirements need to be constructed.
- **System implementation**
The IS needs to be constructed, implemented and tested.

There are three Development/implementation strategies to be considered according to (Whitten J.L. & Bentley L.D):

- **Rapid Application Development**
This strategy emphasizes speed of development through extensive user involvement in the rapid, iterative and incremental construction of series of functioning prototypes that eventually evolve into the final system.

- **Model driven development**

System models are drawn to help visualise and analyse problems, define and analyse business requirements and translate them into an IS design. This is most likely the strategy that will be used to construct the “decision making tool” as the visual aids will allow the system designer and client to see the design in its entirety. It is also much easier to document this type of method.

- **Commercial application package management**

This is a software application that can be bought of the shelf. The “tool” has requirements unique to Nissan and cannot be bought of the shelf, it is tailored to Nissan’s needs.

The following tools and techniques are available for:

- **Requirements discovery**

- ◆ *Sampling of existing database*
- ◆ *Interviews*

Most of the user requirements were collected through interviews with the relevant people at Nissan and SDB (which will be mentioned later). Another aid in discovering requirements was sampling of the existing database i.e. the database extracted from SAP.

- **Modelling system requirements**

- ◆ *Use case modelling*

The process of modelling a systems functions in terms of business events, who initiated the events and how the system responds to those events. (Whitten J.L. & Bentley L.D)

- **Data modelling**

- ◆ *Entity relationship diagram (ERD)*

It is a technique used for organising an organisations data by utilising several notations to depict data in terms of the entities and relationships described by the data. (Whitten J.L. & Bentley L.D) An entity is an object or concept about which data is collected.

- **Process Modelling**

- ◆ *Data flow diagram (DFD)*

A DFD depicts the flow of data through a system and the processing performed by the system. (Whitten J.L. & Bentley L.D)

- **Other**
 - ◆ *Context DFD* to establish project scope
 - ◆ *Events decomposition diagram* to divide the system into subsystems
 - ◆ *Cost benefit analysis* to determine the profitability of this project
 - ◆ *The four test of feasibility* as prescribed by (Whitten J.L. & Bentley L.D)
 - Operational, technical, schedule and economic feasibility.

Another technique that will be applied is “Time boxing”

Time boxing is a technique that delivers information systems functionality and requirements through versioning. The first version of the IS should be available within 60-90 days and should contain all functionality as prescribed by the customer. Improvements to this IS can be added later. (Whitten J.L. & Bentley L.D)

6.3.2 Tools for mathematical programming

According to (Winston W.L. & Venkataramanan M.) operations research is simply a scientific approach to decision making that seeks to best design and operate a system, usually under conditions requiring the allocation of scarce resources. Two operation research methods can be used:

- **Linear programming**

We will attempt to minimize the objective function which is a linear function of the decision variables. All decision variables will be subject to certain constraints.

- **Transportation & assignment problems**

Transportation and assignment problems are characterised by supply and demand points and each. For each supply point to a specific demand point there is a variable cost involved. In Nissan’s case each supply point will be the various vendors and the demand will be Nissan only or possibly Renault and Nissan. The variable cost would be the procurement cost from each vendor.

Both of these methods are equally useful but because it has been decided that LINGO will be used for the optimization, linear programming is more appropriate.

6.4 Key concepts

The following are key concepts that need to be defined for better understanding of the projects:

6.4.1 Shipment consolidation

The larger the quantity being shipped becomes the lower the rates. It therefore makes more sense to have larger shipments. Small shipments are combined to form larger shipments.

6.4.2 Water carriers vs. Air carriers vs. Land carriers

Each has its advantages and disadvantages as set out by (Coyle J.J., Bardi E.J. & Langley J.):

Table 1: Carrier comparison

	Air carrier	Water carrier	Land Carrier
Capacity	Moderate	Very high	Moderate
Variable cost	High	Low	Moderate
Fixed cost	Low	Moderate	Low
Lead time	Short	Long	Moderate
Lead time reliability	High	Moderate	Moderate
Availability	Moderate	Moderate	High
Typical products	Small high value products	A wide variety of products.	A wide variety of products.

6.4.3 Freight forwarders

A freight forwarder is a consolidator that collects small shipments from shippers, consolidates these shipments into larger loads and presents this larger load to carriers for shipment. At the destination the freight forwarder breaks the load down into its smaller shipments and delivers them to the consignee. (Coyle J.J., Bardi E.J. & Langley J.)

According to (www.businessdictionary.com) freight forwarders also arrange storage and shipping on behalf of the shipper. Their services include: tracking, inland transportation, preparation of export documents, insurance and negotiating freight charges.

Savino Del Bene (SDB) is the freight forwarder employed by Nissan SA.

6.4.3.1 Strategic logistical Alliance (SLA) & Savino Del Bene(SDB)

Nissan became SLA's client in 2001. SLA is now part of Savino Del Bene South Africa. Savino Del Bene is a freight forwarding company founded in Florence by Mr. Savino Del Bene in the 20th century. It has since grown to an organization of a 170 offices around the world. SLA joined Savino Del Bene in 2009.

Figure 1: Savino Del Bene and SLA Logo's



6.4.4 Air Waybill (AWB)

An AWB is a document issued by a consolidator to a shipper as a receipt for the goods which will be shipped with other cargo as one consignment. (www.businessdictionary.com). If this document is released by the freight Forwarder (SDB) it is called a house air-waybill (HAWB).

6.4.5 Containerisation

According to (Coyle J.J., Bardi E.J. & Langley J.) a container is a large rectangular box into which a firm places commodities to be shipped. After the container has been loaded is not reopened until it reaches its destination. This reduces the risk of theft and damage. It also reduces handling cost. The products being shipped is never handled. Only the container is handled by the use of machinery.

6.4.6 Customs

The customs service collects duties and also inspects imported merchandise. The inspection is done to determine the value of the import duties, to ensure that items

are marked correctly, to check for illegal products and to control quota amounts. (Coyle J.J., Bardi E.J. & Langley J.)

6.4.7 F.O.B. terms of sale

The F.O.B. (Free on board ship) terms of sale determines the logistics responsibility that the buyer and seller will incur. It determines who is responsible for the transportation charges, who controls the movement of the shipment and when ownership passes to the buyer. Nissan uses F.O.B. Origin. This means that Nissan pays the freight cost and determines the movement of the goods. Ownership passes to Nissan once the goods arrive at the port of origin.

6.4.8 Bonded warehouse

Nissan makes use of a bonded warehouse. Nissan only pays taxes and duties on an item once the item is released from the warehouse.

6.4.9 Split loads

When products are picked up from or delivered to more than one location during the same route it is called a split load.

6.4.10 Volumetric weight

This is used when the space a package occupies actually costs more than the weight of the package. If a large container contains a lightweight item, the space occupied costs more as fewer items can be loaded in the plane.

Volumetric weight (Kg) = [Length (cm) x width (cm) x height (cm)] /6000

6.4.11 Container utilization

The full volume of the container is not always occupied as packages vary in size. Oddly shaped package can waste a lot of space. Based on an estimate provided by SDB, only 80% of the volume of the container is actually used.

6.4.12 Lead time

The lead time for air freight is taken as 14 days while the lead time for sea freight is taken as 70 days. The lead time is the time it takes a part to reach the warehouse once the order has been placed.

6.4.13 Maersk Line & TEU

The Maersk is one of the leading container shipping companies in the world. Maersk is located in more than 125 countries. The Maersk line fleet comprises more than 500 vessels and containers corresponding to 1 900 000 TEU (twenty foot equivalent unit). TEU is a unit used to measure container capacity relative to a standard 20ft container. The most common 20ft containers have a volume of 33m³. A 40ft container is equivalent to 2 TEU and has an average volume of 67m³. A 40ft high-cubed container has a volume of 87m³.

Nissan directly negotiates rates with Maersk.

6.4.14 Bill of lading

It is a document used for sea freight that is the contract between the carrier and the shipper. It provides a receipt of the goods the shipper tenders to the carrier and shows certificate of title.

6.4.15 Restrictions

There are certain restrictions when it comes to the dimension and weight of a parcel.

These include:

- Whenever a package exceeds 150Kg it must be on a pallet.
- The maximum dimensions of a pallet is 150cm x 150cm x 150cm
- Wooden pallets from certain countries need to be fumigated before they can be released, adding to the final cost.

These restrictions do not fall within the scope of this project.

6.5 Breakdown of transportation costs (sea and air)

It is important to note that whenever a cost is based on weight the actual weight of the package and its volumetric weight need to be compared. The Larger of the two is used for the calculation.

6.5.1 Air Freight

The transport of goods via air freight comprises of 6 legs:

Figure 2: The legs of air transport



The following costs are associated with each leg: (It is important to note that not all costs appearing here apply to all countries)

Leg 1: Pick-up

- Origin pre-carriage

This leg is assumed to be prepaid by the shipper.

Leg 2: Origin handling

- Export customs clearance
- Handling fee
- Terminal fee
- Airline transfer fee
- AWB Fee
- X-ray fee
- IRC Fee

Most of these costs are determined per HAWB while some are determined by weight. Very often a minimum and/or maximum charge is set per HAWB.

Leg 3: Airfreight

- Airfreight
- Fuel surcharge
- Security surcharge

Air freight is charged by weight but a minimum cost is set relative to the HAWB. For some countries there are various carriers and routes available to choose from. Each carrier and route has different costs and lead times.

Leg 4: Destination handling

- Airline handling fee
- Airline split fee
- Break-bulk fee /cross docking fee
- Communication fee

The airline split fee is determined by the number of parcels. This poses a problem when estimating costs. There is no way of knowing how many packages there will be.

Leg 5: Clearing

- Customs and excise: SARS(VAT)
- Customs and excise: SARS(Duty)
- Advalorem duty
- Clearing Documentation

Leg 6: Delivery

- Delivery to Pretoria from Oliver Tambo airport
- Fuel surcharge

Other

- Agency fee

6.5.2 Sea freight

The transport of goods via sea freight comprises of the same 6 legs. Maersk Line is Nissan's carrier. Maersk Line bills Nissan directly. The following costs are associated with each leg: (It is important to note that not all costs appearing here apply to all countries)

Leg 1: Pick-up

This leg is assumed to be prepaid by the shipper.

Leg 2: Origin handling

- Export customs clearance
- Forwarding fee

These costs are charged per container

Leg 3: Sea freight

- Ocean freight cost

Leg 4: Destination handling

- Wharfage
- DTHC (Detention/ Demurrage cost)
- Cargo dues

These costs are charged per size of the container

Leg 5: Clearing

- Clearing documentation
- Agency Fee

These costs are not included in the scope of this project.

Leg 6: Delivery

- Railage
- Niscon Fees
- Haulage
- Service and documentation fees
- Inland transport cost

6.6 System requirements

Besides producing an optimal (or close to optimal) solution the following requirements need to be met by the “decision making tool”:

- It should produce accurate results
- It should be user friendly and easy to understand
- It should be visually appealing
- It should produce an answer in an acceptable amount of time
- It should be automated as much as possible
- It should be accompanied by a user manual

7. Data analysis & Cost conversions

7.1 Cost per package

Some costs are charged per package. As it is impossible to predict the actual number of packages, another approach needs to be followed.

Data containing air freight information regarding imported parts and their particular weight and the number of packages have been analysed to determine the average number of packages per total weight. The average number of packages per total weight of a particular part will be used to convert the cost per package into a cost per weight. Figure 3 is used to clarify this concept.

Figure 3: Cost/weight calculation



The airline split fee is then charged per weight instead of per package. It can then be added to all the other costs that are charged per weight.

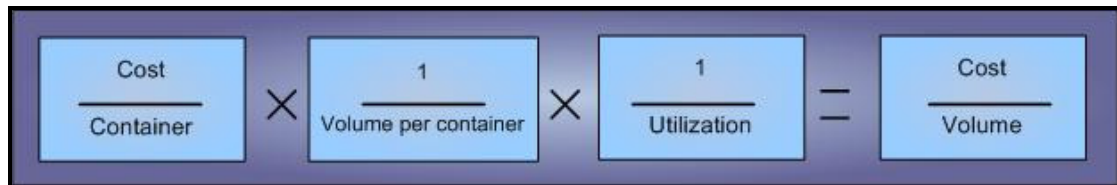
The number of packages per kg was calculated as 0.0134.

7.2 Cost per container

Most costs associated with sea freight are charged per container. As it is impossible to determine the exact amount of containers that will be used the costs per container will be converted into a cost per volume. The volume available per container will be used to perform this conversion.

The total volume of a container is never fully utilized. According to SDB the rule of thumb is that 80% of a container's volume is utilized. This unutilized space still needs to be paid for. Figure 4 illustrates how costs will be converted.

Figure 4: Cost/volume calculation



Note: Utilization is 0.8

8. Concept design

A database will be created in Microsoft Access 2003 by using data obtained from an existing database. This database will be linked to a LINGO model. The appropriate data will be transferred from Access into this LINGO model.

A very simplistic use case diagram and ERD have been constructed to represent the very basic design of the database. This is by no means the final design. Several more use cases and attributes will need to be added to these diagrams.

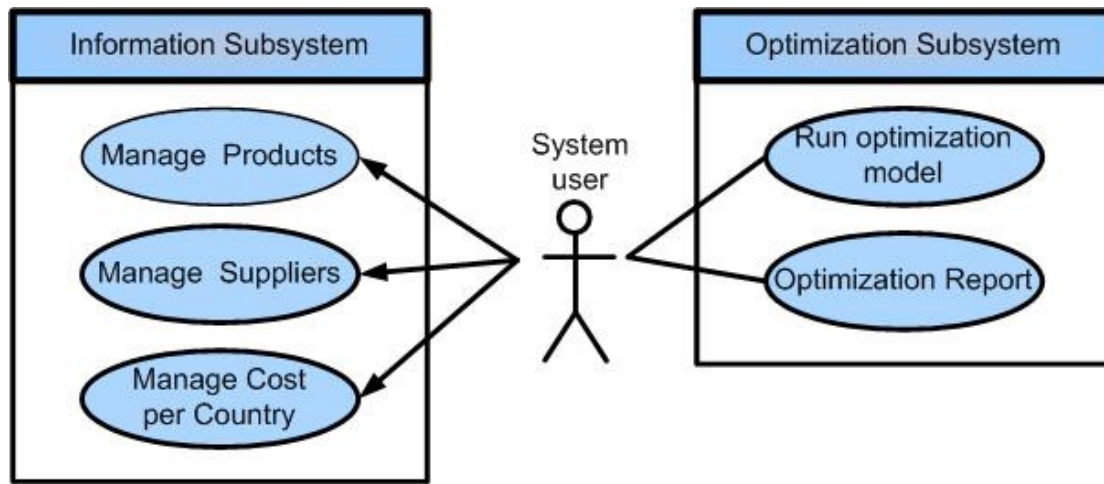
A very plain linear programming model has been constructed to illustrate how the optimization part of the problem will be approached.

8.1 Concept Use cases

The following are examples of the type of uses cases that would be used for the construction of the “decision making tool”:

- **Manage products, suppliers and costs associated with each country**
The user will be able to view, add, delete, or change data. For this tool, product and supplier data will mostly only be viewed except if there is a bizarre reason for changing some of the data. The freight costs per country will need to be entered manually or imported from Excel or a text file.
- **Run optimization model**
The user of the “decision making tool” will have to select the mix of products to include in the optimization model. Unfortunately not all of Nissans’ after sales parts can be included in the model as this would require significant amounts of processing power. This “tool” will be run on a laptop or desktop computer which does not have the processing power required.
- **Optimization report**
Some sort of report should be available to present the solution found by the optimization model. Possible reports can include the vendor to be used, the form of transportation to be used and the total cost.

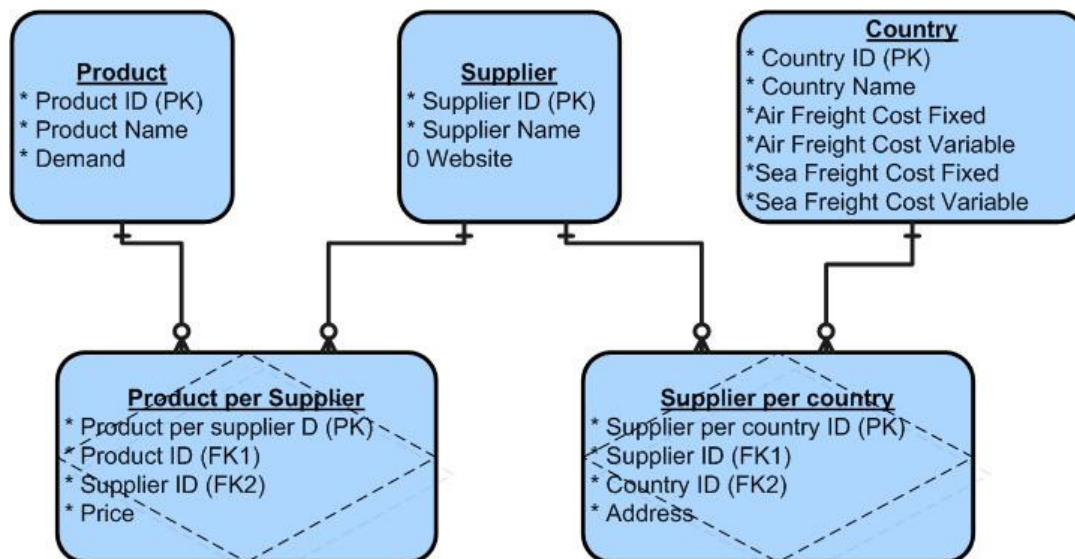
Figure 5: Concept Use Case Diagram



8.2 Concept design of database

The concept ERD contains the attributes that were used in the concept design of the formulation. Data about products and suppliers are part of the existing database while the information regarding the transport costs per country are provided by SDB and Maersk line. Data from the different sources will need to be combined.

Figure 6: Concept Entity Relationship Diagram



Many more entities and attributes will need to be added to the final design. Figure 6 is merely an illustration of what will be done. The fixed and variable cost will be broken down into all the various costs as mentioned in section 6.5. Other details like the HAWB number etc. will need to be added. This is by no means the final design.

8.3 Concept design of the formulation

Once the mix of products needed for the optimization model have been selected the data will be exported to LINGO. The following is a simple example of the formulation that will be used:

8.3.1 Variables

- p_{ij} = is the given price of product i sourced from supplier j where $i=\{1..n\}$ and $j=\{1..m\}$
- d_i = is the given demand for product i where $i=\{1..n\}$
- g_i = is the given weight for the demand of product i where $i=\{1..n\}$
- a_j = the given variable cost of shipping of shipping a product from supplier j via air freight where $j=\{1..m\}$
- A_j = the given fixed cost of shipping of shipping a product from supplier j via air freight where $j=\{1..m\}$
- s_j = the given variable cost of shipping of shipping a product from supplier j via sea freight where $j=\{1..m\}$
- S_j = the given fixed cost of shipping of shipping a product from supplier j via sea freight where $j=\{1..m\}$
- x_{ij} = is 1 if product i is sourced from supplier j where $i=\{1..n\}$ and $j=\{1..m\}$
else it is 0
- z_{ij} = is 1 if product i sourced from supplier j is shipped via air freight where $i=\{1..n\}$
and $j=\{1..m\}$
else it is 0
- y_{ij} = is 1 if product i sourced from supplier j is shipped via sea freight where $i=\{1..n\}$ and $j=\{1..m\}$
else it is 0

8.3.2 Objective function

Minimum total cost = Unit price + Fixed transport cost + variable transport cost

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m (p_{ij}d_{ij} + [a_jg_{ij} + A_j][z_{ij}] + [s_jg_{ij} + S_j][y_{ij}])x_{ij}$$

8.3.3 Constraints

A product can only be sourced from one supplier:

$$\sum_{j=1}^m x_{ij} = 1 \quad (i = 1, 2, \dots, n)$$

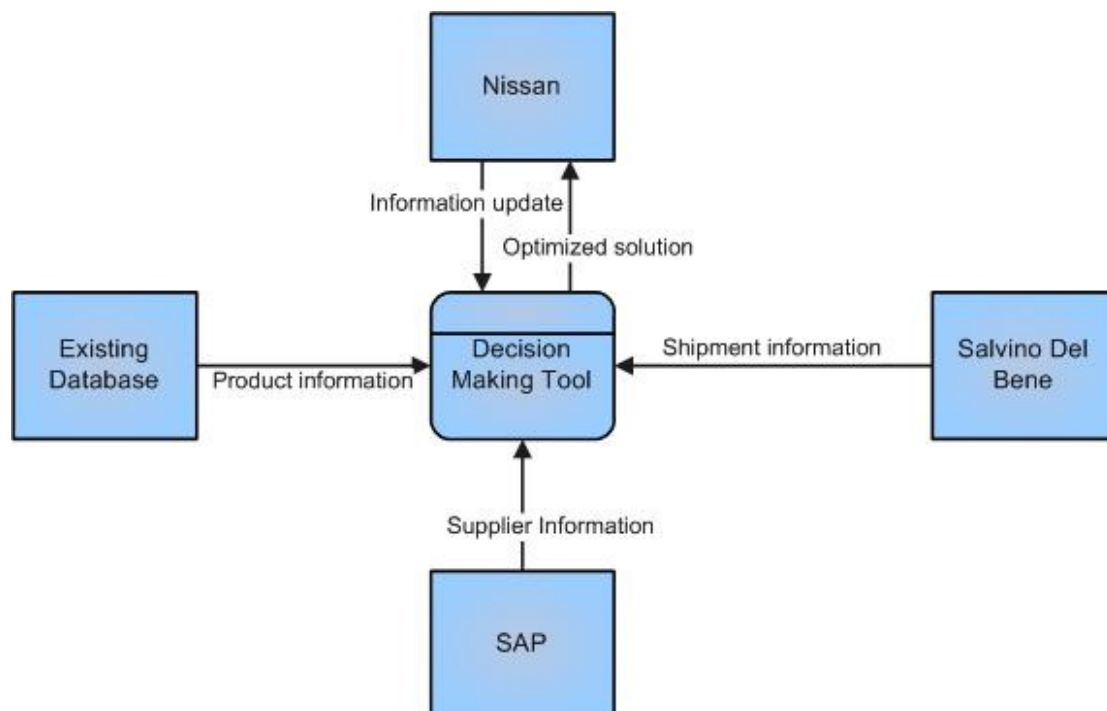
A product can only be transported by either air or sea freight but not both:

$$\sum_{i=1}^n \sum_{j=1}^m (z_{ij} + y_{ij}) = 1 \quad (i = 1, 2, \dots, n)$$

9. Detail design of database

The database will be constructed by combining the product information extracted from an existing database (into an excel or text file) with the transportation information provided by Savino Del Bene and supplier information extracted from SAP. This concept is illustrated in figure 7.

Figure 7: Context Data Flow Diagram



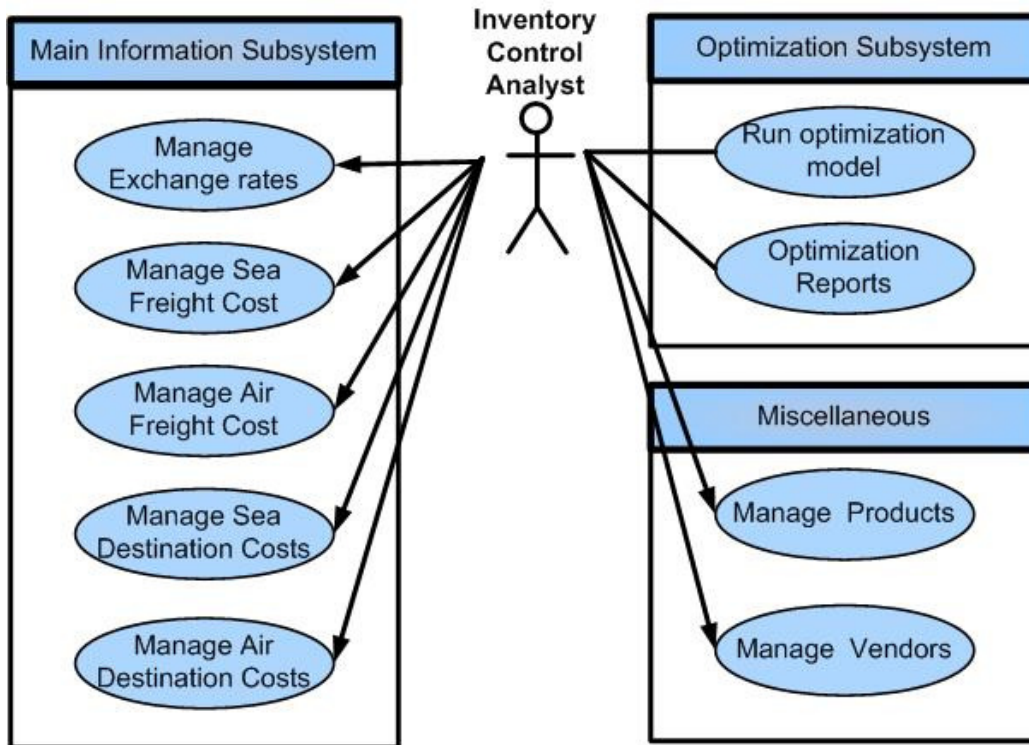
The inventory control analyst of Nissan will be able to run the optimization every time data has been updated. The system will then provide an optimized solution for importing those specific products. The “decision tool” is flexible. It can be run for all parts or it can be run for only parts of a new car that has been introduced. The user has control over which products are included in the optimization.

The main reason for the database is to organize all the data that will be used in running the optimization model. Updating the database will be a time consuming task. This is not seen as a major problem as the optimization model will seldom be used.

9.1 User requirements and specifications

All requirements and specifications have been grouped and represented in terms of use cases. The use case diagram in figure 8 indicates that all the business events or use cases will be initiated by the inventory control analyst i.e. the inventory control analyst is the primary business actor to all events. Only the optimization subsystem will return information to the system user. The other two subsystems only receive information. The narratives of all the use cases appear in appendix A. Table 2 is a short summary of the functions of each use case.

Figure 8: Use Case Diagram



Notes:

- Once parts have arrived in South Africa, the airline handling fee, cartage to Pretoria & all other destination handling fees are the same. These costs are all billed in Rand. Therefore these destination costs as they are called are grouped in a separate use case.
- Most of these use cases will rarely be used but are necessary for the operation of the decision making tool.

Table 2: Use Case Summary

Name	Description / Will be used to:
Manage Products	View the list of products
Manage Vendors	View the list of suppliers
Manage Sea Freight Cost	Manage the freight costs prior to reaching the harbour
Manage Air Freight Cost	Manage the freight costs prior to reaching the airport
Manage Sea Destination Cost	Manage the costs once parts have reached SA via Sea Freight.
Manage Air Destination Cost	Manage the costs once parts have reached SA via Air Freight.
Run Optimization Model	Prepares the necessary tables to initiate the model.
Optimization Report	Produces reports of the optimal solution
Manage Exchange Rate	Manage all countries from which Nissan import and their respective exchange rates

9.2 Data modelling

The following assumptions have been made regarding the relationships between various entities:

- Each Vendor can supply zero or more products
- Each product is produced by zero or more vendors
- Vendors are situated in only one country
- Each country is home to zero or more vendors
- Each country has one set of freight cost for air and sea freight
- Nissan parts arrive in SA in only one location with a specific mode of transport but to make the tool flexible provision has been made for multiple destinations.
- Each part will only be bought from one vendor
- Essentially a solution should be linked to only one product and a product should be linked to only one solution but this relationship had to be defined as a “one to many” relationship due to the manner in which LINGO exports data.

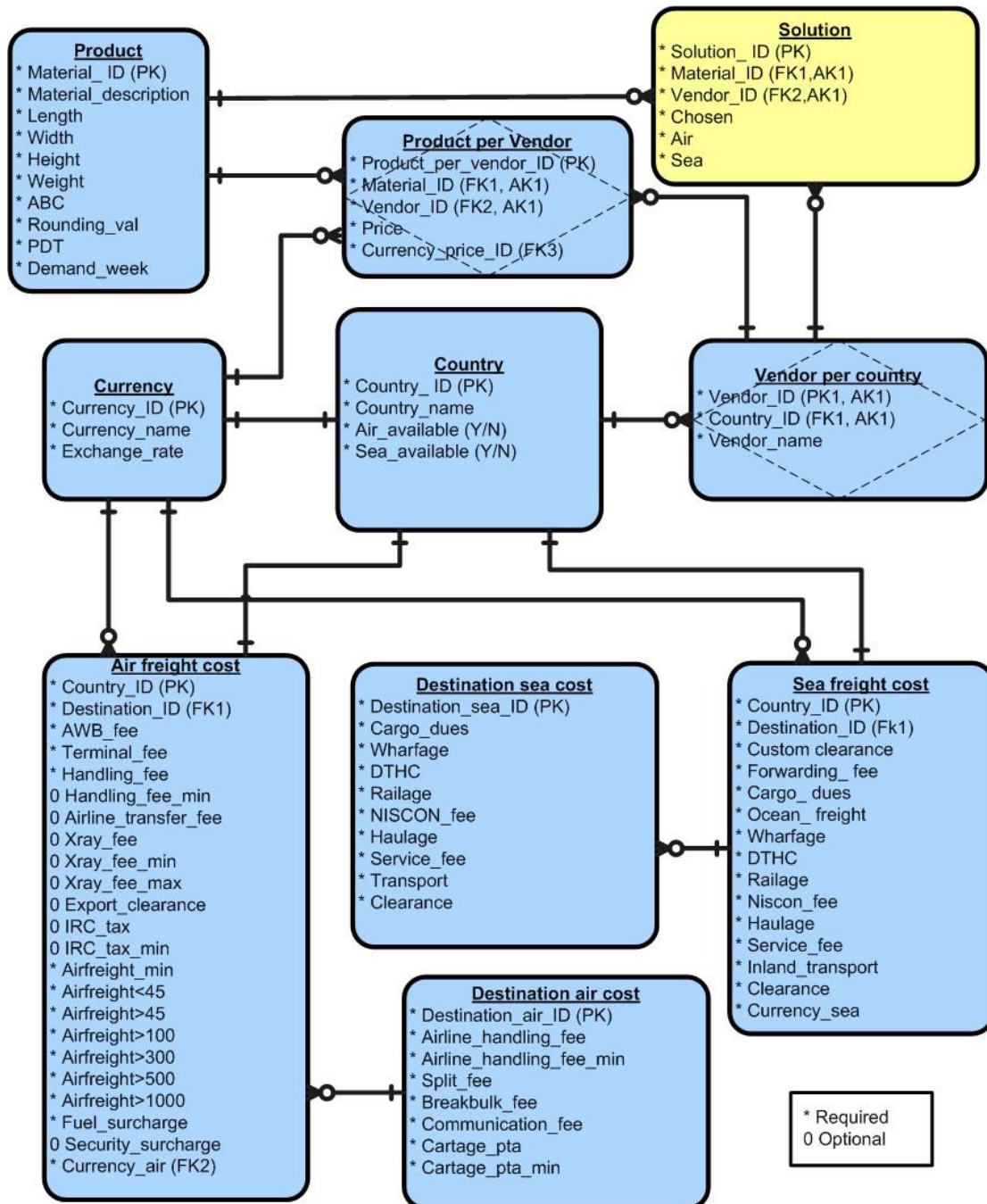
The attribute chosen indicates which part is assigned to which vendor.

The database will be modelled according to the entity relationship diagram in figure 9. The database will be modelled in the format in which data is available from Nissan.

Notes:

- In situations where there are multiple flight options available, such as with Tokyo, the highest airfreight cost will be used in the calculations.
- Destination costs refer to costs that are incurred once imported parts reach SA.
- Some information included in the database will not be used during this project. It is however included to allow for future upgrading of the “decision making tool”.

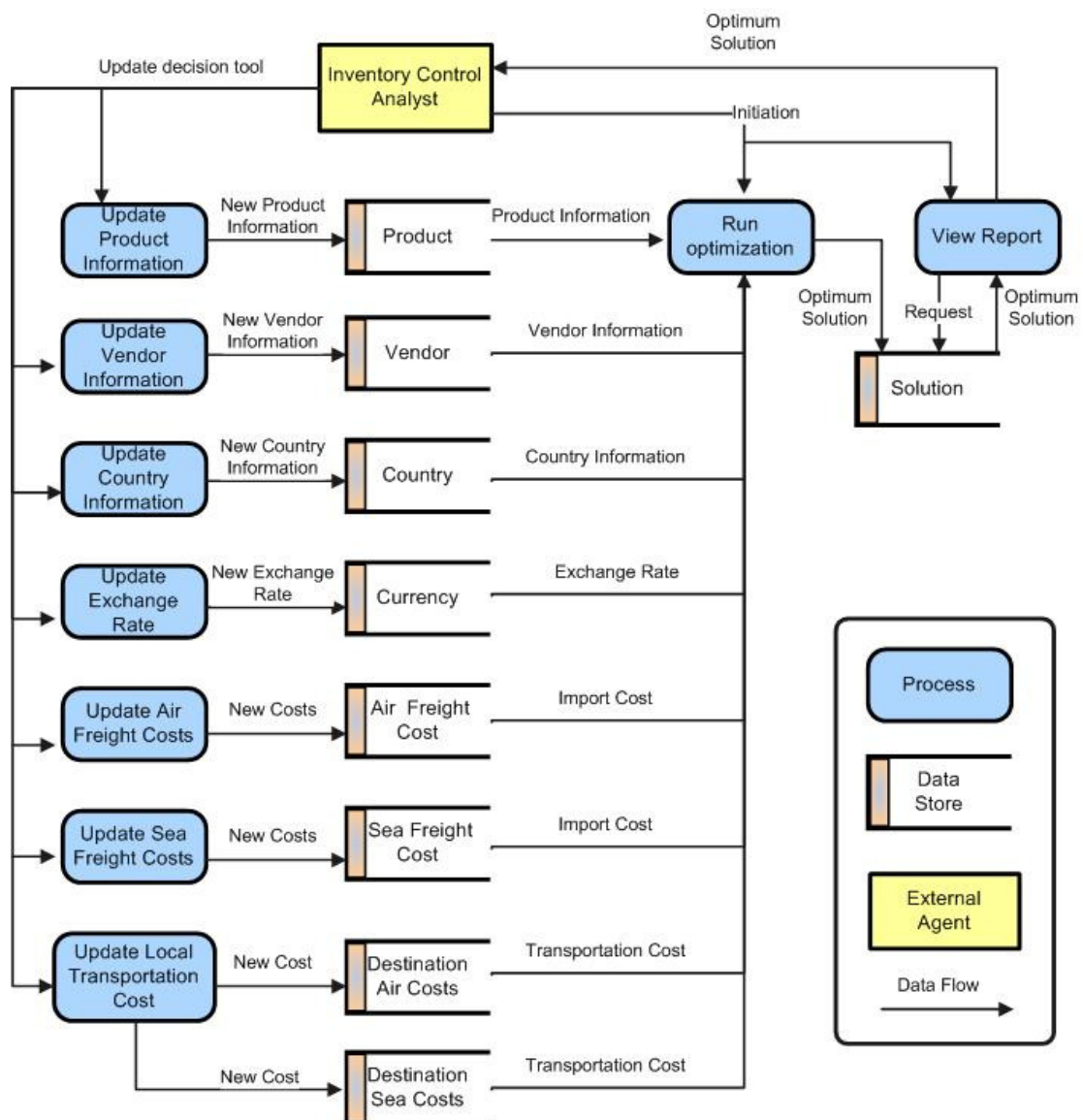
Figure 9: Entity Relationship Diagram



9.3 Process modelling

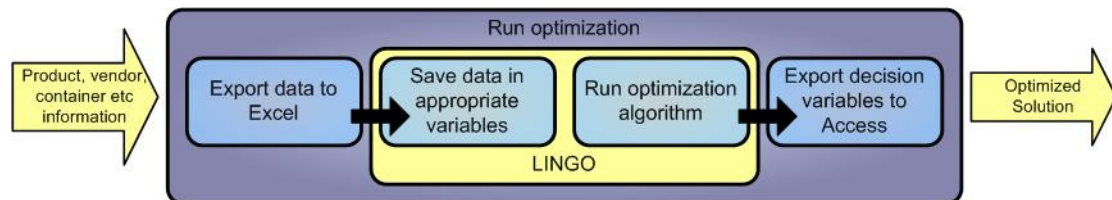
A process model is used to depict the flow of data through the system and the processing performed by the system. Data flow diagrams are a popular tool for process design. Figure 10 illustrates the data flow within the database section of the decision making tool.

Figure 10: Data Flow Diagram



The data flow diagram does not show what happens to the data during the “Run optimization” process. Figure 11 is a very simple illustration of what happens during the “Run optimization” process.

Figure 11: Optimization Process Description



9.5 Feasibility tests

Operational feasibility:

The “decision tool” will be fully operational. It is important to note that it is only a tool to aid in the decision making process of which vendor to source a part from and how to transport that part to SA. It is simply a guide and by no means the final/most correct answer. Experience and common sense will still need to be factored into the equation.

Technical feasibility:

The tool is run in Access and LINGO. These type of problems can be effectively solved by LINGO but because of the substantial volume of data used in the model it may take a while to compile a solution.

Schedule feasibility:

The amount of time allocated to the project is reasonable. The “tool” should be fully operational at the time of the completion date.

Economic feasibility:

No costs need to be incurred to acquire software as it is already available. This is not a capital intensive project.

10. Preliminary Design of optimization model

10.1 Variables

All the “given” variables below represent the data that will be exported from Access to LINGO. The decision variables represent the variables that will be exported from LINGO to access.

Product related variables:

p_{ij} = is the given price of product i sourced from vendor j where $i=\{1..n\}$ and $j=\{1..m\}$

d_i = is the given demand/economic order quantity for product i where $i=\{1..n\}$

g_i = is the given weight of product i where $i=\{1..n\}$

Note: Either real weight or volumetric weight will be stored in g_i depending which is bigger.

v_i = is the given volume of product i where $i=\{1..n\}$

Note: Will be determined by multiplying length, width and height. May or may not be used in the optimization model. Depends on the how costs will be charged for sea freight but the information is not yet available.

Cost related variables:

a_j = the given variable cost of shipping a product from vendor j via air freight where $j=\{1..m\}$

Note: The variable cost refers to the costs that are charged per kg. All the costs that are charged per kg will be added together.

A_j = the given fixed cost of shipping a product from vendor j via air freight where $j=\{1..m\}$

Note: The fixed cost refers to the costs that are charged per HAWB. All the costs that are charged per HAWB will be added together. It is assumed that only one product is charged per HAWB.

$s_j =$ the given variable cost of shipping a product from vendor j via sea freight where $j=\{1..m\}$

Note: The variable cost refers to the costs that are charged per volume. All the costs that are charged per volume will be added together. The costs per container have been converted into cost per volume as discussed in data analysis.

Important assumption:

Nissan will only make use of the larger 40ft high cubed container and not the 20ft container as it is more cost effective. Therefore all variable costs will be calculated based on the costs charged for a 40ft container. The volume of a 40ft container is $86m^3$.

$S_j =$ the given fixed cost of shipping a product from vendor j via sea freight where $j=\{1..m\}$

$e =$ is the given cost per weigh for imported goods.

Note: A value for packages per weight has been calculated. There is a fixed cost per number of packages once parts arrive in SA. Multiplying these two will give the cost per weight. This has already been explained in the data analysis.

Transport availability Related variables:

$Z_j =$ 1 if a product sourced from vendor j can be shipped via air
else it is zero

$Y_j =$ 1 if a product sourced from vendor j can be shipped via sea
else it is zero

Decision Variables:

X_{ij} = is 1 if product i is sourced from vendor j where $i=\{1..n\}$ and $j=\{1..m\}$
 else it is 0

z_{ij} = is 1 if product i sourced from vendor j is shipped via air freight where $i=\{1..n\}$
 and $j=\{1..m\}$
 else it is 0

y_{ij} = is 1 if product i sourced from supplier j is shipped via sea freight where
 $i=\{1..n\}$ and $j=\{1..m\}$
 else it is 0

10.2 Objective function

The objective is to minimize the total cost of all imports needed to meet the demand i.e. the sum of *the total cost to acquire a product* for all imported products need to be a minimum. Figure 12 illustrates how the total cost of an individual part is calculated.

Figure 12: Total cost per order calculation

Total Cost				
Unit Cost	Transport cost			
	Air Freight		Sea Freight	
	Fixed cost	Variable cost	Fixed cost	Variable cost

TC = total cost

Min TC = $\sum_{i=1}^n \sum_{j=1}^m$ Total cost of an individual product * demand* X_{ij}

Note: X_{ij} confirms whether product i is bought from vendor j. If X_{ij} is 1, all costs are charged else if it is 0, no costs are charged.

Min TC = $\sum_{i=1}^n \sum_{j=1}^m$ (Unit Cost + Transport Cost) * d_i * X_{ij}

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m (p_{ij} + \text{Air freight cost}[z_{ij}] + \text{Sea freight cost}[y_{ij}]) d_i \cdot X_{ij}$$

Note: z_{ij} and y_{ij} indicates which mode of transport will be taken. Only the costs of the mode of transport used will be charged.

$$\begin{aligned} \text{Air freight cost} &= \text{Fixed cost} + \text{Variable cost} \\ &= A_j + (a_j + e) g_i \quad (\text{Note: } e \text{ is the split fee}) \\ \text{Sea freight cost} &= \text{Fixed cost} + \text{Variable cost} \\ &= S_j + s_j g_i \end{aligned}$$

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m (p_{ij} + [A_j + (a_j + e) g_i][z_{ij}] + [S_j + s_j g_i][y_{ij}]) d_i \cdot X_{ij}$$

10.3 Constraints

A product can only be sourced from one vendor:

$$\sum_{j=1}^m X_{ij} = 1 \quad (i = 1, 2, \dots, n)$$

(1) Vendor constraint

Products can only be imported by either air or sea freight but not both.

$$\sum_{j=1}^m (z_{ij} + y_{ij}) = 1 \quad (i = 1, 2, \dots, n)$$

(2) Transport system constraint

A part can only be imported by air or sea if that option is available.

$$z_{ij} \leq Z_j \quad (i = 1, 2, \dots, n; j = 1, 2, \dots, m)$$

$$y_{ij} \leq Y_j \quad (i = 1, 2, \dots, n; j = 1, 2, \dots, m)$$

(3) Transport availability constraints

10.4 Restrictions

The formulation has the following restrictions:

1. It assumes that all parts are ordered simultaneously
2. It assumes that all parts are ordered only once
3. It assumes that there is one product per HAWB. This is an error rather than a limitation. The formulation will need to be adapted to correct this error.

In order to resolve the first *two* restrictions changes would have to be made to the “decision tool” design or to the optimization model. The following alternatives were considered:

1. ABC Split

Parts are given an ABC rating based on their demand. A part with an “A” rating is in high demand while a part with an “I” rating has barely any demand. The part with the “A” rating will have a higher order frequency i.e. it will be ordered more regularly than the “I” part. The formulation however does not recognise that some parts are ordered more than others.

The first possible solution was to split the products according to their ABC rating and run an optimization model for each category. This will however create a new set of problems. Not every order consists of only “A” or only “B” products. This will complicate the calculation of costs in terms of the HAWB as all products ordered appear on one HAWB.

2. ABC weight factor

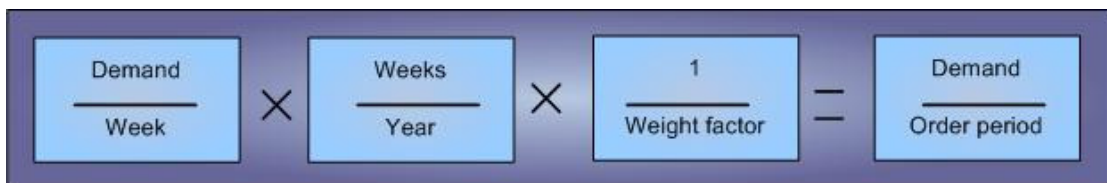
The next possible solution was to determine an ABC weight factor. Each ABC category would be assigned a weight factor based on the average number of times that category of parts are ordered.

For example: If “A” parts are ordered every 3 months they would get a rating of 4. An “I” part is only ordered once a year and therefore receives a rating of 1.

The weight factor can then be used in two possible ways:

2.1. The total cost per part (for one order) in the objective function can be multiplied by this weight factor to accommodate for the fact that some products are ordered more than once. The demand per product must then be converted from the demand per week which is currently available to the demand per order period. This can easily be done using the weight factor. Figure 13 illustrates how.

Figure 13: Demand/ Order period calculation



Total cost per year = Factor * (total cost per order period)

2.2 The following method can also be used:

Total cost per year = unit cost per year + variable transport costs per year + fixed transport cost per order * factor (*number of orders*)

The demand per week will be converted to the demand per year.

Using the ABC weighted factor method still has one problem; it still assumes that there is one part per HAWB. It can however be combined with other ideas.

3. Order selection

Another alternative is to prompt the user to upload a list of products that will be placed in an order. In this situation the formulation will be valid as all the products on the list are ordered at once. This significantly simplifies the calculation of the cost charged per HAWB as all products ordered from a specific country appear on the same HAWB.

This will be a tedious task. The purpose of the tool is to run the optimization once to determine the supplier and freight option only once. The capability to upload a list of products can however still add value to the “tool”. Instead of uploading a list of one specific order, new products can be added or a specific group of parts can be selected.

The ABC weight factor can be used to rectify the first two restrictions. In order to rectify the last restriction the following alternatives were considered:

4. Charge a fraction of the cost per HAWB to each part

When determining the total cost of a product only a fraction of the cost per HAWB can be added to the total instead of charging the entire cost per HAWB as is currently being done. The problem that arises is determining the fraction to be used. The fraction would vary from country to country. It would be difficult to determine a truthful estimate.

5. Using a fixed number of HAWB per year

Orders are placed continuously during the week but are flown in roughly once a week. All the orders placed during the week are thus placed on one HAWB. This amounts to 52 HAWB each year from every country. Therefore the cost of 52 HAWB will be added to the total cost per year, independent from the variable cost of the products. This alternative will be used to construct the formulation.

6. Using the ABC weight factor to determine the number of HAWB per country per year.

The assumption can be made that the number of HAWB from a specific country will be roughly the same as the maximum order frequency of any given product shipped from that country.

For example:

An “A” part is ordered once a week and a “B” part is ordered once every two weeks.

“A” and “B” parts are sourced from country X while only “B” parts are sourced from country Y. Country X will then have 52 HAWBs while country Y will only have 26 as the flights from this country is less regular. Should no parts be sourced from a specific country, no HAWB costs should be charged.

Two revisions of the formulation were completed, the first using alternative 5 and the second using alternative 6.

11. First revision of the optimization model

11.1 Variables

Product related variables:

p_{ij} = is the given price of product i sourced from vendor j where $i=\{1..n\}$ and $j=\{1..m\}$

d_i = is the given demand per year for product i where $i=\{1..n\}$

Note: The demand is per year.

g_i = is the given weight of product i in kg where $i=\{1..n\}$

Note: Either real weight or volumetric weight will be stored in g_i depending which is bigger.

v_i = is the given volume of product i in cubic metre where $i=\{1..n\}$

Note: Will be determined by multiplying length, width and height.

c_{jk} = is given as 1 if vendor j is situated in country k where $j=\{1..m\}$ and $k=\{1..q\}$ else it is 0

Cost related variables:

a_j = the given variable cost (per kilogram) of shipping a product from vendor j via air freight where $j=\{1..m\}$

Note: The variable cost refers to the costs that are charged per kg. All the costs that are charged per kg will be added together.

r_k = the given fixed cost (per HAWB) for shipping a product from country k via air freight where $k=\{1..q\}$

Note: The fixed cost refers to the costs that are charged per HAWB. All the costs that are charged per HAWB will be added together.

s_j = the given variable cost (per cubic metre) of shipping a product from vendor j via sea freight where $j=\{1..m\}$

Note: The variable cost refers to the costs that are charged per volume. All the costs that are charged per volume will be added together. The costs per container have been converted into cost per volume as discussed in data analysis.

Important assumptions:

1. Nissan will only make use of the larger 40ft high cubed container and not the 20ft container as it is more cost effective. Therefore all variable costs will be calculated based on the costs charged for a 40ft container. The volume of a 40ft container is 86m^3 .
2. Costs are all charged per container. There are no charges per bill of lading.

Transport availability Related variables:

$e_j =$ is given as 1 if a product sourced from vendor j can be shipped via air else it is zero where $j=\{1..m\}$

$f_j =$ is given as 1 if a product sourced from vendor j can be shipped via sea else it is zero where $j=\{1..m\}$

Decision Variables:

$x_{ij} =$ is 1 if product i is sourced from vendor j where $i=\{1..n\}$ and $j=\{1..m\}$ else it is 0

$z_{ij} =$ is 1 if product i sourced from vendor j is shipped via air freight where $i=\{1..n\}$ and $j=\{1..m\}$ else it is 0

$y_{ij} =$ is 1 if product i sourced from supplier j is shipped via sea freight where $i=\{1..n\}$ and $j=\{1..m\}$ else it is 0

11.2 Objective function

The objective is to minimize the total cost of all imports needed to meet the demand i.e. the sum of *the total cost to acquire a product for an entire year* for all imported products need to be a minimum. The total variable and the total fixed cost per year will be split. The demand that will be used is the demand for the total year.

Figure 14: Total cost per year calculation

Total cost per year			
Total variable cost per year			Total Fixed cost per year
Unit price	Transport cost		
	Variable Sea Freight	Variable Air Freight	Fixed Air Freight

TC = total cost

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m [\text{Total variable cost of an individual product per year}] + \sum_{k=1}^q \text{Fixed cost per country per year}$$

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m \text{Total variable cost of an individual product} * \text{demand per year} * x_{ij} + \sum_{k=1}^q \text{Cost per HAWB per country} * 52 \text{ weeks}$$

Note: X_{ij} confirms whether product i is bought from vendor j . If x_{ij} is 1, all variable costs are charged else if it is 0, no costs are charged.

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m (\text{Unit Cost} + \text{Variable Transport Cost}) * d_i * x_{ij} + \sum_{k=1}^q r_k * 52$$

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m (p_{ij} + \text{Air freight cost}[z_{ij}] + \text{Sea freight cost}[y_{ij}]) d_{ij} * x_{ij} + \sum_{k=1}^q r_k * 52$$

Note: z_{ij} and y_{ij} indicates which mode of transport will be taken. Only the costs of the mode of transport used will be charged.

$$\text{Air freight cost} = a_j * g_i$$

$$\text{Sea freight cost} = s_j * v_i$$

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m (p_{ij} + ((a_j g_i)[z_{ij}] + (s_j v_i)[y_{ij}]) d_i * x_{ij} + \sum_{k=1}^q r_k * 52$$

11.3 Constraints

A product can only be sourced from one vendor:

$$\sum_{j=1}^m X_{ij} = 1 \quad (i = 1, 2, \dots, n)$$

(1) Vendor constraint

Products can only be imported by either air or sea freight but not both and should be imported from the chosen vendor.

$$X_{ij} = (Z_{ij} + y_{ij}) \quad (i = 1, 2, \dots, n; j = 1, 2, \dots, m)$$

(2) Transport system constraint

A part can only be imported by air or sea if that option is available.

$$z_{ij} \leq e_j \quad (i = 1, 2, \dots, n; j = 1, 2, \dots, m)$$

$$y_{ij} \leq f_j \quad (i = 1, 2, \dots, n; j = 1, 2, \dots, m)$$

(3) Transport availability constraints

Parts can only be imported from a specific country if a 20ft container can be filled over a period of 3 months.

$$\sum_{i=1}^n \sum_{j=1}^m v_i * d_i * y_{ij} * c_{jk} \geq 132 * [\sum_{i=1}^n \sum_{j=1}^m v_{ij} * c_{jk}] \quad (k = 1, 2, \dots, q)$$

(4) Container constraint

Note: The volume of a 20ft container is 33m³. If parts can only be imported from a specific country if a 20ft container can be filled over a period of 3 months it means that 132 m³ (33 x 4) needs to be imported per year from a specific country. It was stated earlier that only 40ft containers are used; this is because all costs are charged as for a 40ft container. Exception can however be made to this rule. If a 20ft container can be filled it proves that it is feasible to consider the sea freight option.

Restrictions: The formulation currently assumes that there are 52 HAWBs per country. If for some reason no products are purchase from a specific country, the cost of 52 HAWBs will still be added even though there were no flights.

12. Second revision of the optimization model

12.1 Variables

There are only two additional variables that weren't used in the first revision.

b_i = is the given ABC weight factor/order frequency of product i per year where $i=\{1..n\}$.

h_{ik} = is the maximum ABC weight factor for country k when product i has been checked where $k=\{1..N\}$ and $i=\{1..n\}$.

The following table is used to illustrate how h_{ik} is calculated:

Table 3: Calculation of the maximum number of HAWBs per country

Product	ABC weight (order frequency)	Bought in country k	Order frequencies applicable to country k	Maximum order frequency
i	b_i	$x_{ij} * c_{jk}$	$b_i * x_{ij} * c_{jk}$	h_{ik}
1	0	1	0	0
2	0	0	0	0
3	1	1	1	1
4	4	1	4	4
5	3	1	3	4
6	4	0	0	4
7	6	1	6	6
$n-1$	0	1	0	6
n	3	1	3	6

h_{nk} is thus the final maximum number of HAWBs for country k i.e. the number of HAWBs charged per country.

In order to determine h_{ik} the following constraints are used:

$$b_i * x_{ij} * c_{jk} \leq h_{ik}$$

And

$$h_{(i-1)k} \leq h_{ik}$$

Should no parts be sourced from country k, h_{nk} will be zero.

12.2 Objective function

The objective is still to minimize the total cost of all imports needed to meet the demand i.e. the sum of *the total cost to acquire a product for an entire year* for all imported products need to be a minimum. The total variable and the total fixed cost per year will be split. The demand that will be used is the demand for the total year. Instead of assuming that there are 52 HAWBs from each country, the cost per HAWB will be multiplied by the maximum number of HAWBs for each country.

$$\begin{aligned} \text{Min TC} &= \sum_{i=1}^n \sum_{j=1}^m [\text{Total variable cost of an individual product per year}] \\ &+ \sum_{k=1}^q \text{Fixed cost per country per year} \end{aligned}$$

$$\begin{aligned} \text{Min TC} &= \sum_{i=1}^n \sum_{j=1}^m \text{Total variable cost of an individual product} * \text{demand per year} * X_{ij} \\ &+ \sum_{k=1}^q \text{Cost per HAWB per country} * \text{Maximum number of HAWB per country} \end{aligned}$$

Note: X_{ij} confirms whether product i is bought from vendor j. If X_{ij} is 1, all variable costs are charged else if it is 0, no costs are charged.

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m (\text{Unit Cost} + \text{Variable Transport Cost}) * d_{ij} * X_{ij} + \sum_{k=1}^q r_k * h_{nk}$$

$$\begin{aligned} \text{Min TC} &= \sum_{i=1}^n \sum_{j=1}^m (p_{ij} + \text{Air freight cost}[z_{ij}] + \text{Sea freight cost}[y_{ij}]) d_i * X_{ij} \\ &+ \sum_{k=1}^q r_k * h_{nk} \end{aligned}$$

Note: z_{ij} and y_{ij} indicates which mode of transport will be taken. Only the costs of the mode of transport used will be charged.

$$\text{Air freight cost} = a_j * g_i$$

$$\text{Sea freight cost} = s_j * v_i$$

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m (p_{ij} + (a_j g_i)[z_{ij}] + (s_j v_i)[y_{ij}]) d_i * X_{ij} + \sum_{k=1}^q r_k * h_{nk}$$

12.3 Constraints

The constraints are the same as for the first revision except for the following additional constraints:

$$b_i + x_{ij} * c_{jk} \leq h_{ik} \quad \text{for all } i, j \text{ and } k \text{ where } i=\{1..n\}, j=\{1..m\} \text{ and } k=\{1..N\}$$

(5.1) Maximum order frequency

And

$$h_{(i-1)k} \leq h_{ik} \quad \text{for all } i \text{ and } k \text{ where } i=\{2..n\} \text{ and } k=\{1..N\}$$

Note: $i=1$ is not included
(5.2) Maximum order frequency

Restrictions: Assumes that the number of HAWB from a specific country will be roughly the same as the maximum order frequency of any given product shipped from that country.

13. Concept/ idea evaluation and selection

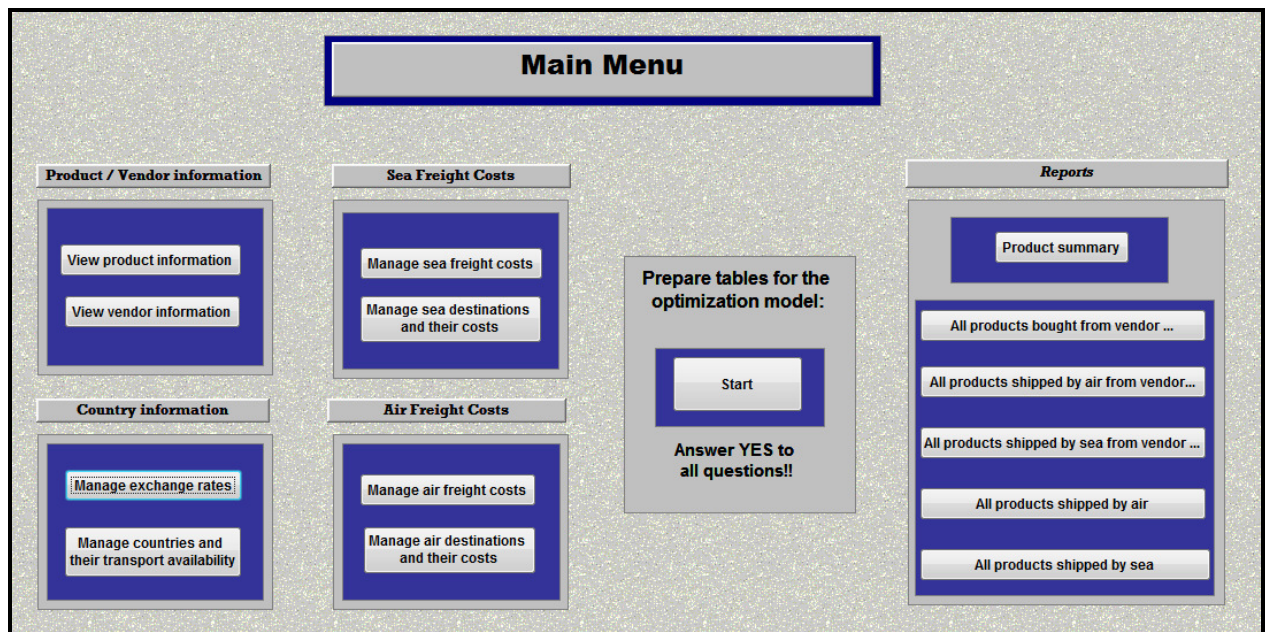
The second revision will require substantially more computing power than the first revision when a large number of parts and vendors need to be considered. Using the second revision, to optimise the problem, may put unnecessary strain on the computer running the model for what may prove to be very little improvement from the first revision. The first revision of the optimization model will be used.

14. Functionality of the decision making tool

The main menu of the decision tool appears in figure 15. The menu consists of 3 basic sections. These sections include:

- The information section
- The prepare tables for optimisation section
- The reports section

Figure 15: Main Menu of the "decision tool"



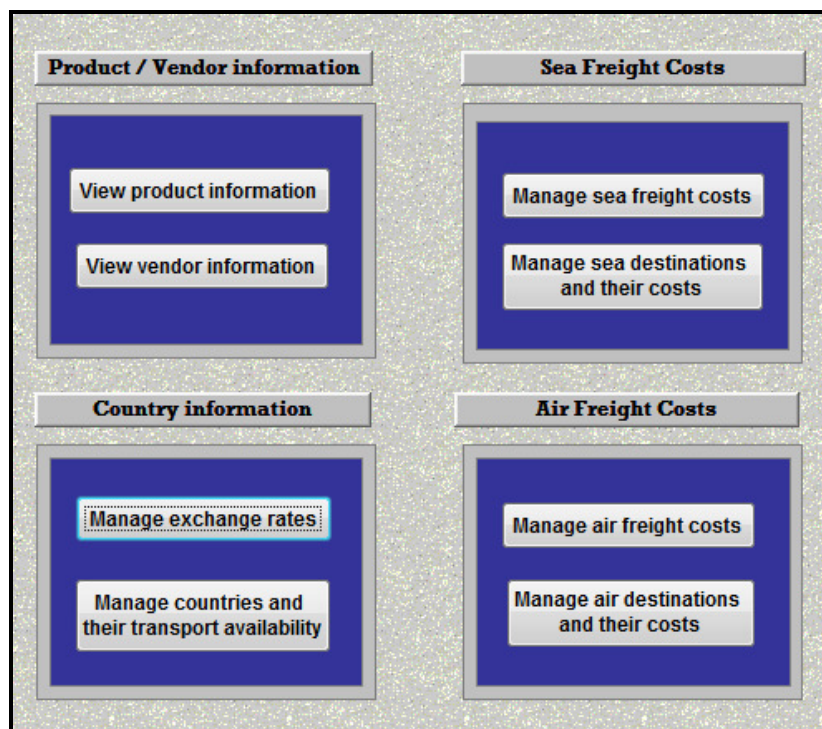
14.1 The information section

The information section (figure 16) includes the following forms:

- Product / vendor information
 - Allows the user to view forms containing all product and vendor information. These forms will rarely be used to add, delete or change product and vendor information. This information is imported straight into the actual data tables as the tool is designed to handle a large amount of parts.
- Country information
 - Exchange rates need to be updates before the model is run in order to achieve accurate results.

- The user can indicate which countries can be exported from as well as the modes of transport available for that specific country. For example: should Nissan for some reason decide that they do not wish to receive air freight from Japan they can simply indicate that the air freight option does not exist for Japan.
- Sea freight costs
 - The sea freight costs need to be updated before the model can be run. It is important that the user ensures that the costs for all countries listed as having sea freight available have their costs stored in the database.
 - All in-land transportation costs need to be up to date. The model makes provision for more than one destination even though there is currently just one. Destination refers to the location of the harbour where the shipments arrive.
- Air freight cost
 - It is the same concept as sea freight cost.

Figure 16: Information section

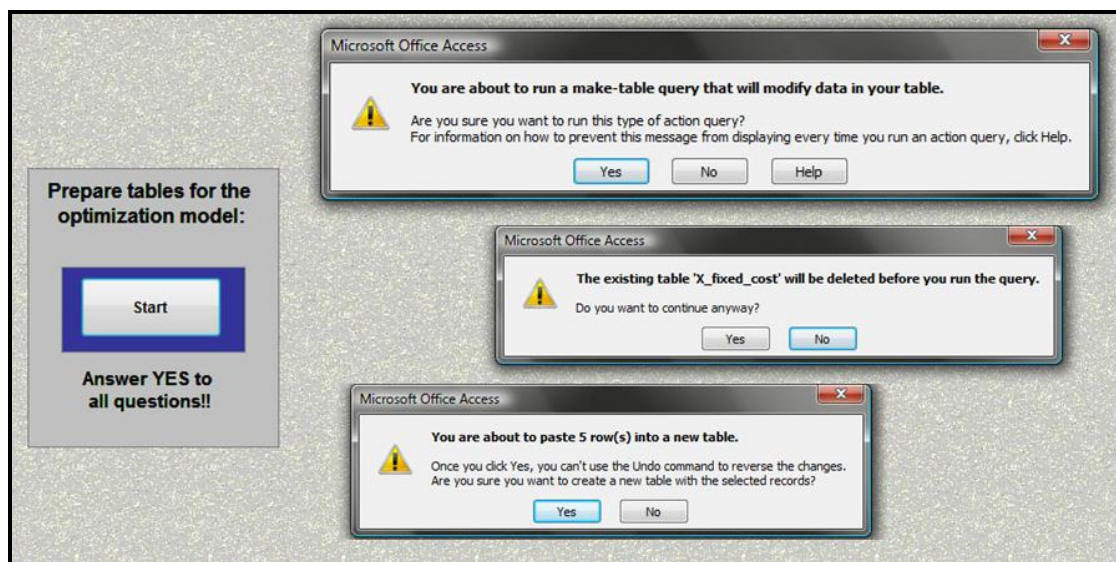


Completing the information in this section is the first step in using the “decision tool”. All data should be correct before the next step is taken.

14.2 The Optimisation section

Once all information has been updated and before the optimization model can be run some calculations and table preparations need to be performed by the tool. The user needs to tell the tool when it is time to perform these actions. Once the user presses start a multitude of pop-up windows will appear. It is vital that the user answers YES to all the questions. These actions are all necessary to create tables that represent data in a way that can be used by LINGO. It is strongly recommended that chapter 3 in Appendix D (Configuration manual) be consulted to fully understand this section.

Figure 17: Run optimisation section



Once the necessary actions table preparations have been performed the LINGO model can be executed.

The user needs to open LINGO and load the "Nissan_decision_tool" file. All the user is required to do is to run the file. The results are automatically exported to Access. The user should make no changes to the LINGO file. This will be explained in greater detail in chapter 3 of appendix C (User manual).

The LINGO model and examples of its results appear in Appendix E. Data values have been changed to adhere to Nissan policy of non-disclosure.

14.3 The reports section

Once the optimisation has been executed the results can be viewed in two different ways. The user can either go to the product information form or can make use of the reports section (figure 18).

The following reports can be generated:

- A product summary which states the chosen vendor and the chosen mode of transport for a specific product. The user needs to provide the material ID to specify which product. The summary also show the costs associated with buying and importing the specific product.
- All products sourced from a specific vendor. The user needs to provide the vendor ID to specify which vendor.
- All products sourced from a specific vendor and are transported by air. The user needs to provide the vendor ID to specify which vendor.
- All products sourced from a specific vendor and are transported by sea. Again the user needs to provide the vendor ID to specify which vendor.
- A report of all products shipped per air.
- A report of all products shipped per sea.

Figure 18: Reports section



All forms and report are explained in detail in the user guide in appendix C. The construction and configuration of the tool is explained in appendix D.

15. Conclusion

The “decision tool” can successfully be used to re-evaluate the vendor and mode of transport used to acquire a part, should Nissan and Renault choose to consolidate their parts.

It is important to note that it is only a tool to aid in the decision making process of which vendor to source a part from and how to transport that part to SA. It is simply a guide and by no means the final/most correct answer. Experience and common sense will still need to be factored into the equation.

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1. Main information Subsystem

Use Case Name	Manage Exchange Rates
Primary Business Actor	Inventory Control Analyst
Other Participating actors	None
Description	All countries from which parts are sourced and their exchange rates can be viewed, edited, added and deleted in this use case. The exchange rate should be kept up to date.
Precondition	None
Trigger	<ul style="list-style-type: none"> • Time based: The exchange rates must be updated on a regular basis to ensure the accuracy of data. • At will of the user
Typical Course of Events	It is important that the exchange rate represents the most current data.

Use Case Name	Manage Sea Freight Cost
Primary Business Actor	Inventory Control Analyst
Other Participating actors	None
Description	Sea freight cost can be viewed, edited, added and deleted in this use case. These freights costs will differ between countries. Costs can be charged per unit, by volumetric weight or by the number of packages.
Precondition	None
Trigger	<ul style="list-style-type: none"> • Time based: The costs must be updated on a regular basis to ensure the accuracy of data. • At will of the user
Typical Course of Events	Data is only updated when there has been a significant change in costs.

Use Case Name	Manage Air Freight Cost
Primary Business Actor	Inventory Control Analyst
Other Participating actors	None
Description	Air freight cost can be viewed, edited, added and deleted in this use case. These freights costs will differ between countries. Costs can be charged per unit, by volumetric weight, by the number of packages etc.
Precondition	None

Trigger	<ul style="list-style-type: none"> • Time based: The costs must be updated on a regular basis to ensure the accuracy of data. • At will of the user
Typical Course of Events	Data is only updated when there has been a significant change in costs.

Use Case Name	Manage Sea Destination Cost
Primary Business Actor	Inventory Control Analyst
Other Participating actors	None
Description	All costs are the same once the shipments reach the harbour. The costs can be viewed and edited.
Precondition	None
Trigger	<ul style="list-style-type: none"> • Time based: The costs must be updated on a regular basis to ensure the accuracy of data. • At will of the user
Typical Course of Events	Step 1: Select the location. Step 2: The appropriate window will be displayed allowing the correct costs to be entered.

Use Case Name	Manage Air Destination Cost
Primary Business Actor	Inventory Control Analyst
Other Participating actors	None
Description	All costs are the same once the shipments reach the airport. The costs can be viewed and edited.
Precondition	None
Trigger	<ul style="list-style-type: none"> • Time based: The costs must be updated on a regular basis to ensure the accuracy of data. • At will of the user
Typical Course of Events	Step 1: Select the location. Step 2: The appropriate window will be displayed allowing the correct costs to be entered.

2. Optimization Subsystem

Use Case Name	Run Optimization model
Primary Business Actor	Inventory Control Analyst
Other Participating actors	None
Description	Tells the system when to perform the table preparations before data can be exported to LINGO.
Precondition	All data in the information must be up to date.
Trigger	At the will of the user: The user will run the models for a selected number of parts
Typical Course of Events	Step 1: Ensure that all data is up to date Step 2: Press the start button Step 3: Answer Yes to all questions Step 4: Run the model in LINGO

Use Case Name	Optimization reports
Primary Business Actor	Inventory Control Analyst
Other Participating actors	None
Description	Provides the user with the ability to view optimization reports.
Precondition	All data in the information must be up to date.
Trigger	At the will of the user
Typical Course of Events	Step 1: The user will be requested to enter a product or vendor ID Step 2: A report will be generated for that particular product or vendor. Alternative: A report of all products or all vendors can be provided.

3. Miscellaneous

Use Case Name	Manage/ View products
Primary Business Actor	Inventory Control Analyst
Other Participating actors	None
Description	Products can viewed, edited, added and deleted in this use case. The list of products can be updated. Product information like: name, demand, volumetrics, unit cost etc can be viewed.
Precondition	None
Trigger	<ul style="list-style-type: none"> • Time based: The list must be updated on a regular basis to ensure the accuracy of data. • At will of the user
Typical Course of Events	Once data is suspected to be out of date, the user will prompt the system to update the list of products.

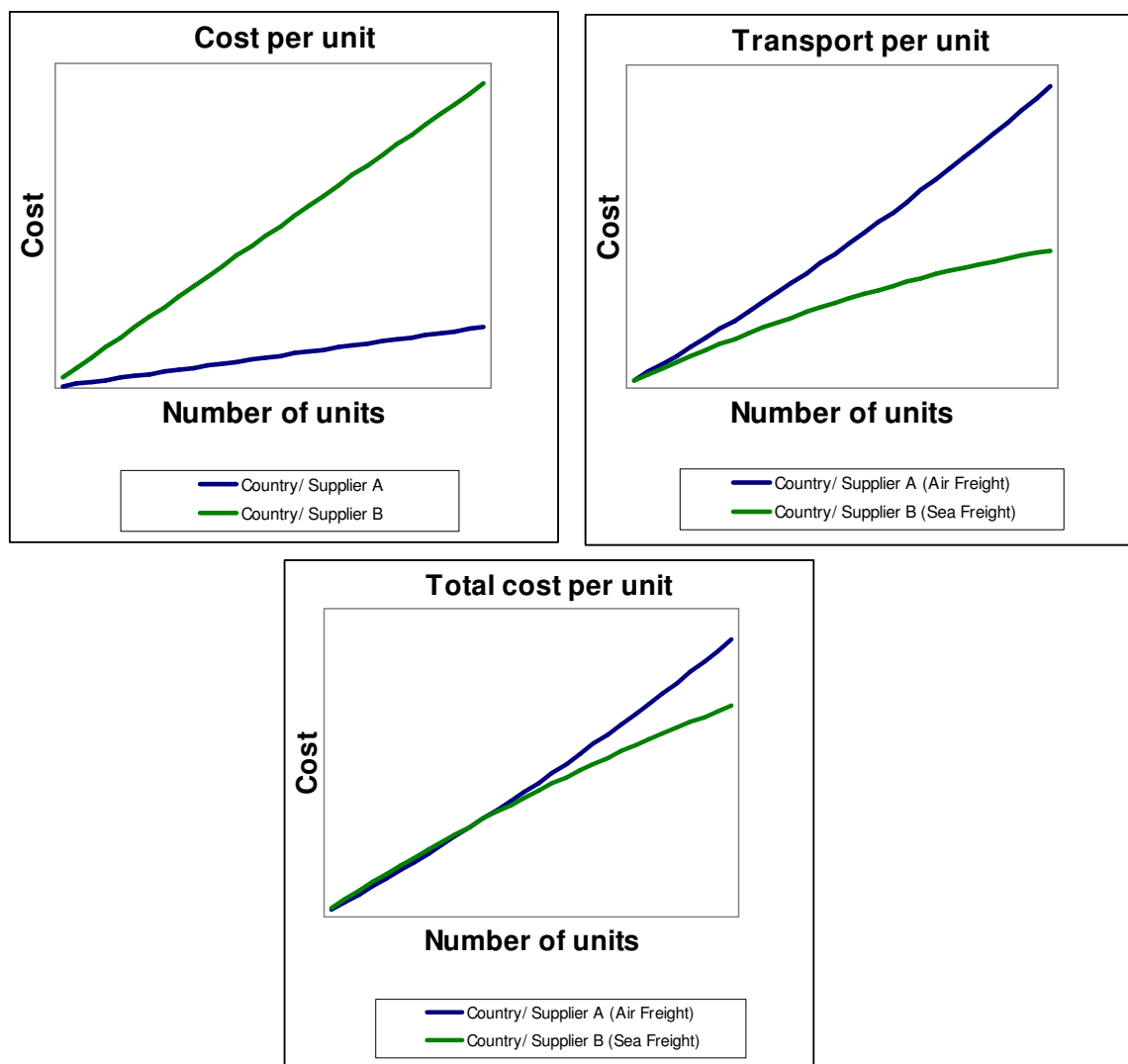
Use Case Name	Manage Vendors
Primary Business Actor	Inventory Control Analyst
Other Participating actors	None
Description	Suppliers can viewed, edited, added and deleted in this use case. The list of suppliers can be updated. Supplier information like: name, location etc can be viewed.
Precondition	None
Trigger	<ul style="list-style-type: none"> • Time based: The list must be updated on a regular basis to ensure the accuracy of data. • At will of the user
Typical Course of Events	Once data is suspected to be out of date, the user will prompt the system to update the list of vendors.

Appendix B

Cost per unit vs. transport cost

Cost per unit vs. transport cost

A product can be bought from supplier A at a lower cost than from supplier B. As this particular product is one of very few that are bought from country A it has to be flown in. If this particular product is bought from supplier B it will be shipped via sea freight with various other products. Supplier A and B are in different countries. The costs compare as follows:



It appears that at some stage it is more cost effective to buy the more expensive products from supplier B as the total procurement cost is lower.

Appendix C

User Manual

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1. Introduction

The Nissan decision tool is used to determine the cheapest way to acquire a specific batch of parts. It determines which vendor to source from as well as which mode of transportation to use. You, the user, determine which products and which vendors are included in the optimization model.

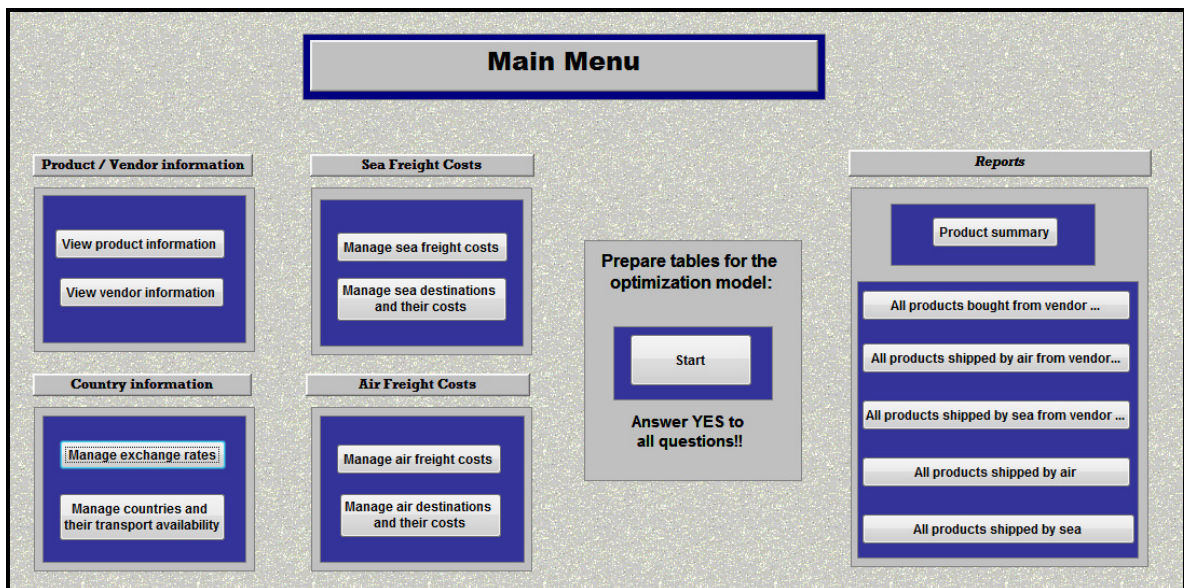
The tool uses Access to organize all the required data and LINGO to perform the linear programming calculations. Most activity occurs within Access. The following manual documents the functions that are available in the tool as well as the steps to perform these functions.

When you open the Access file called "Nissan_decision_tool", go to forms and click on the "Main menu" form. The main menu of the decision tool appears in figure 1. The menu consists of 3 basic sections. These sections include:

- The information section
- The prepare tables for optimisation section
- The reports section

All of which will be discussed in detail.

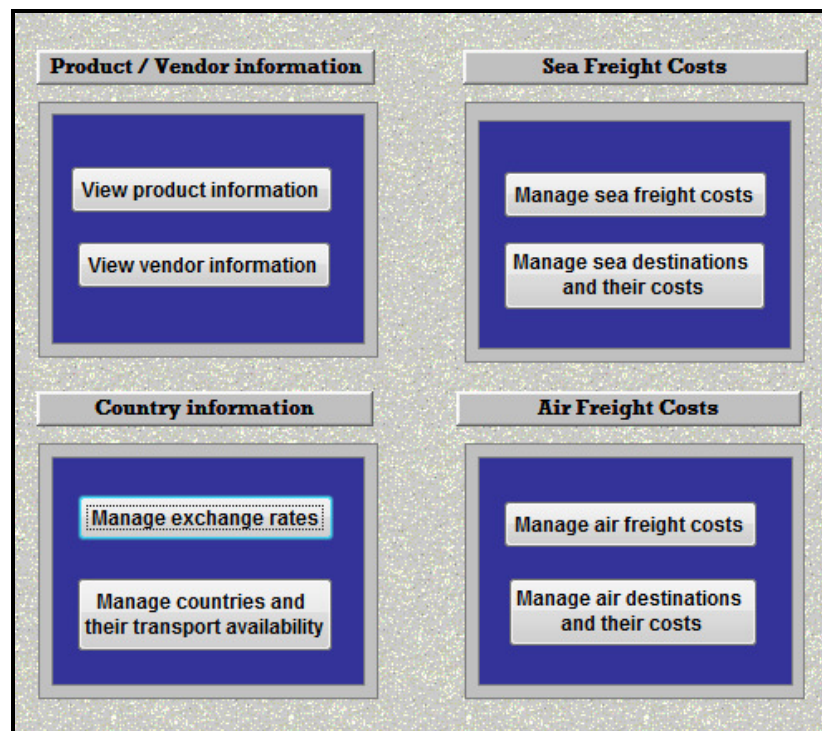
Figure 1: Main Menu of the "decision tool"



The information section

Completing the information in this section is the first step in using the “decision tool”. All data should be correct before the next step is taken.

Figure 2: Information section



The information section (Figure 2) includes the following forms:

- Product / vendor information
 - Allows the user to view forms containing all product and vendor information. These forms will rarely be used to add, delete or change product and vendor information. This information is imported straight into the actual data tables as the tool is designed to handle a large amount of parts.
- Country information
 - Exchange rates need to be updates before the model is run in order to achieve accurate results.
 - The user can indicate which countries can be exported from as well as the modes of transport available for that specific country. For example: should Nissan for some reason decide that they do not which to

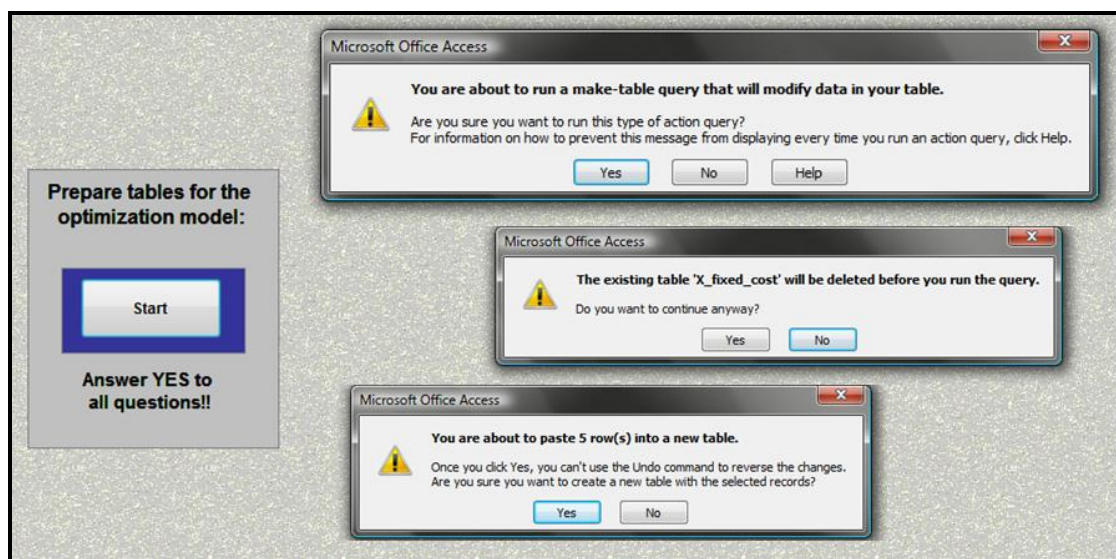
receive air freight from Japan they can simply indicate that the air freight option does not exist for Japan.

- Sea freight costs
 - The sea freight costs need to be updated before the model can be run. It is important that the user ensures that the costs for all countries listed as having sea freight available have their costs stored in the database.
 - All in-land transportation costs need to be up to date. The model makes provision for more than one destination even though there is currently just one. Destination refers to the location of the harbour where the shipments arrive.
- Air freight cost
 - It is the same concept as sea freight cost.

The Optimisation section

Once all information has been updated and before the optimization model can be run some calculations and table preparations need to be performed by the tool. The user needs to tell the tool when it is time to perform these actions. Once the user presses start a multitude of pop-up windows will appear. It is vital that the user answers “YES” to all the questions. These actions are all necessary to create tables that represent data in a way that can be recognized by LINGO.

Figure 3: Run optimisation section



Once the necessary table preparations have been performed the LINGO model can be executed. The user needs to open LINGO and load the “Nissan_decision_tool” file. All the user is required to do is to run the file. The results are automatically exported to Access. The user should make no changes to the LINGO file. This will be explained in greater detail in chapter 3.

The reports section

Once the optimisation has been executed the results can be viewed in two different ways. The user can either go to the product information form or can make use of the reports section (Figure 4).

Figure 4: Reports section



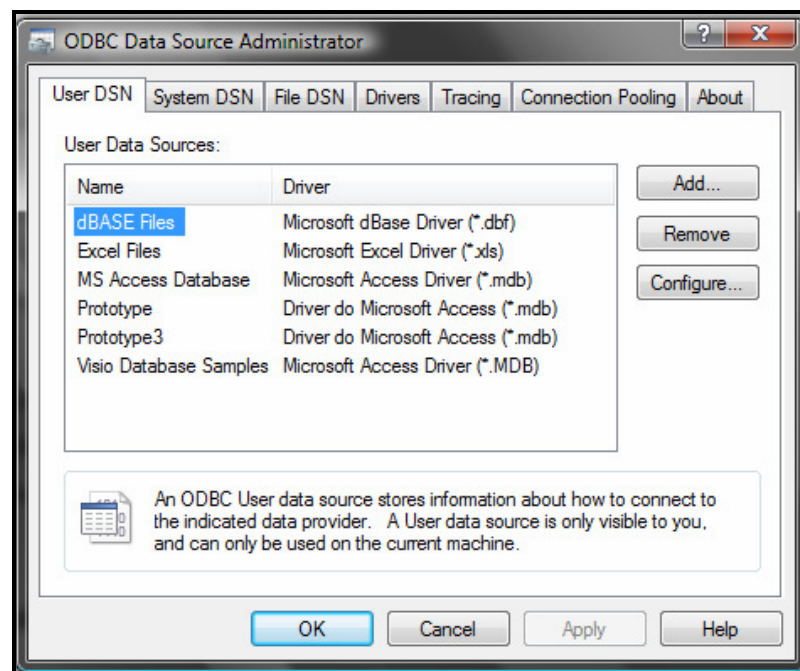
2. Linking the database and the LP model

The Access database and Lingo LP (Linear programming) model, both called “Nissan_decision_tool”, need to be saved on the user’s computer. In order to link the database with the LP model the following steps need to be followed:

Step 1: Locate your PC’s ODBC source administrator. (Figure 5)

The simplest way to do this is to use the search function of your computer located in your start menu. (Tip: simply search ODBC) For older versions of windows you must select the 32-bit ODBC icon in your computer’s control panel.

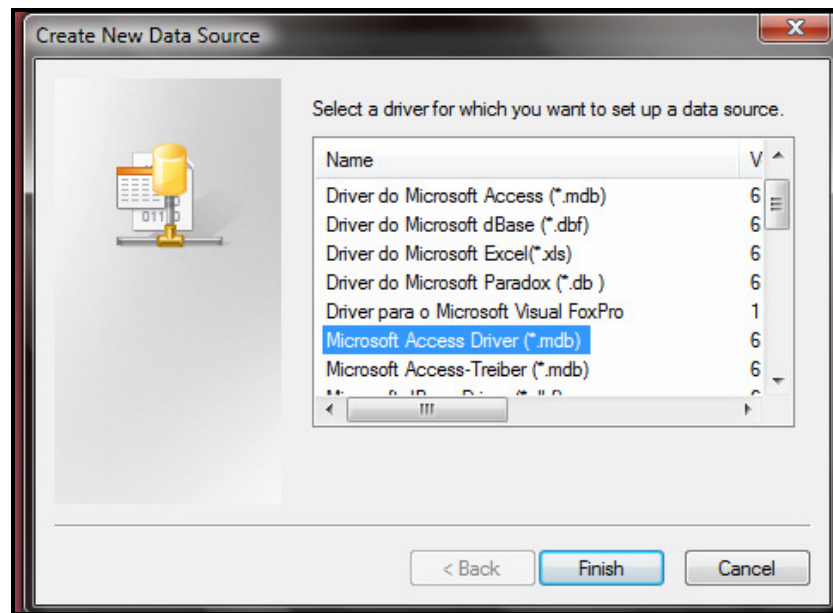
Figure 5: ODBC source administrator



Step 2: Select the driver

Click on the add button to reveal figure 6 and select the Microsoft Access Driver and press finish.

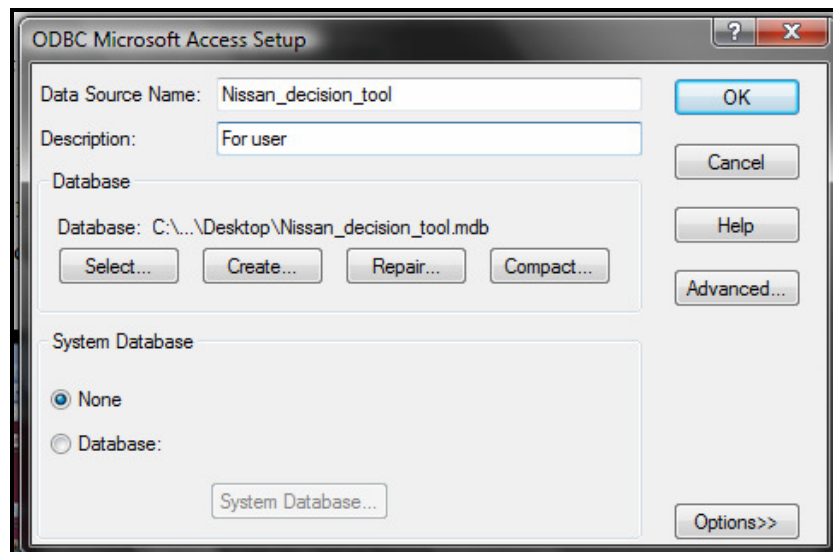
Figure 6: Create new data source window



Step 3: Select the database

Figure 7 will appear. In data source name type “Nissan_decision_tool”. The description is for the user’s convenience. Next press the select button. Select the database “Nissan_decision_tool” from the location were it is stored. Press OK.

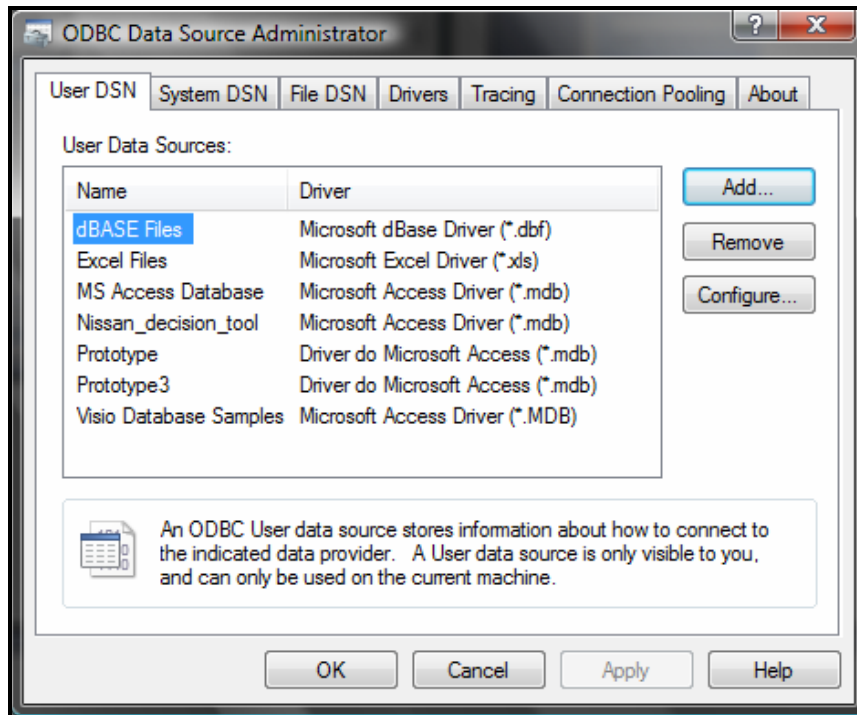
Figure 7: ODBC setup window



Step 4: Add the database

Figure 8 will appear. Check that the database “Nissan_decision_tool” appears on the list and press OK.

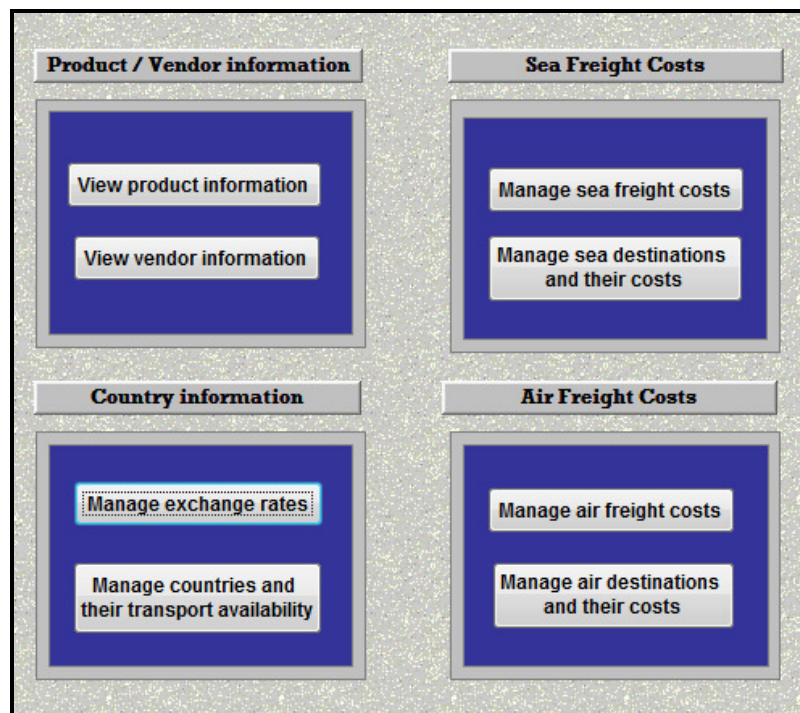
Figure 8: ODBC source administrator window



3. The information section

It is very important that the information in this section is correct and complete before the optimization model is run. Not all of the forms in the information section will be used to enter data; some forms are there only for convenience sake.

Figure 9: Information section



The following information will be entered using the forms:

- Vendor information
- Country information
 - The exchange rates
 - The transport availability of various countries
- Sea freight costs
 - The sea freight costs
 - The sea freight destination costs
- Air freight cost
 - The air freight costs
 - The air freight destination costs

The following information will be imported straight into the data tables:

- Product information
- Product per vendor information

2.1 Importing data into the tables

This is usually the first step in using the “decision tool”. If the database is being used for the first time the forms in section 2.2 should be completed first.

2.1.1 Product information

As the user you have full control over which products to include in the optimization. You as user need to create an Excel file (Figure 10) containing all the necessary information.

The product information required is:

- Material ID (which will be your primary key)
- Material description
- Length (mm)
- Width (mm)
- Height (mm)
- Weight (g)
- ABC (optional)
- Rounding value (Optional)
- PDT (Optional)
- Demand week

Optional values are values that are not currently required by the tool but provision has been made for them should the tool be expanded.

Figure 10: Example of import file for product information

	A	B	C	D	E	F	G	H	I	J
1	Material	Material Description	All_max(mm)	All_mid(mm)	All_min(mm)	All_weight(g)	ABC	Rounding val	PDT	Avg Demand
11594	4321552L60	Bearing	77	77	22	335 E		0	70	0.423
11595	43215G8100	Bearing-rear Ax	77	77	22	335 I		0	70	0.038
11596	1303037500	Washer	77	61	30	335 G		0	70	0.038
11597	9552006J06	Mtng-rubber-body:lower	77	75	75	440 F		0	70	0.308

2.1.1.1 Importing the data

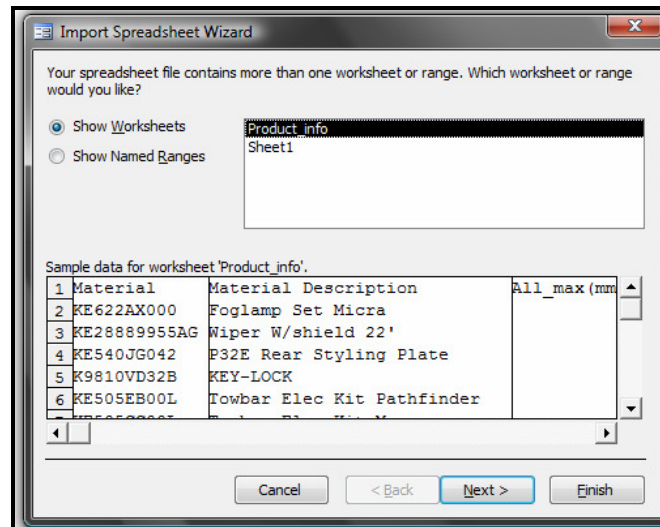
Step 1: Delete all information from the tables called “Product” and “Import_product”

Press “Ctrl” and “A” together to select all records and press “Delete”. This process may take a while. Remember to do this for both tables.

Step 2: Activate the import wizard

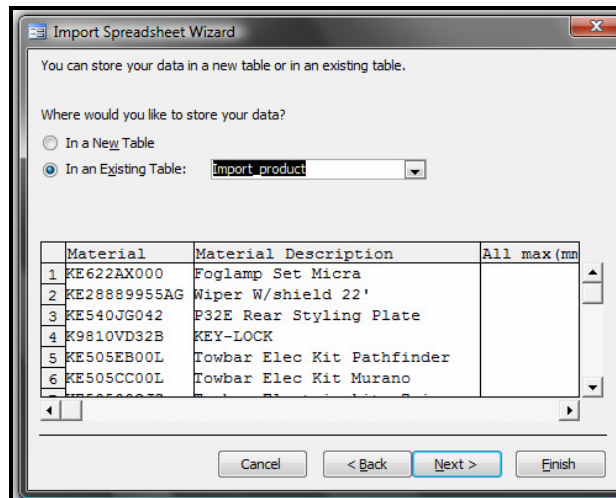
In Access, click on the “File” menu and select “Get external data” and then “Import”. Select the Excel file you have created from its location. Check that the file type is set as Excel. The import wizard will now be displayed (Figure 11). Select the correct worksheet and click “Next”.

Figure 11: Import wizard for product information



In the next window indicate that the first row is the column headings and click “Next”. Store the information in an existing table called “Import_product”. Make sure that you have selected the right table and click “Next”. (Figure 12)

Figure 12: Select existing table called "Import _product"

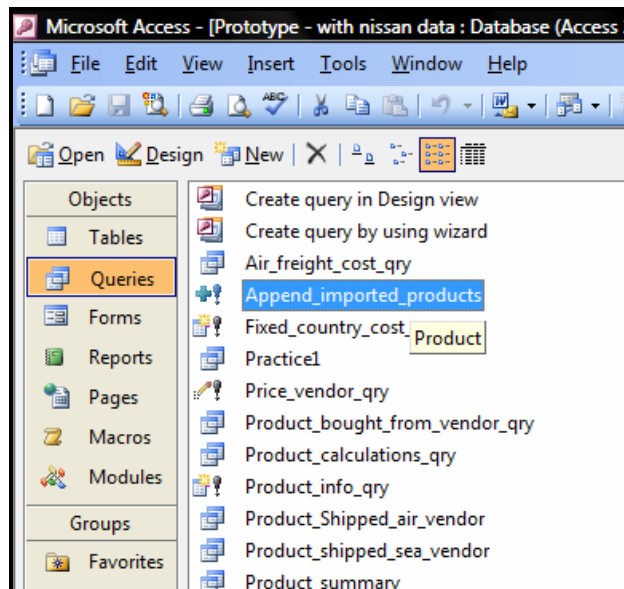


Click "Finish" and then "OK" if the message states that the files have been imported.

Step 3: Append the product information

Click on the append query called "Append_imported_products". And answer "YES" to all questions. (Figure13)

Figure 13: Select "Append_imported_products" query



2.1.1.2 Viewing the data

To view the product information, simply click on the “View product information” button on the main menu. This window will display the following (Figure 14):

- *Product information*
Product information includes the demand per week, dimensions, weight etc.
- *Available vendors*
All vendors that supply the specific product will be displayed and their respective unit costs. This sub-form will only be populated once the product per vendor information has been imported (refer to 2.1.2).
- *Chosen vendor*
Displays the vendor from which the product will eventually be sourced as well as the mode of transport to be used. This sub-form will only be populated once the optimization model has been executed (refer to 3).

Figure 14: View product information form

The screenshot displays the 'View Products' form with the following sections:

- Product information:** Material_ID (1002), Material description (ProductB), Length (12), Width (12), Height (12), Weight (6), ABC (A), Rounding val (2), PDT (7), Demand per week (3).
- Available Vendors:** A table with columns: Vendor ID, Price, Currency (price), Vendor name, Country. Data rows: (2001, 3, USD, VendorA, USA), (2002, 2, JPY, VendorB, Japan), (2003, 2, EUR, VendorC, Europe). A record indicator shows 'Record: 1 of 3'.
- Chosen Vendors:** Vendor ID (2001), Vendor name (VendorA), Sea (0), Air (1), Country name (USA), Price (3), Currency ID (USD).

2.1.2 Product per vendor cost

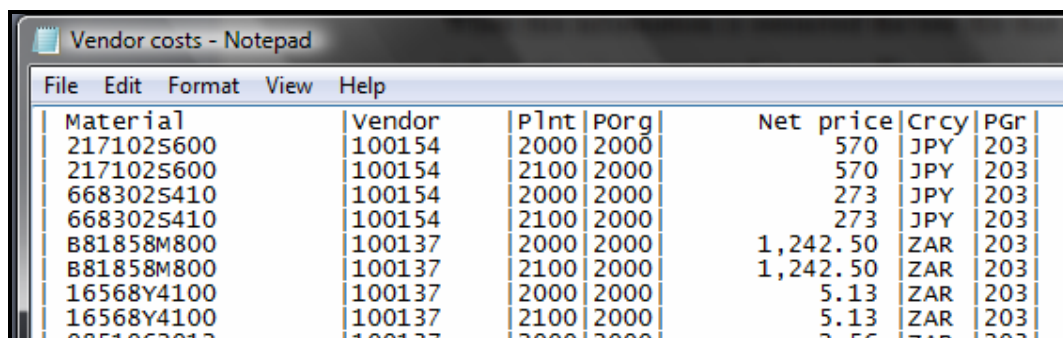
The product per vendor cost can only be imported once all other information has been updated. It is of critical importance that the list of products, the list of all vendors and the currency table is complete before this information is imported.

The necessary information includes:

- The material ID
- The vendor ID
- The price
- The Currency the price is charged in.

When this information is extracted the text file that is created looks like figure15. This information is represented in a text file as it is too large for an Excel spreadsheet.

Figure 15: Example of import file for vendor costs per product



Material	Vendor	Plnt	POrg	Net price	Crcy	PGr
217102S600	100154	2000	2000	570	JPY	203
217102S600	100154	2100	2000	570	JPY	203
668302S410	100154	2000	2000	273	JPY	203
668302S410	100154	2100	2000	273	JPY	203
B81858M800	100137	2000	2000	1,242.50	ZAR	203
B81858M800	100137	2100	2000	1,242.50	ZAR	203
16568Y4100	100137	2000	2000	5.13	ZAR	203
16568Y4100	100137	2100	2000	5.13	ZAR	203
0851062010	100137	2000	2000	2.56	ZAR	203

2.1.2.1 Importing the data

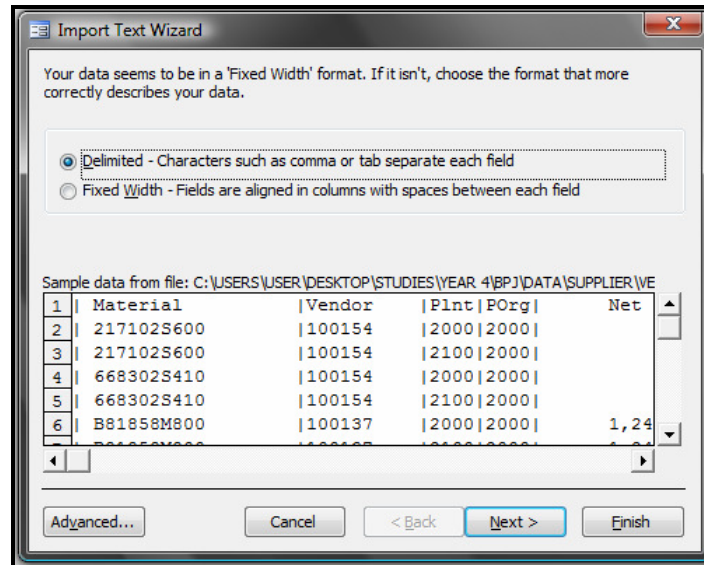
Step 1: Delete all information from the tables called “Product_per_vendor” and “Import_vendor”.

Press “Ctrl” and “A” together to select all records and press “Delete”. This process may take a while. Remember to do this for both tables.

Step 2: Activate the import wizard

In Access, click on the “File” menu and select “Get external data” and then “Import”. Select the Excel file you have created from its location. Check that the file type is set as Text. The import wizard will now be displayed (Figure 16). Select the format as delimited and click “Next”.

Figure 16: Import wizard for vendor costs



In the next window select other as you delimiter and enter “|” in the space provided. Also indicate that the first row is the column headings. Then click on the advanced button.

Figure 17: Set delimiter in import wizard

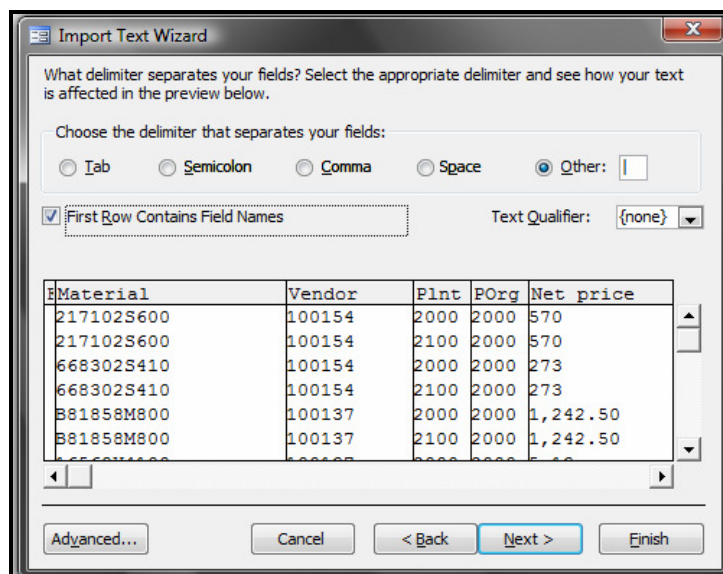
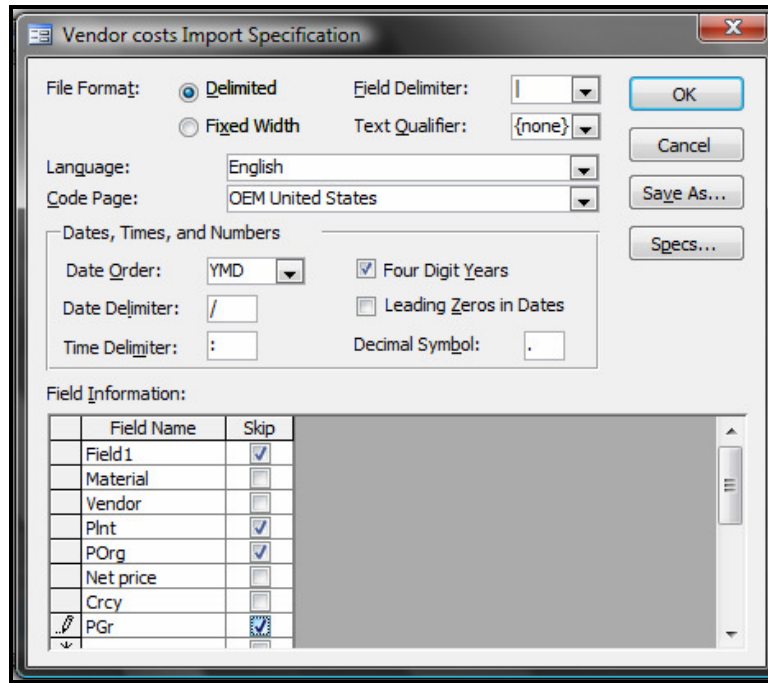


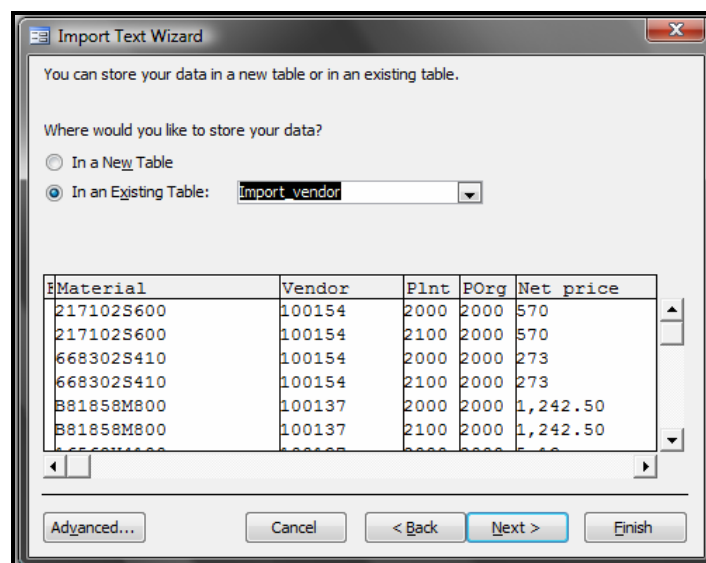
Figure 18 will appear. Indicate that you want to skip “Field1”, “Plnt”, “POrg” and “PGr”. And click OK. You are now back at figure 17. Simply click “Next”. A pop-up window will appear, just click “YES” and then click “Next”.

Figure 18: Indicate which rows to skip when importing



Store the information in an existing table called “Import_vendor”. Make sure that you have selected the right table and click “Next”. (Figure 18)

Figure 19: Import data to "Import_vendor" table

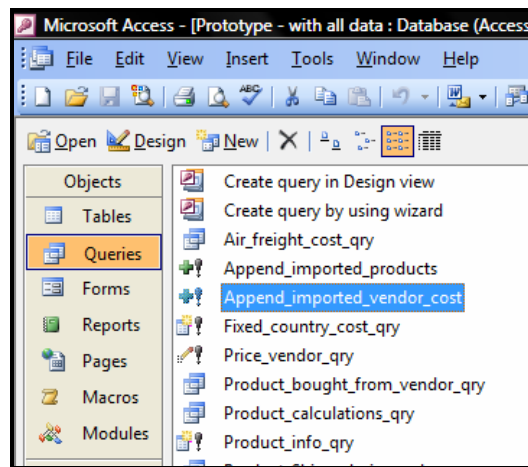


Click “Finish” and then “OK” if the message states that the files have been imported. It is normal for an error message to occur.

Step 3: Append the product information

Click on the append query called “Append_imported_vendor_cost”. And answer “YES” to all questions. (Figure 20). Only the data for which there exists a product and a vendor and a currency will be appended.

Figure 20: Select "Append_imported_vendor_cost" query



2.1.2.2 Viewing the data

The product per vendor information appears on the product information form. Refer to 2.1.1.2.

2.2 Entering data into the forms

The data that can be entered into the forms are usually low volume. It is of critical importance that the data is entered correctly and is kept up to date.

2.2.1 Country information

2.2.1.1 Countries and their transport availability

When the database is being used for the first time transport availability form needs to be completed before the vendor form and the exchange rate form (2.2.2.2).

All countries that host vendors need to be listed as well as their transport availability. Should you want to restrict the use of a certain mode of transport for a specific country; you simply indicate that that mode is not available. (Figure 21)

Figure 21: Countries & transport availability form

Country ID	Country name	Air freight available	Sea freight available
1	USA	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
2	Japan	<input type="checkbox"/>	<input checked="" type="checkbox"/>
3	Europe	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
4	Brazil	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
5	Phillipines	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(AutoNumber)		<input type="checkbox"/>	<input type="checkbox"/>

2.2.1.2 Manage exchange rates

Exchange rates need to be updated before the model is executed. These exchange rates should be checked every time the model is executed to make sure they are realistic. (Figure 22)

Figure 22: Exchange rate form

Currency ID	Currency name	Exchange rate
EUR	Euro	16
JPY	Yen	12
USD	Dollar	8
		0

2.2.2 Vendor information

2.2.2.1 View vendor information

Vendor ID should preferably be added before the product per vendor information is imported. The vendor ID, vendor name and location are required. Once the product per vendor information has been added the list of products linked to a specific vendor will appear on the sub-form. (Figure 23)

Figure 23: Vendor form

Material ID	Material description	Price	Currency
1004	ProductD	10	USD
1001	ProductA	20	USD
1003	ProductC	3	USD
1005	ProductE	10	USD
1002	ProductB	3	USD
1006	ProductF	2	USD

Record: 1 of 6

2.2.3 Sea freight costs

It is important to note that not all costs are applicable to all countries. Simply fill in those that are.

2.2.3.1 Manage sea freight costs

When entering the sea freight cost (Figure 24) it is important that there exists a cost record for each county for which you have indicated that sea freight is possible (refer to 2.2.11).

For each country you should state the destination i.e. the port. The currency required here is the currency in which they charge container costs.

Destinations can be defined in two ways:

1. Enter all destinations and their associated costs first on the “destination cost for sea freight” form before starting with the “sea freight cost” form (refer to 2.2.3.2).
2. Click on the add destination button and add the information for the required destination.

Figure 24: Manage sea freight cost form

Origin handling and Sea freight:		Destination Handling:	
Country	USA	Cargo dues	2 per container
Destination	Richardsbay	Wharfage	2 per container
* Currency	USD	DTHC	2 per container
* Currency in which origin and sea freight costs are charged.		Railage	2 per container
Custom clearance	10 per container	NISCON fee	2 per container
Forwarding fee	20 per container	Haulage	2 per container
Ocean freight	20 per container	Service fee	2 per container
		Transport	2 per container
		Clearance	2 per container

All Destination handling costs are in Rand

Buttons: Close Form, Add another country, Add another destination or edit destination costs

2.2.3.2 Manage sea freight destinations and their costs

The destination refers to the port where the ship unloads in South Africa. All costs are charged in Rand.

Figure 25: Destination costs for sea freight form

Destination Costs for Sea Freight		Close Form
Destination ID	Durban	
Cargo dues	<input type="text"/>	1 Rand
Wharfage	<input type="text"/>	1 Rand
DTHC	<input type="text"/>	1 Rand
Railage	<input type="text"/>	1 Rand
NISCON fee	<input type="text"/>	1 Rand
Haulage	<input type="text"/>	1 Rand
Service fee	<input type="text"/>	1 Rand
Transport	<input type="text"/>	1 Rand
Clearance	<input type="text"/>	1 Rand

* All costs are charged in Rand

2.2.4 Air freight cost

It is important to note that not all costs are applicable to all countries. Simply fill in those that are. Air freight costs are charged either per kilogram, per HAWB (House Air Way Bill) or per package. Should a cost not appear on the form, simply add it to another cost that is charged against the same unit.

2.2.4.1 Manage air freight costs

When entering the air freight cost (Figure 26) it is important that there exists a cost record for each country for which you have indicated that air freight is possible (refer to 2.2.11).

For each country you should state the destination i.e. the airport. The currency required here is the currency in which costs are charged.

Destinations can be defined in two ways:

1. Enter all destinations and their associated costs first on the “destination cost for air freight” form before starting with the “air freight cost” form (refer to 2.2.4.2).
2. Click on the add destination button and add the information for the required destination.

Figure 26: Manage air freight cost form

2.2.4.2 Manage destination costs for air freight

The destination refers to the airport where the plane unloads in South Africa. All costs are charged in Rand.

Figure 27: Destination cost for airfreight form

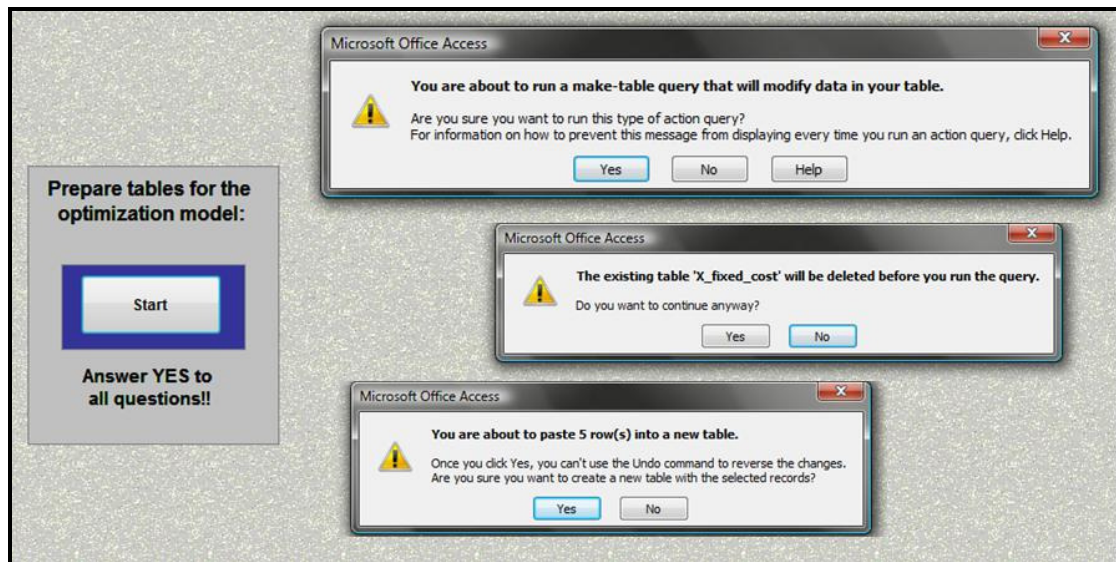
3. The optimization section

It is very important that the information section is complete and correct before the optimization model is run.

Step 1: Prepare the tables

To prepare the tables to be exported to LINGO press the start button. Answer “YES” to ALL questions. Make sure that a “NO” isn’t accidentally pressed.

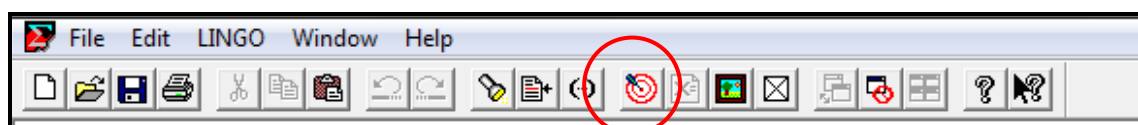
Figure 28: Run optimisation section



Step 2: Run the LINGO model

- Open LINGO. (You do not have to close the database)
- Open the model called “Nissan_decision_tool”.
- Press the Bulls eye icon on the toolbar appearing in figure 29.
- Close the LINGO status toolbar.
- Close all other windows and exit LINGO

Figure 29: LINGO toolbar



5. The reports section

Once the optimisation has been executed the results can be viewed in two different ways. The user can either go to the product information (refer to 2.1.1.1) form or can make use of the reports section (Figure 30).

Figure 30: Reports section



5.1 Product summary

The product summary states the chosen vendor and the chosen mode of transport for a specific product. The user needs to provide the material ID to specify which product. The summary also show the costs associated with buying and importing the specific product. This is the report that will be used most often.

The air freight cost per HAWB is not included as there is no means to determine the portion of the HAWB cost a specific part is responsible for.

Figure 31: Product summary report

<i>Product summary</i>		
<i>Material ID</i>	1001	
<i>Material description</i>	ProductA	
<i>Demand per week</i>	2	
<i>Vendor and shipment information:</i>		
<i>Vendor ID</i>	2002	
<i>Vendor</i>	VendorB	
<i>Country</i>	Japan	
<i>Sea shipment</i>	No	
<i>Air shipment</i>	No	
<i>Price</i>	3	
<i>Currency</i>	JPY	
<i>Exchange rate</i>	12	
<i>Costs in Rand:</i>		
		<i>Total per year</i>
<i>Sea freight cost per m³</i>	7.107558139535	0
<i>Air freight cost per kg</i>	200.3	0 *
<i>Purchase price</i>	38	3744
	<i>Total</i>	3744
* The air freight cost per HAWB is not included here.		

5.2 Products bought from vendor X

This report lists all products sourced from a specific vendor. The user needs to provide the vendor ID to specify which vendor. It also states which mode of transport is used to ship the product.

Figure 32: Products per vendor report

<i>All products bought from vendor: 2002</i>		VendorB	
<i>Material ID</i>	<i>Material description</i>	<i>Sea Shipment</i>	<i>Air Shipment</i>
1001	ProductA	No	Yes
1002	ProductB	Yes	No
1003	ProductC	Yes	No
1004	ProductD	Yes	No
1005	ProductE	No	Yes

5.3 Products shipped by air from vendor X

This report lists all products that are transported by air and sourced from a specific vendor. The user needs to provide the vendor ID to specify which vendor. It also states the total weight per year of each product.

Figure 33: Air shipped products per vendor report

<i>All products shipped by air from vendor: 2002</i>		VendorB
<i>Material ID</i>	<i>Material description</i>	<i>Weight per year (kg)</i>
1001	ProductA	520
1002	ProductB	936
1003	ProductC	728
1004	ProductD	85973333.333
1005	ProductE	5441.8

5.4 Products shipped by sea from vendor X

This report lists all products that are transported by sea and sourced from a specific vendor. The user needs to provide the vendor ID to specify which vendor. It also states the total volume per year of each product.

Figure 34: Sea shipped products per vendor report

<i>All products shipped by sea from vendor:</i> 2001		VendorA
<i>Material ID</i>	<i>Material description</i>	<i>Volume per year (m³)</i>
1002	ProductB	0.000269568
1003	ProductC	0.000228488
1004	ProductD	515840
1005	ProductE	0.000014196

5.5 All products shipped by air

It is simply a list of all products that are shipped per air, irrespective of the country or vendor being sourced from.

Figure 35: Air shipped products report

<i>Products shipped by air:</i>		
<i>Material ID</i>	<i>Material description</i>	<i>Weight per year (Kg)</i>
1002	ProductB	936
1003	ProductC	728
1005	ProductE	5441.8

5.6 All products shipped by sea

It is simply a list of all products that are shipped per air, irrespective of the country or vendor being sourced from.

Figure 36: Sea shipped products report

<i>Products shipped by sea:</i>		
<i>Material ID</i>	<i>Material description</i>	<i>Volume per year (m³)</i>
1002	ProductB	0.000269568
1003	ProductC	0.000228488
1004	ProductD	515840
1005	ProductE	0.000014196

6. Conclusion

Most data will remain unchanged. The only data that should change every time the tool is run is the product and vendor per product information.

This tool is only as accurate as the data it is presented with. It is therefore critical that all data be complete and accurate.

Appendix D

Configuration Manual for Access

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1. Introduction

The data has been modelled according to the detail design in chapter 9 of the main document.

The following assumptions have been made regarding the relationships between various entities:

- Each Vendor can supply zero or more products
- Each product is produced by zero or more vendors
- Vendors are situated in only one country
- Each country is home to zero or more vendors
- Each country has one set of freight cost for air and sea freight
- Nissan parts arrive in SA in only one location with a specific mode of transport but to make the tool flexible provision has been made for multiple destinations.
- Each part will only be bought from one vendor
- Essentially a solution should be linked to only one product and a product should be linked to only one solution but this relationship had to be defined as a “one to many” relationship due to the manner in which LINGO exports data. The attribute chosen indicates which part is assigned to which vendor.

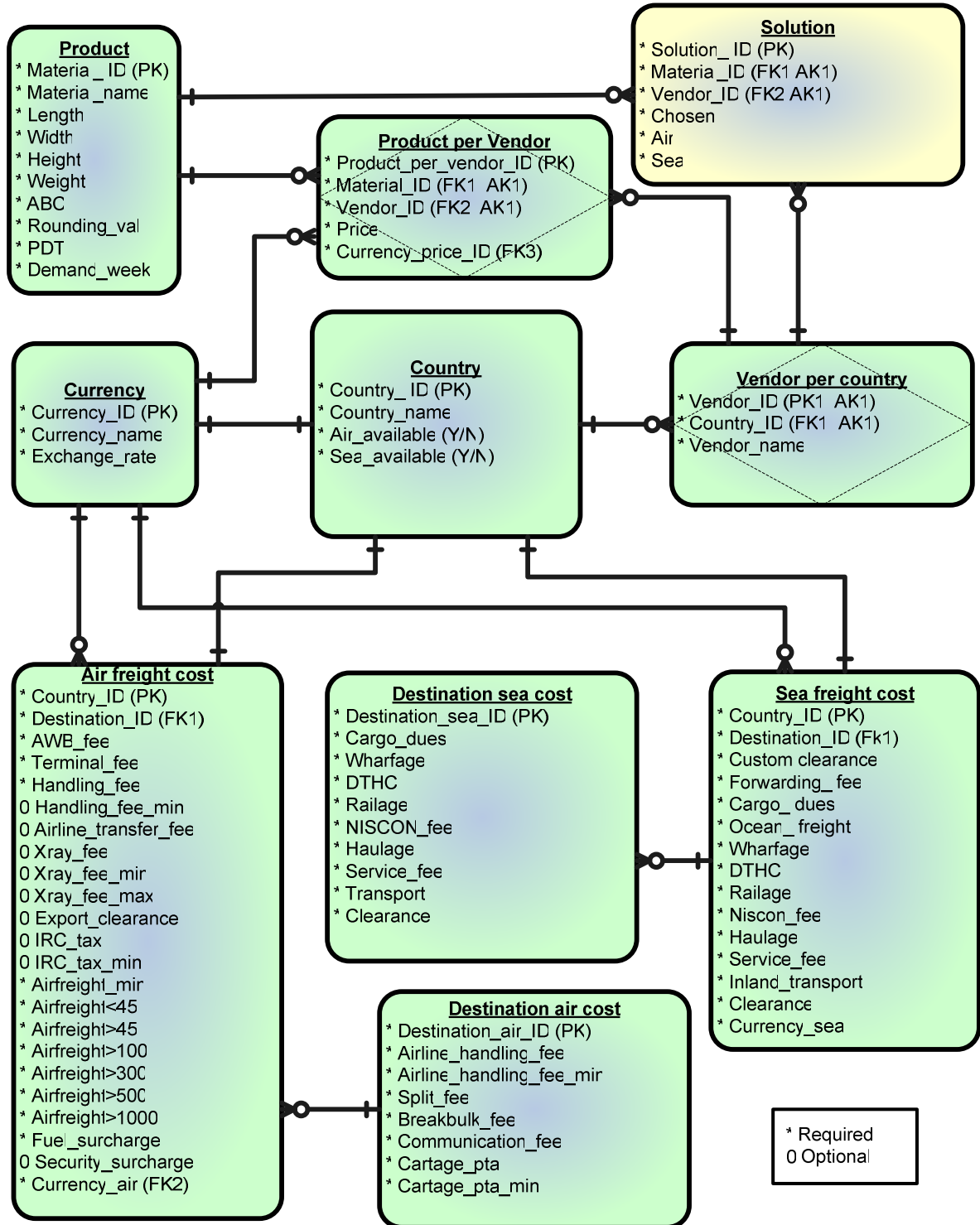
The main data tables in the database were constructed according to the entity relationship diagram in figure 1.

Notes:

- Some information included in the database will not be used during this project. It is however included to allow for future upgrading of the “decision making tool”.

This manual will describe the purpose and design of each table, query, form and report.

Figure 1: Entity Relationship Diagram



2. Tables

2.1. Main data tables

2.1.1 Product

The “Product” data table contains all information regarding a specific part. The part number is the primary key as it is unique to each part. All attributes of the data type “Number” has a field size “Double”.

Figure 2: "Product" table design

	Field Name	Data Type
PK	Material_ID	Text
	Material_description	Text
	Lenght	Number
	Width	Number
	Height	Number
	Weight	Number
	ABC	Text
	Rounding_val	Number
	PDT	Number
	Demand_week	Number

2.1.2 Country

The “Country” table contains information regarding the countries in which vendors are located and their associated transport availability. A country ID is automatically generated for convenience sake.

Figure 3: "Country" table design

	Field Name	Data Type
PK	Country_ID	AutoNumber
	Country_name	Text
	Air_available	Yes/No
	Sea_available	Yes/No

2.1.3 Currency

The "Currency" table contains information regarding the exchange rate of each currency to rand. The Currency ID (primary key) is a 3 letter abbreviation of the currency name; for example US solar is USD.

Figure 4: "Currency" table design

	Field Name	Data Type
🔑	Currency_ID	Text
	Currency_name	Text
	Exchange_rate	Number

2.1.4 Vendor per country

The "Vendor_per_country" table is a list of all suppliers and the country in which they are located. The Vendor ID is set as the primary key as each vendor should only appear once in this table.

Figure 5: "Vendor per product" table design

	Field Name	Data Type
🔑	Vendor_ID	Text
	Vendor_name	Text
	Country_ID	Number

2.1.5 Product per vendor

The "Product_per_vendor" table is used to indicate which vendor supplies which products and at what price. The "Currency_price_ID" refers to the currency in which the price is charged. The "Material_ID" and "Vendor_ID" was set as an alternative key as the combination may only appear once.

Figure 6: "Product per vendor" table design

	Field Name	Data Type
🔑	Product_per_vendor_ID	AutoNumber
	Material_ID	Text
	Vendor_ID	Text
	Price	Number
	Currency_price_ID	Text

2.1.6 Solution

The “solution” table indicates which vendor is eventually chosen to supply a product and which mode of transport is used to import the product. It is essential that the solutions table contain all possible combinations of products and vendors prior to being exported to LINGO. This will be explained in greater detail in chapter 3.2.7

Figure 7: "Solution" table design

	Field Name	Data Type
🔍	Solution_ID	AutoNumber
	Material_ID	Text
	Vendor_ID	Text
	Chosen	Number
	Sea	Number
	Air	Number

2.1.7 Air freight Cost

The “Air_freight_cost” table contains all possible cost associated with air freight from a specific country except for the costs incurred once packages arrive in South Africa. The primary key here is the same as for the “Country” data table. This ensures a one-to-one relationship between entities.

Figure 8: "Air freight cost" table design

	Field Name	Data Type
🔍	Country_ID	Number
	AWB_fee	Number
	Terminal_fee	Number
	Handling_fee	Number
	Handling_fee_min	Number
	Airline_transfer_fee	Number
	Xray_fee	Number
	Xray_fee_min	Number
	Xray_fee_max	Number
	Export_clearance	Number
	IRC_tax	Number
	IRC_tax_min	Number
	Airfreight_min	Number
	Airfreight<45	Number
	Airfreight>45	Number
	Airfreight>100	Number
	Airfreight>300	Number
	Airfreight>500	Number
	Airfreigh>1000	Number
	Fuel_surcharge	Number
	Security_surcharge	Number
	Destination_air_ID	Text
	Currency_air_ID	Text

2.1.8 Destination cost air

The "Destination_cost_air" table contains all possible cost associated with air freight from a specific country once packages arrive in South Africa at a specific location. The location name is the primary key.

Figure 9: "Destination cost air" table design

	Field Name	Data Type
🔑	Destination_air_ID	Text
	Airline_handling_fee	Number
	Airline_handlingfee_min	Number
	Split_fee	Number
	Breakbulk_fee	Number
	Communication_fee	Number
	Clearing_documentation	Number
	Cartage_pta	Number
	Cartage_pta_min	Number
	Agency_fee	Number
	Agency_fee_min	Number

2.1.9 Sea freight Cost

The "Sea_freight_cost" table contains all possible cost associated with sea freight from a specific country except for the costs incurred once packages arrive in South Africa. The primary key here is the same as for the "Country" data table. This ensures a one-to-one relationship between entities.

Figure 10: "Sea freight cost" table design

	Field Name	Data Type
🔑	Country_ID	Number
	Custom_clearance	Number
	Forwarding_fee	Number
	Ocean_freight	Number
	Destination_sea_ID	Text
	Currency_Sea_ID	Text

2.1.10 Destination cost sea

The "Destination_cost_sea" table contains all possible cost associated with sea freight from a specific country once packages arrive in South Africa at a specific location. The location name is the primary key.

Figure 11: "Destination cost sea" table design

	Field Name	Data Type
🔑	Destination sea ID	Text
	Cargo_dues	Number
	Wharfage	Number
	DTHC	Number
	Railage	Number
	NISCON_fee	Number
	Haulage	Number
	Service_fee	Number
	Transport	Number
	Clearance	Number

2.2 Supporting data tables

These tables are used to import data from external sources. Data is not imported directly into the appropriate tables because the imported data needs to be filtered first. The field names in these tables correspond to the table headings in the source files. How the data is imported is explained in the user manual (Appendix C) in chapter 2.1.

2.2.1 Import product

The "Import_product" table contains all product information imported from an Excel file created by the user. Refer to the Appendix C the user manual, chapter 2.1.1.

Figure 12: "Import product" table design

	Field Name	Data Type
🔑	Material	Text
	Material Description	Text
	All_max(mm)	Text
	All_mid(mm)	Text
	All_min(mm)	Text
	All_weight(g)	Number
	ABC	Text
	Rounding val	Number
	PDT	Number
	Avg Demand	Number

2.2.2 Import vendor

The "Import_vendor" table contains information regarding the products supplied by each vendor imported from a Text file created by the user. Refer to the Appendix C the user manual, chapter 2.1.2.

Figure 13: "Import vendor" table design

	Field Name	Data Type
▶	Material	Text
	Vendor	Text
	Net price	Number
	Crcy	Text

2.3 Exported data tables

These tables are prepared using a series of queries that will be discussed in chapter 3. The design of these queries is critical to the successful use of LINGO and its @ODBC function. The @ODBC function is used to import and export data from and to Access within a LINGO model. All data tables that are used to export data is marked with an X.

These data tables represent the variables that have been defined in the detail design of the optimization model as defined in chapter 11 of the main document.

2.3.1 X Product

The "X_product" table contains a list of all products and their associated volume, final weight, ABC weight and demand. The volume, final weight and ABC weight have all been calculated using a series of queries as explained in chapter 3.2.1.

Figure 14: "X product" table design

	Field Name	Data Type
▶	Material_ID	Text
	Volume	Number
	Weight_final	Number
	ABC_weight	Number
	Demand	Number

2.3.2 X price vendor

The "X_price_vendor" table contains all possible combinations of products and vendors even if a specific vendor does not supply that particular product. If a vendor supplies the particular product the product price in rand is stored in the table. If the vendor does not supply the product the value 1000 000 appears in the price field. This is a linear programming principle that ensures that, that particular vendor will not be assigned to that product as the price is ridiculously high. This table has been constructed using a series of queries. Refer to chapter 3.2.2 and 3.2.3.

Figure 15: "X price vendor" design

	Field Name	Data Type
▶	Material_ID	Text
	Vendor_ID	Text
	Price_R	Number

2.3.3 X fixed cost

The "X_fixed_cost" table contains the total cost per HAWB per country. This table has been constructed using a series of queries. Refer to chapter 3.2.6

Figure 16: "X fixed cost" table design

	Field Name	Data Type
▶	Country_name	Text
	Cost_HAWB	Number

2.3.4 X variable cost

The "X_variable_cost" table contains the total variable transport cost per vendor. It is used to indicate whether air and/or sea transport is available from that specific vendor and what the associated costs are. Air shipments are charged per kilogram while sea shipments are charged per cubic metre. This table has been constructed using a series of queries. Refer to chapter 3.2.5

Figure 17: "X variable cost" table design

	Field Name	Data Type
▶	Vendor_ID	Text
	Air_possible	Number
	Sea_possible	Number
	Cost_volume	Number
	Cost_kg	Number

2.3.5 X vendor country

The "X_vendor_country" table contains all possible combinations of vendors and countries. Should a vendor be located in a specific country the value of "c" will be one, if not it will be zero. This table has been constructed using a series of queries. Refer to chapter 3.2.4.

Figure 18: "X vendor country" table design

	Field Name	Data Type
▶	Vendor_ID	Text
	Country_name	Text
	c	Number

3. Queries

3.1 Calculation queries

These queries are used to build the queries that are used to create the tables containing the data that needs to be exported.

3.1.1 Product calculations

The “Product_calculation_qry” only uses the table product.

Figure 19: "Product calculation" query design

Field:	Material_ID	Volume:	Volumetric_weight:	Weight_final:	ABC	ABC_weight:	Demand_week	Demand:
Table:	Product				Product		Product	
Sort:								
Show:	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Criteria:								
or:								

The “Product_calculation_qry” performs the following calculations:

- **The volume**

The volume is calculated by multiplying the length, width and height of the part and converting from millimetre to metre.

$$Volume: ([Product]![Lenght]*[Product]![Width]*[Product]![Height])/(10^9)$$

- **The volumetric weight**

The volumetric weight is calculated by finding the volume of the part in cubic centimetres and dividing it by 6000.

Volumetric_weight:

$$((([Product]![Lenght]*[Product]![Width]*[Product]![Height])/(10^3))/6000)$$

- **The final weight**

Determines which is bigger, the actual or the volumetric weight and assigns that value to the final weight that will be used to calculate the cost per kg.

*Weight_final: If([Product]![Weight]/1000)
>[Volumetric_weight],[Product]![Weight]/1000,[Volumetric_weight])*

- **The ABC weight**

The function can be included when the tool is improved.

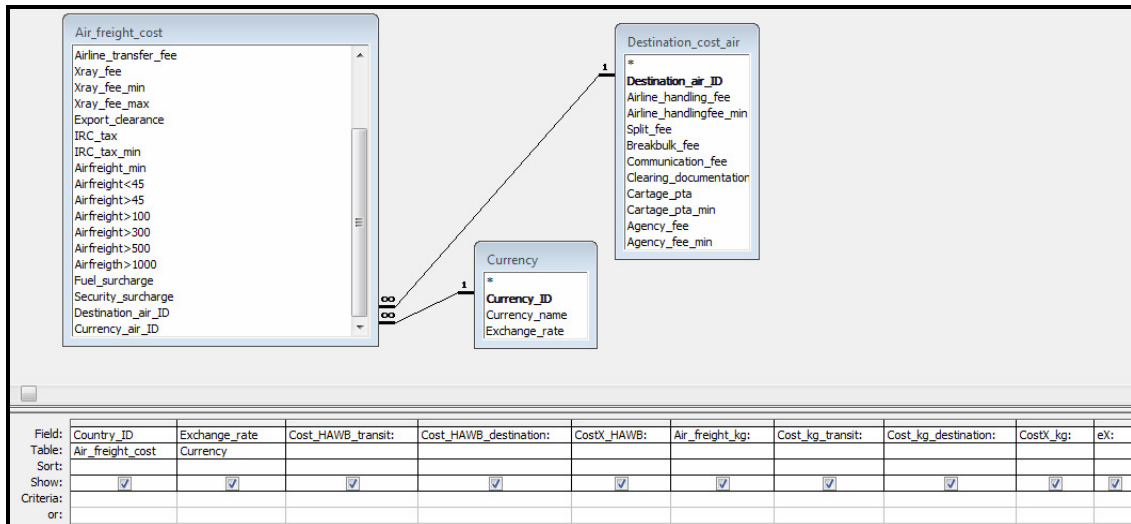
- **The demand per year**

*Demand: [Product]![Demand_week]*52*

3.1.2 Air freight cost

The “Air_freight_cost_qry” is used to determine the total variable and fixed air freight costs for each country. Costs are calculated and converted to Rand using the exchange rate.

Figure 20: "Air freight cost" query design



The “Air_freight_cost_qry” performs the following calculations

- **The total cost per HAWB for transport to the airport in SA**

All cost in the “Air_freight_cost” table that are charged per HAWB is added together and converted to Rand.

Cost_HAWB_transit:

$([Air_freight_cost]![Terminal_fee]+[Air_freight_cost]![Export_clearance])^*$
 $[Currency]![Exchange_rate]$

- **The total cost per HAWB for transport from the airport to the warehouse**
All cost in the “Destination_cost_air” table that are charged per HAWB is added together. These costs are already in Rand.

Cost_HAWB_destination: $([Destination_cost_air]![Breakbulk_fee]+$
 $[Destination_cost_air]![Communication_fee])$

- **The overall total cost per HAWB**

CostX_HAWB: $[Cost_HAWB_transit]+[Cost_HAWB_destination]$

- **The average airfreight cost per kilogram**

The actual airfreight cost contains price breaks. As the package becomes heavier the price per kg starts to decrease. The average price per kilogram is calculated to reduce the complexity of the optimization model.

Air_freight_kg:

$([Air_freight_cost]![Airfreight<45]+[Air_freight_cost]![Airfreight>45]+[Air_freight$
 $_cost]![Airfreight>100]+[Air_freight_cost]![Airfreight>300]+[Air_freight_cost]![Ai$
 $rfreight>500]+[Air_freight_cost]![Airfreigh>1000])/6$

- **The total cost per kilogram for transport to the airport in SA**

All cost in the “Air_freight_cost” table that are charged per kilogram is added together and converted to Rand.

Cost_kg_transit:

$([Air_freight_cost]![AWB_fee]+[Air_freight_cost]![Handling_fee]+$
 $[Air_freight_cost]![Airline_transfer_fee]+[Air_freight_cost]![Xray_fee]+$
 $[Air_freight_cost]![IRC_tax]+[Air_freight_cost]![Fuel_surcharge]+$
 $[Air_freight_cost]![Security_surcharge]+$
 $[air_freight_kg])^*[Currency]![Exchange_rate]$

- **The total cost per kilogram for transport from the airport to the warehouse**

All cost in the “Destination_cost_air” table that are charged per HAWB is added together. These costs are already in Rand.

$Cost_kg_destination: ([Destination_cost_air]![Airline_handling_fee]+ [Destination_cost_air]![Cartage_pta])$

- **The overall total cost per kilogram**

$CostX_kg: [Cost_kg_transit]+[Cost_kg_destination]$

- **The split fee per package cost conversion to cost per kilogram.**

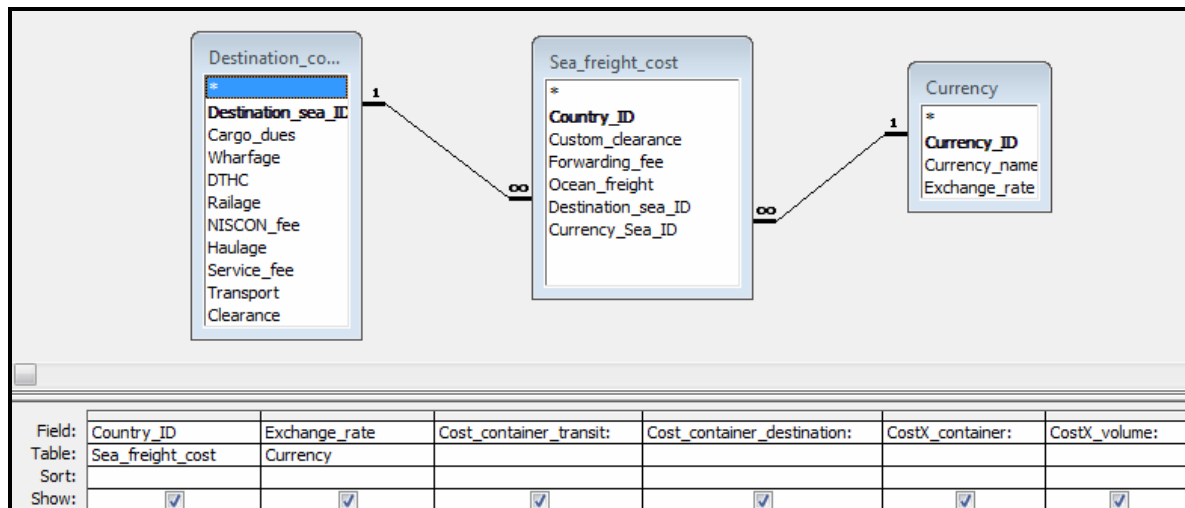
The split fee is charged per package. A conversion factor has been calculated to convert the split fee to a kost per kilogram. Refer to the main document chapter 7.1.

$eX: ([Destination_cost_air]![Split_fee]*0.0134)$

3.1.3 Sea freight cost

The “Sea_freight_cost_qry” is used to determine the total variable sea freight costs for each country. Costs are calculated and converted to Rand using the exchange rate. Costs are charged per container. The cost per container needs to be converted to costs per volume.

Figure 21: "Sea freight cost" query design



The “Air_freight_cost_qry” performs the following calculations

- **The total cost per container for transport to the harbour in SA**

All cost in the “Air_freight_cost” table that are charged per HAWB is added together and converted to Rand.

Cost_container_transit:

$$([Sea_freight_cost]![Custom_clearance]+[Sea_freight_cost]![Forwarding_fee]+[Sea_freight_cost]![Ocean_freight])*[Currency]![Exchange_rate]$$

- **The total cost per container for transport from the harbour to the warehouse**

All cost in the “Destination_cost_air” table that are charged per HAWB is added together. These costs are already in Rand.

Cost_container_destination:

$$([Destination_cost_sea]![Cargo_dues]+[Destination_cost_sea]![Wharfage]+[Destination_cost_sea]![DTHC]+[Destination_cost_sea]![Railage]+[Destination_cost_sea]![NISCON_fee]+[Destination_cost_sea]![Haulage]+[Destination_cost_sea]![Service_fee]+[Destination_cost_sea]![Transport]+[Destination_cost_sea]![Clearance])$$

- **The overall total cost per container**

CostX_container: [Cost_container_transit]+[Cost_container_destination]

- **The conversion from cost per container to cost per volume**

It is assumed that 40Ft high containers will be used that have a volume of 86 cubic metres. It is also assumed that only 80% of a containers volume is utilized. Refer to the main document chapter 7.2.

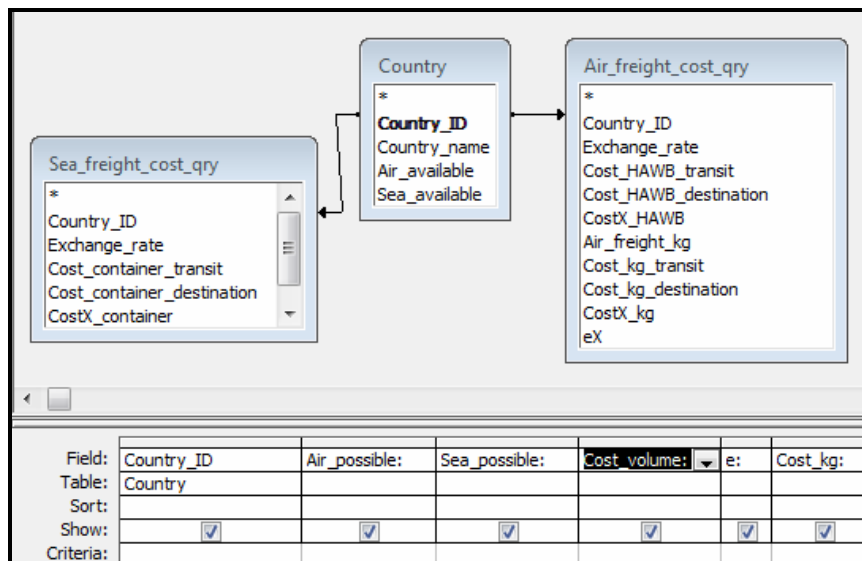
CostX_volume: ([CostX_container]/86)/0.8

3.1.4 Variable country cost

The “Variable_country_cost” query assigns a cost per kilogram and cost per volume to each country. If a particular country does not have air transport the value zero will be assigned to its cost per kilogram. If a particular country does not have sea transport the value zero will be assigned to its cost per volume.

The joins between the “Country” table and the air and sea freight cost queries had to be changed to include all countries even if air or sea freight costs is not available.

Figure 22: "Variable country cost" query design



The "Air_freight_cost_qry" performs the following calculations

- **Indicates whether air freight is available**

If air transport is available the value of 1 is assigned to the attribute "Air_possible", if not a 0 is assigned.

Air_possible: IIf([Air_available]=Yes,1,0)

- **Indicates whether sea freight is available**

If sea transport is available the value of 1 is assigned to the attribute "Sea_possible", if not a 0 is assigned.

Sea_possible: IIf([Sea_available]=Yes,1,0)

- **Assigns a zero value to costs if they are not available for a specific country**

This may seem like an unnecessary task but it is essential for LINGO's operation that zero values be assigned here.

Cost_volume: IIf([CostX_volume]>0,[CostX_volume],0)

e: IIf([eX]>0,[eX],0)

- **Adds the split fee cost that has been converted to the cost per kilogram**

Cost_kg: IIf([CostX_kg]>0,[CostX_kg]+[e],0)

3.2 Create exported data tables queries

3.2.1 Product info

The “Product_info_qry” is a make table query that creates the table “X_product”. The table “X_product” (refer to 2.3.2) contains all the necessary information required by the LINGO model for each product.

All information is based on the “Product_calculation_qry” in chapter 3.1.1.

Figure 23: "Product info" make table query design

Field:	Material_ID	Volume	Weight_final	ABC_weight	Demand
Table:	Product_calculation	Product_calculation	Product_calculation	Product_calculation	Product_calculation
Sort:					
Show:	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Criteria:					

An example of the output appears in figure 24.

Figure 24: "X product" table sample

	Material_ID	Volume	Weight_final	ABC_weight	Demand
▶	1001	0.000005	0.03	1	10400
	1002	0.1725	28.75	0	52
	1003	1.0725	600	0	10.4

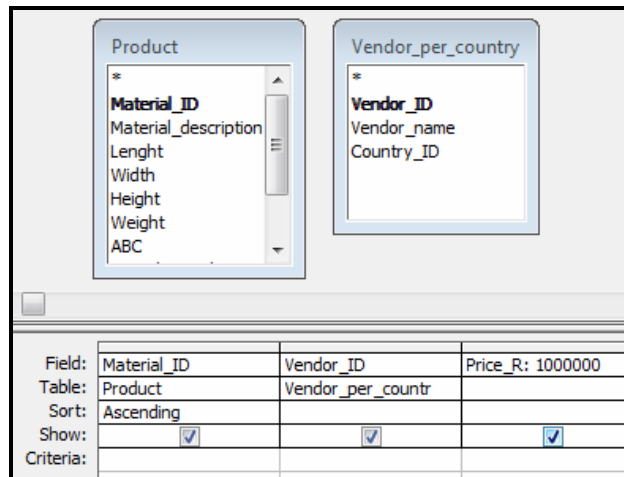
3.2.2 Product vendor possibilities

The “Product_vendor_possibilities” is a make table query that creates the table “X_price_vendor”. The table contains all possibilities of products and vendors even if

a vendor does not supply the specific product. It also assigns a large value to the price of each possibility. Refer to chapter 2.3.2.

The relationship between the two tables has been removed which makes it possible to list all the combinations.

Figure 25: "Product vendor possibilities" make table query

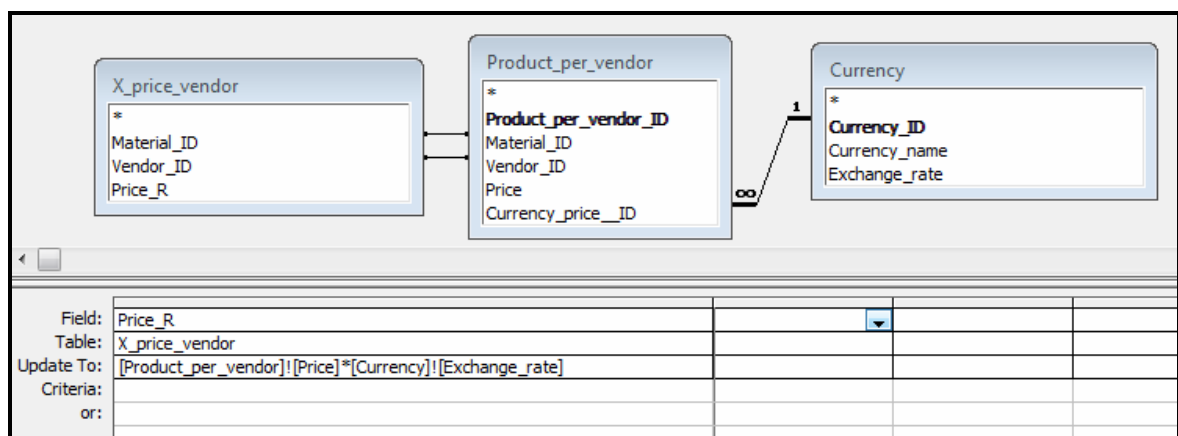


The price for combinations that do exist will be updated in the next query.

3.2.3 Price vendor query

The "Price_vendor_qry" is an update query that updates the price of products to the actual value if the combination of product and vendor actually exists.

Figure 26: "Price vendor" update query design



An example of table "X_price_vendor" appears in figure 27. Product 1001 is actually supplied by vendors 2002 and 2001 but not by vendor 2003.

Figure 27: "X price vendor" table sample

X_price_vendor : Table		
Material_ID	Vendor_ID	Price_R
1001	2003	1000000
1001	2002	24
1001	2001	24
1002	2003	4000
1002	2002	1000000
1002	2001	2400
1003	2003	192000
1003	2002	1000000
1003	2001	80000

3.2.4 Vendor per country

The "Vendor_per_country" is a make table query that creates the table "X_vendor_country" (refer to 2.3.5). It lists all possible combinations of countries and vendors. Only the combinations that exist is assigned a "c" value of one else it is assigned a value of zero.

Figure 28: "Vendor per country" make table query design

Field:	Vendor_ID	Country_name	c: IIf([Vendor_per_country].[Country_ID]=[Country].[Country_ID],1,0)
Table:	Vendor_per_countr	Country	
Sort:	Ascending	Ascending	
Show:	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Criteria:			

An example of table "X_vendor_country" appears in figure 29. Vendor 2001 is located in the USA therefore the combination is assigned a 1 and the rest of the combinations including vendor 2001 is assigned a 0.

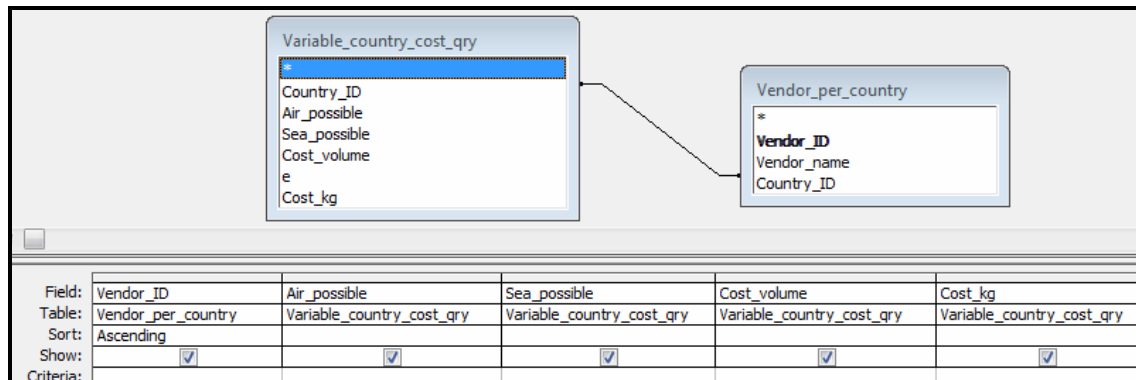
Figure 29: "X vendor country" table sample

X_vendor_country : Table			
	Vendor_ID	Country_name	c
	2001	Europe	0
	2001	Japan	0
	2001	USA	1
	2002	Europe	0
	2002	Japan	1
	2002	USA	0
	2003	Europe	1
	2003	Japan	0
	2003	USA	0

3.2.5 Vendor transport cost

The "Vendor_transport_cost" is a make table query that creates the table "X_variable_cost" (refer to 2.3.4). All countries have been assigned a variable cost using the "Variable_country_cost" query. Each vendor is located in a specific country. The "Vendor_transport_cost" query assigns a variable cost to each vendor. It also determines which mode of transport is available from a specific vendor.

Figure 30: "Vendor transport cost" make table query design



An example of the output appears in figure 31.

Figure 31: "X variable cost" table sample

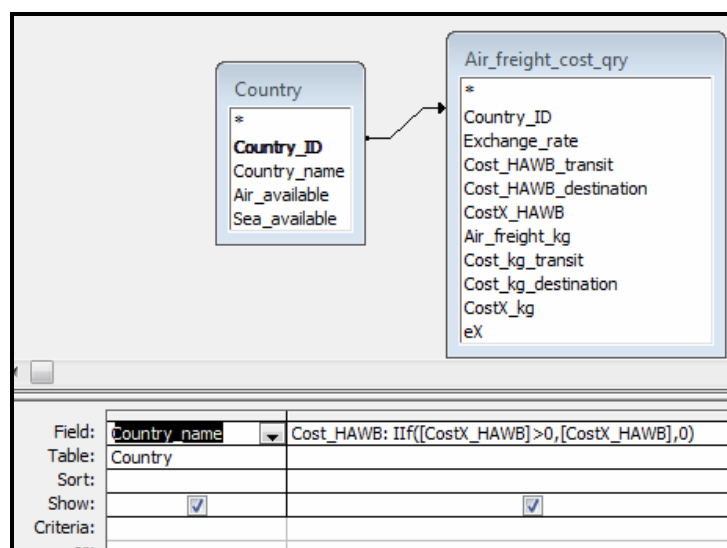
X_variable_cost : Table					
	Vendor_ID	Air_possible	Sea_possible	Cost_volume	Cost_kg
	2001	1	1	6.0988372093	72.3
	2002	0	1	7.1075581395	200.3
	2003	1	1	21.191860465	384

3.2.6 Fixed country cost

The “Fixed_country_cost” is a make table query that creates the table “X_fixed_cost” (refer to 2.3.3). It assigns a cost per HAWB to each country. If a particular country does not have air transport the value zero will be assigned to its cost per HAWB.

The join between the “Country” table and “Air_freight_cost_qry” was changed to one which includes all records from “Country”.

Figure 32: "Fixed_country_cost" query design



An example of the output appears in figure 33.

Figure 33: "X fixed cost" table sample

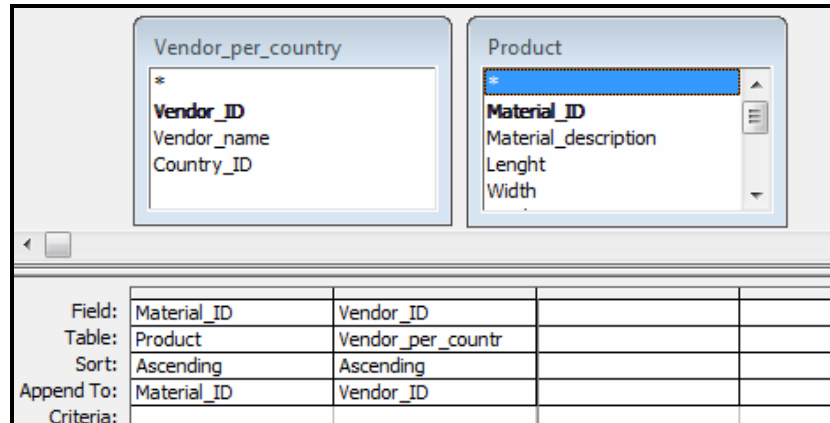
X_fixed_cost : Table		
Country_name	Cost_HAWB	
USA		25
Japan		57
Europe		96

3.2.7 Solutions options

The “Solutions_options” is an append table query that adds record to the table “Solution” (refer to 2.1.6). All possibilities of products and vendors are listed. Only “Material_ID” and “Vendor_ID” are added to the table. The other attributes are

assigned a zero. This ensures that data for the correct combinations are exported from LINGO into Access.

Figure 34: "Solution options" append query design



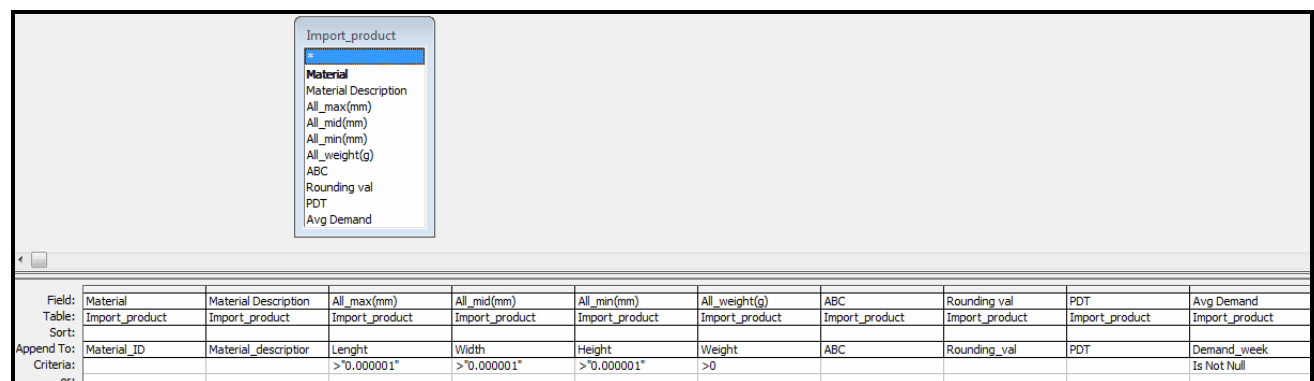
All data is deleted in the "solutions" table before this query is run. Refer to 4.2

3.3 Append imported data queries

3.3.1 Append imported products

The "Append_imported_products" query acts as a filter for the imported data. All data in table "Import_product" (refer to 2.2.1) that is not null is appended to the table "Product" (refer to 2.1.1).

Figure 35: "Append imported products" query design

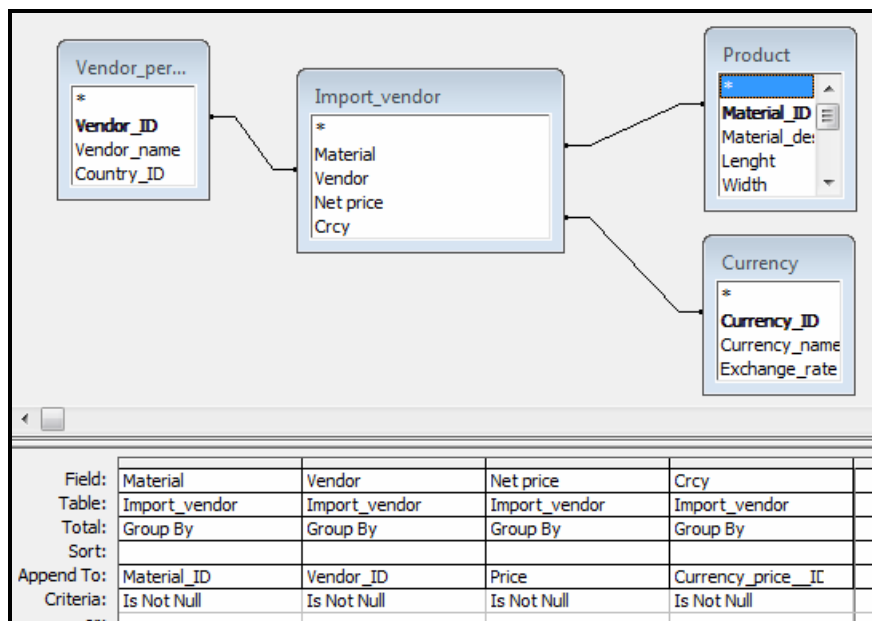


3.3.2 Append imported vendor costs

The “Append_imported_vendor_cost” query acts as a filter for the imported data. All data in table “Import_vendor” (refer to 2.2.2) that is not null is appended to the table “Product_per_vendor” (refer to 2.1.4).

Only records, for which there exists a “Material_ID”, “Vendor_ID” and “Currency_ID”, will be added to the “Product_per_vendor” table.

Figure 36: "Append imported vendor costs" query design



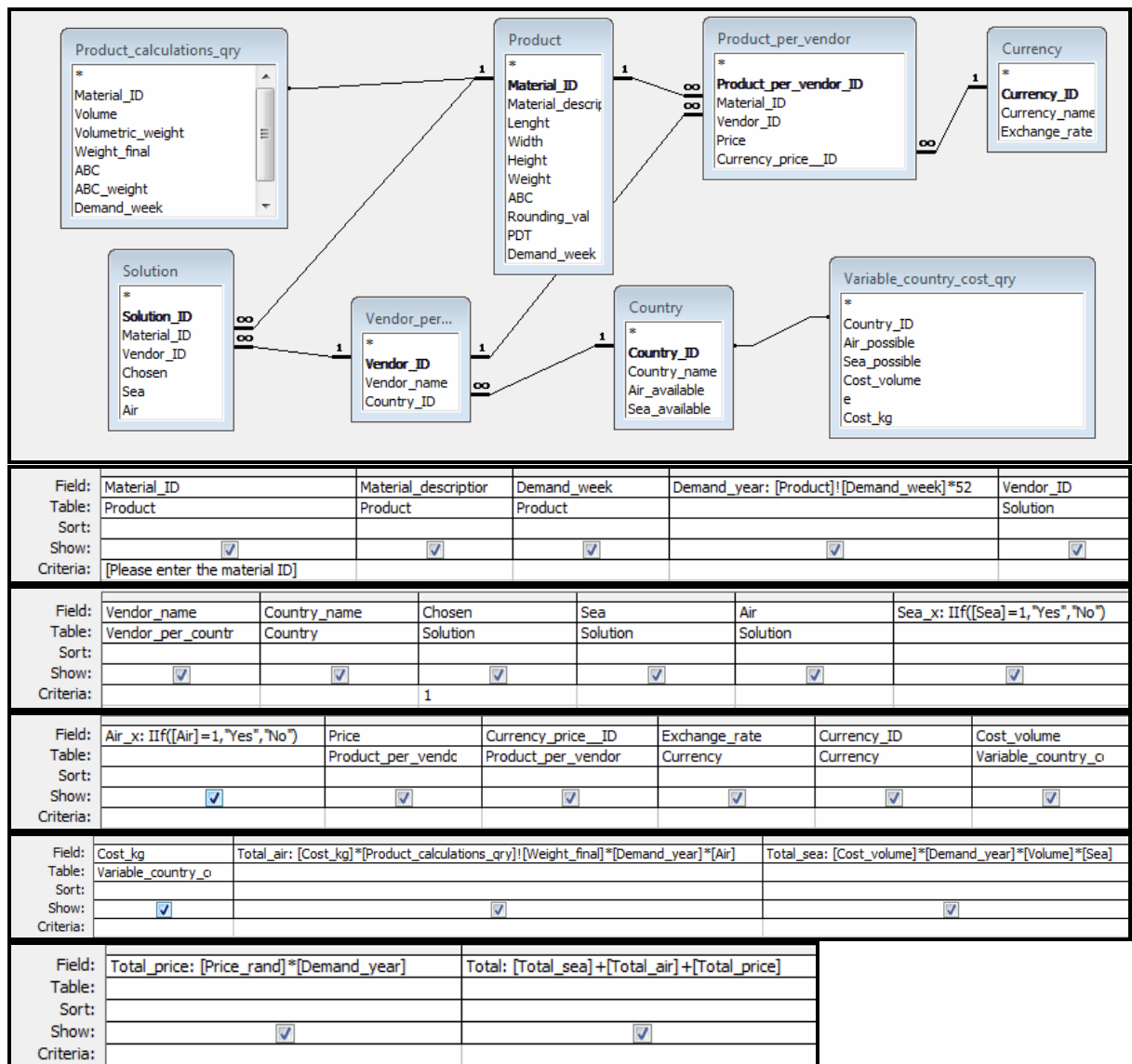
3.4 Report Queries

The following queries were built to create reports. All reports were based on one of the following queries.

3.4.1 Product summary

The “Product_summary” query provides an overall summary of one specific product. The user is prompted to enter the “Material_ID”. This query is used to create the “Product summary” report (refer to 5.1).

Figure 37: "Product summary" query design



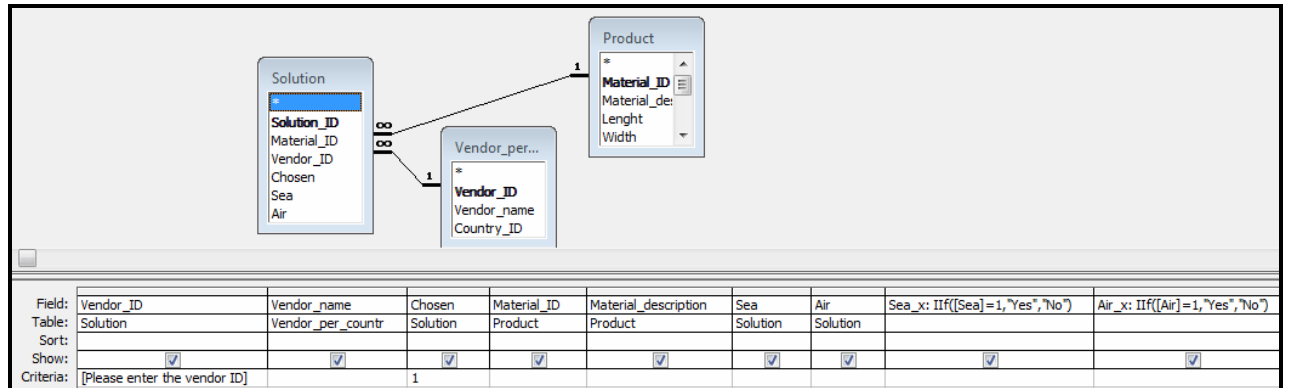
It indicates the product demand along with its chosen vendor and chosen mode of transport. It also includes basic cost calculations like the total unit cost and total transport cost (Per volume or per kilogram). The cost per HAWB is not included here as it is impossible to determine which fraction of the cost per HAWB a part is actually responsible for.

3.4.2 Product bought from vendor

The "Product_bought_from_vendor" query is used to create the "Product_bought_from_vendor" report (refer to 5.2).

The user is prompted to enter a "Vendor_ID". All products that should be bought from that supplier are displayed. It also shows which mode of transport should be used to import the product.

Figure 38: "Product_bought_from_vendor" query design



3.4.3 Product shipped air vendor

The "Product_shipped_air_vendor" query is used to create the "Product_shipped_air_vendor" report (refer to 5.3).

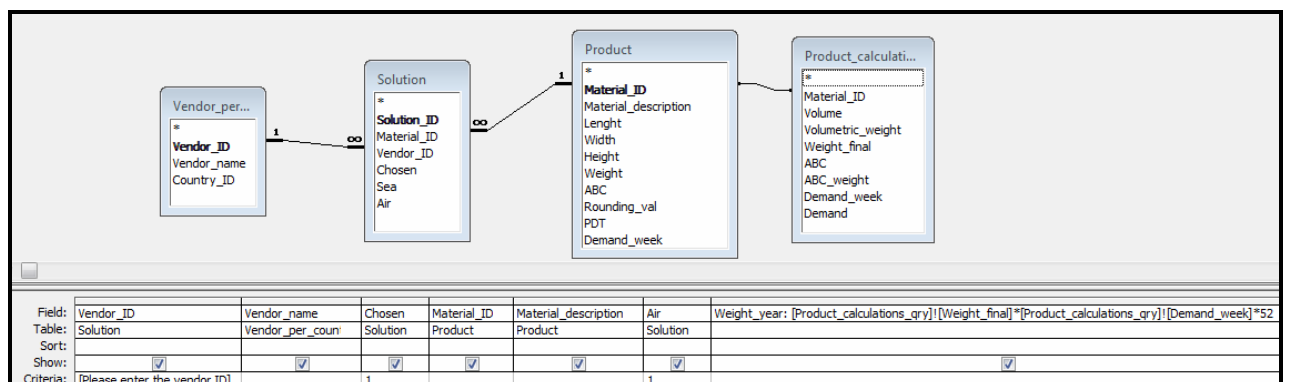
The user is prompted to enter a "Vendor_ID". All products that should be bought from that supplier and is shipped by air are displayed. It also calculates the total weight per year that will be shipped. This weight calculation involves the final weight i.e. it is a combination of the actual and volumetric weights.

The total weight per year is calculated as follows:

$$Weight_year: [Product_calculations_qry]![Weight_final]*$$

$$[Product_calculations_qry]![Demand_week]*52$$

Figure 39: "Product_shipped_air_vendor" query design



3.4.4 Products shipped sea vendor

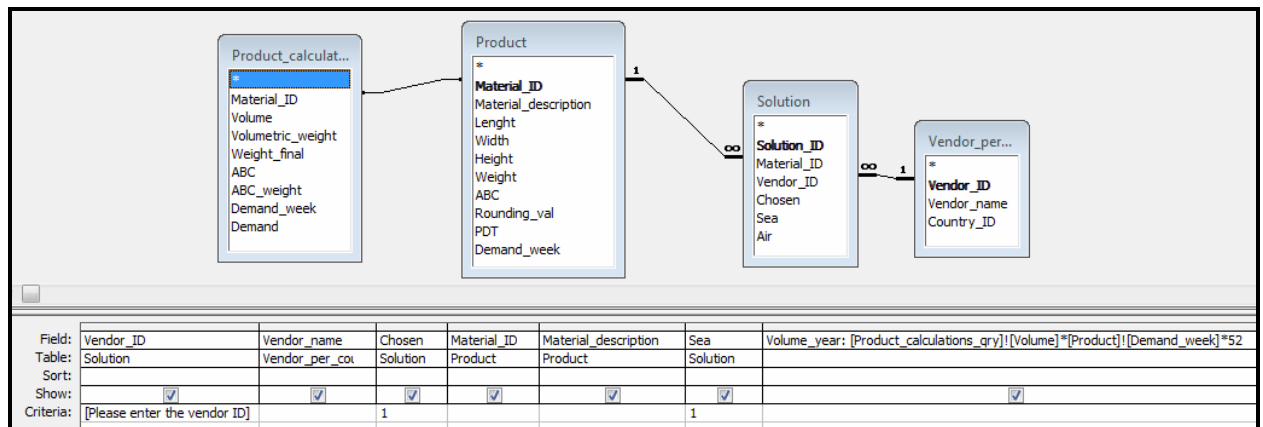
The “Product_shipped_sea_vendor” query is used to create the “Product_shipped_sea_vendor” report (refer to 5.4).

The user is prompted to enter a “Vendor_ID”. All products that should be bought from that supplier and is shipped by sea are displayed. It also calculates the total volume per year that will be shipped.

The total weight per year is calculated as follows:

$$Volume_year: [Product_calculations_qry]![Volume]*[Product]![Demand_week]*52$$

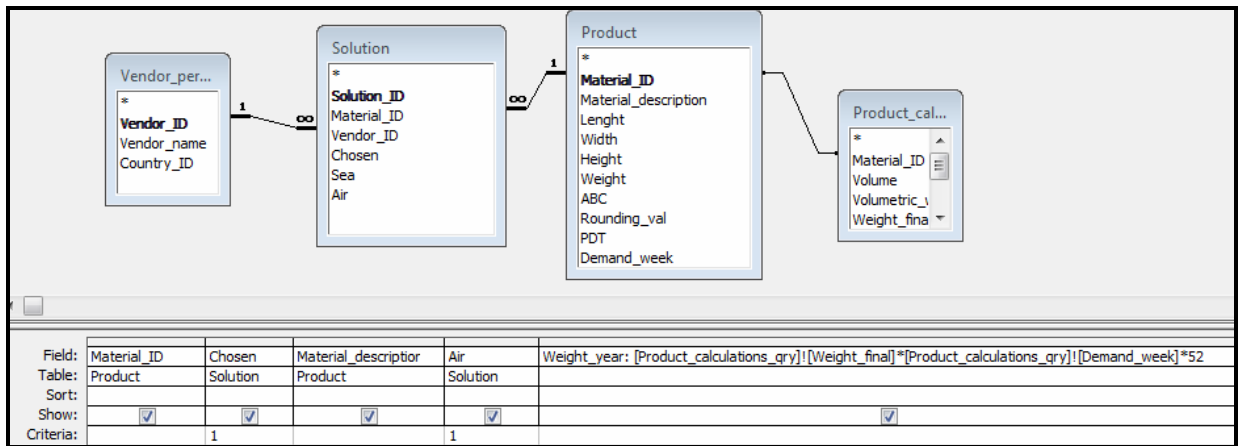
Figure 40: "Product_shipped_sea_vendor" query design



3.4.5 Products shipped air

The “Product_shipped_air” query is used to create the “Product_shipped_by_air” report (refer to 5.5). This query lists all products that will be shipped by air regardless of the vendor or country being shipped from. The total weight for each product is also calculated.

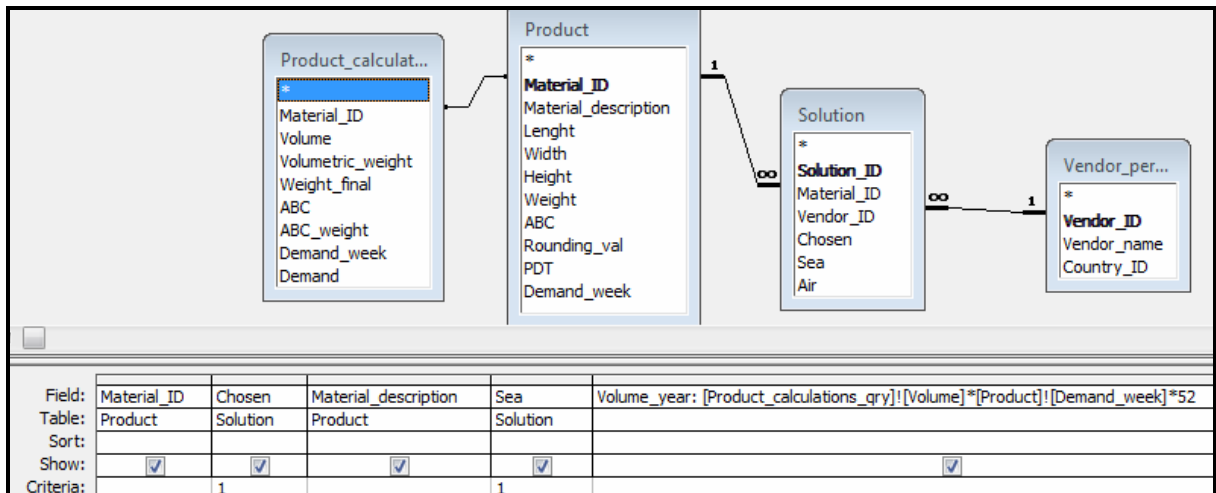
Figure 41: "Product_shipped_air" query design



3.4.6 Products shipped sea

The "Product_shipped_sea" query is used to create the "Product_shipped_by_sea" report (refer to 5.6). This query lists all products that will be shipped by sea regardless of the vendor or country being shipped from. The total volume for each product is also calculated.

Figure 42: "Product_shipped_sea" query design



4. Forms

4.1 Basic forms

Most forms are based on a single table with a few exceptions like the “Product_form” form and “Vendor_form” form. These forms are used to allow the user to enter data in a user friendly manner.

4.1.1 Product form

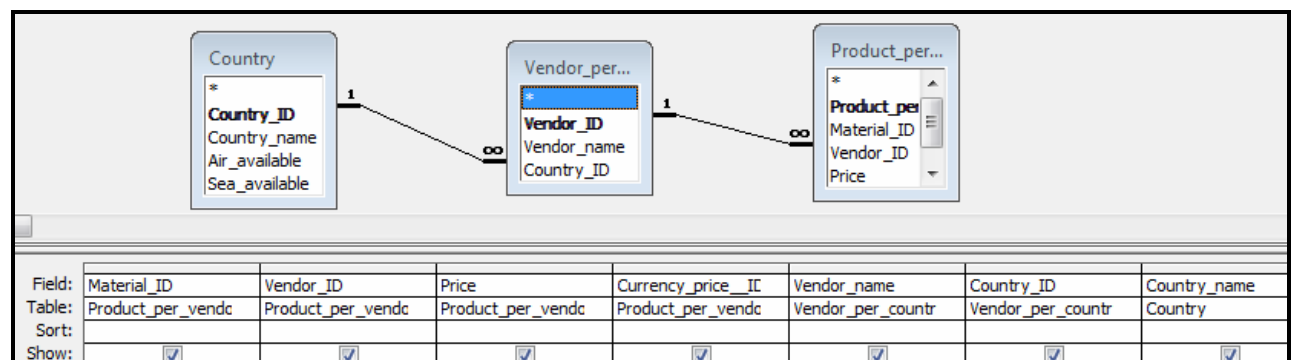
The “Product_form” form is constructed using two sub forms and the “Product” table.

The sub forms include the “Product_per_vendor_subform2” and the “Solution_subform” forms. The field that links both these sub forms to the product form is “Material_ID”.

4.1.1.1 Product per vendor sub form 2

The “Product_per_vendor_subform2” form is based on the following query defined in the record source query builder. It lists all the vendors for a particular product and the associated cost per vendor.

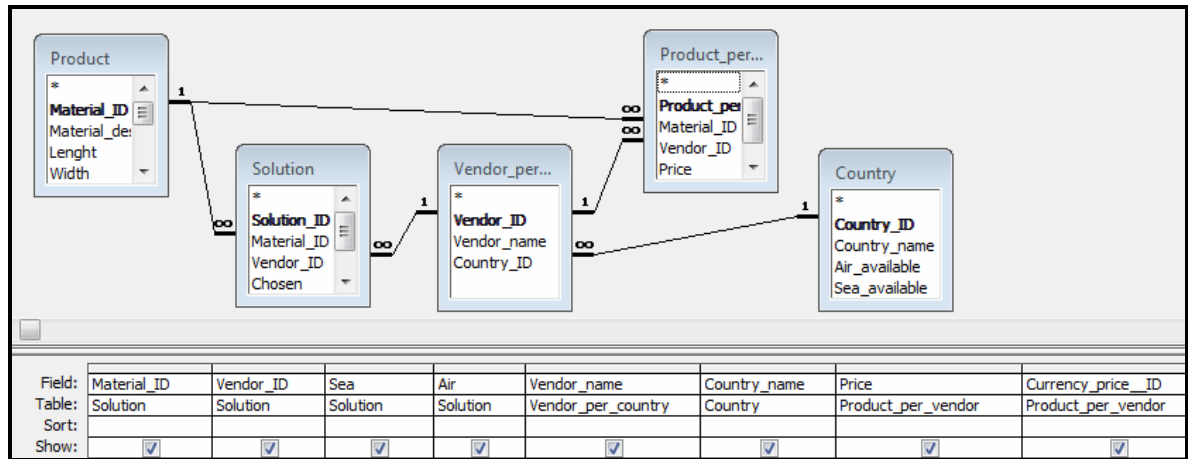
Figure 43: "Product per vendor sub form 2" design



4.1.1.2 Solution sub form

The "Solution_subform" form is based on the following query defined in the record source query builder. It provides a summary of the chosen vendor and the chosen mode of transport.

Figure 44: "Solution_subform" design



4.1.2 Vendor form

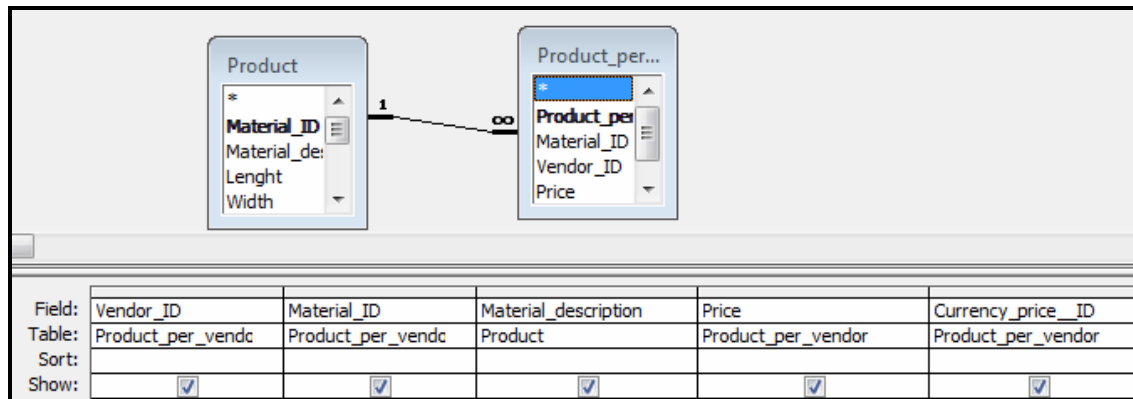
The "Vendor_form" form is constructed using a sub forms and the "Vendor_per_country" table.

The sub form is the "Product_per_vendor_subform". The field that links the sub form to the main for is the

4.1.1.1 Product per vendor sub form

The "Product_per_vendor_subform" form is based on the following query defined in the record source query builder. It lists all the products sold by a specific vendor.

Figure 45: "Product per vendor sub form" design



4.1.3 Country form

The form "Country_form" is based solely on the table "Country".

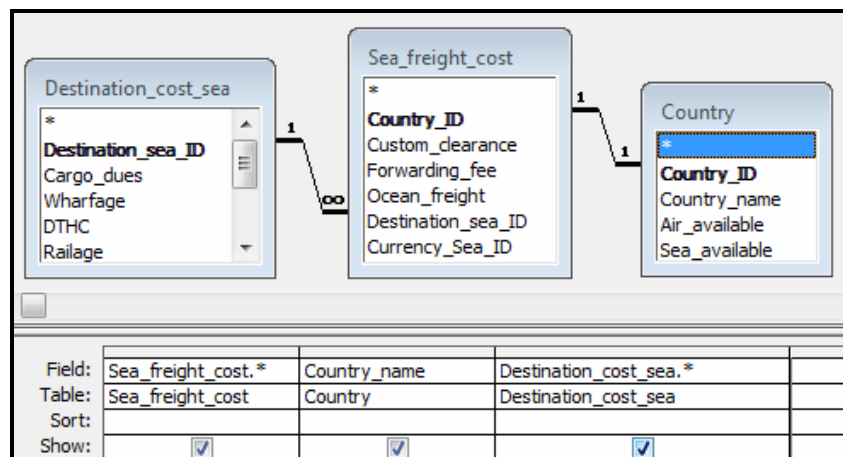
4.1.4 Currency form

The form "Currency_form" is based solely on the table "Currency".

4.1.5 Sea freight cost form

The "Sea_freight_cost_form" form is based on the following query defined in the record source query builder:

Figure 46: "Sea freight cost form" design



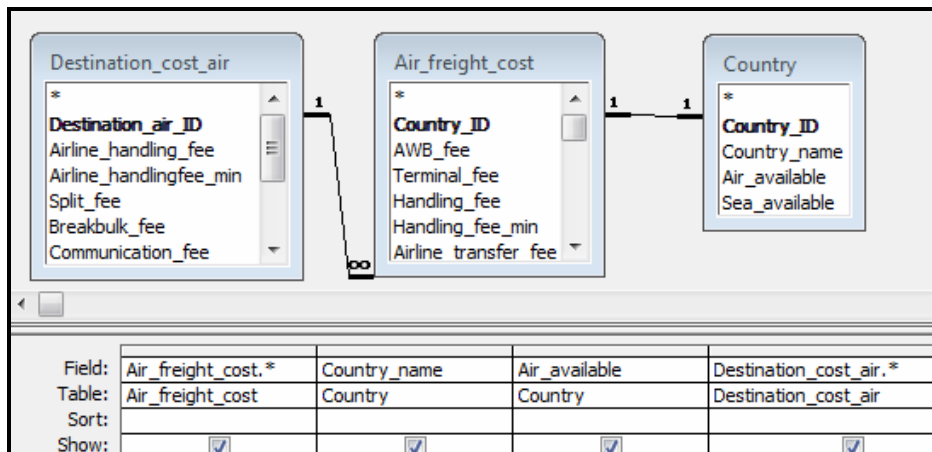
4.1.6 Destination cost sea form

The form "Destination_cost_sea_form" is based solely on the table "Destination_cost_sea".

4.1.7 Air freight cost form

The "Sea_freight_cost_form" form is based on the following query defined in the record source query builder:

Figure 47: "air freight cost form" design



4.1.8 Destination cost air form

The form "Destination_cost_air_form" is based solely on the table "Destination_cost_air".

4.2 Main Menu

The main menu contains the links to all the other forms as well as the reports. The main menu also contains the start button which initiates all the action queries discussed in chapter 3.2.

The event procedure of the start button was altered to include all the necessary queries. The content of the table "Solution" needs to be deleted before new record can be appended to it using the "Solution_options_qry" append query. The other queries are make table queries, therefore their tables do not need to be cleared.

The code includes the following:

```
Private Sub Prepare_tables_btn_Click()  
On Error GoTo Err_Prepare_tables_btn_Click  
  
    Dim stDocName As String  
  
    stDocName = "Fixed_country_cost_qry"  
    DoCmd.OpenQuery stDocName, acNormal, acEdit  
  
    stDocName = "Product_info_qry"  
    DoCmd.OpenQuery stDocName, acNormal, acEdit  
  
    stDocName = "Vendor_per_country_qry"  
    DoCmd.OpenQuery stDocName, acNormal, acEdit  
  
    stDocName = "Vendor_transport_costs_qry"  
    DoCmd.OpenQuery stDocName, acNormal, acEdit  
  
    DoCmd.RunSQL ("DELETE*FROM Solution;")  
  
    stDocName = "Solution_options_qry"  
    DoCmd.OpenQuery stDocName, acNormal, acEdit  
  
    stDocName = "Product_vendor_possibilities"  
    DoCmd.OpenQuery stDocName, acNormal, acEdit  
  
    stDocName = "Price_vendor_qry"  
    DoCmd.OpenQuery stDocName, acNormal, acEdit  
  
Exit_Prepare_tables_btn_Click:  
Exit Sub
```

5. Reports

All reports are based on queries. Therefore reports will not be discussed in detail.

5.1 Product summary

The “Product summary” report was created using the “Product_summary” query (refer to 3.4.1)

The product summary states the chosen vendor and the chosen mode of transport for a specific product. The user needs to provide the material ID to specify which product. The summary also show the costs associated with buying and importing the specific product. This is the report that will be used most often.

The air freight cost per HAWB is not included as there is no means to determine the portion of the HAWB cost a specific part is responsible for.

5.2 Products bought from vendor

The “Product_bought_from_vendor” report was created using the “Product_bought_from_vendor” query (refer to 3.4.2)

This report lists all products sourced from a specific vendor. The user needs to provide the vendor ID to specify which vendor. It also states which mode of transport is used to ship the product.

5.3 Products shipped air vendor

The “Product_shipped_air_vendor” report was created using the “Product_shipped_air_vendor” query (refer to 3.4.3)

This report lists all products that are transported by air and sourced from a specific vendor. The user needs to provide the vendor ID to specify which vendor. It also states the total weight per year of each product.

5.4 Products shipped sea vendor

The “Products_shipped_sea_vendor” report was created using the “Product_shipped_sea_vendor” query (refer to 3.4.3)

This report lists all products that are transported by sea and sourced from a specific vendor. The user needs to provide the vendor ID to specify which vendor. It also states the total volume per year of each product.

5.5 Products shipped by air

The “Product_shipped_by_air” report was created using the “Product_shipped_air” query (refer to 3.4.5)

It is simply a list of all products that are shipped per air, irrespective of the country or vendor being sourced from.

5.6 Products shipped by sea

The “Product_shipped_by_sea” report was created using the “Product_shipped_sea” query (refer to 3.4.6)

It is simply a list of all products that are shipped per air, irrespective of the country or vendor being sourced from.

6. Conclusion

Provisions have been made to accommodate improvements of the tool. For example the ABC weight calculation can easily be added to the “Product_calculation_qry” query. It is also already part of the “Product_info_qry” which creates the “X_product” table that is used to export data to the optimization tool.

The purpose of the database is to organise data in a style that can be understood by mathematical solvers. Should the user wish to use GAMS, Matlab etc. instead of LINGO he/she can still use the same database.

Appendix E

LINGO Model

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1. The formulation

1.1 Variables

Product related variables:

p_{ij} = is the given price of product i sourced from vendor j where $i=\{1..n\}$ and $j=\{1..m\}$

d_i = is the given demand per year for product i where $i=\{1..n\}$

g_i = is the given weight of product i in kg where $i=\{1..n\}$

v_i = is the given volume of product i in cubic metre where $i=\{1..n\}$

c_{jk} = is given as 1 if vendor j is situated in country k where $j=\{1..m\}$ and $k=\{1..q\}$
else it is 0

Cost related variables:

a_j = the given variable cost (per kilogram) of shipping a product from vendor j via air freight where $j=\{1..m\}$

r_k = the given fixed cost (per HAWB) for shipping a product from country k via air freight where $k=\{1..q\}$

s_j = the given variable cost (per cubic metre) of shipping a product from vendor j via sea freight where $j=\{1..m\}$

Transport availability Related variables:

e_j = is given as 1 if a product sourced from vendor j can be shipped via air
else it is zero where $j=\{1..m\}$

$f_j =$ is given as 1 if a product sourced from vendor j can be shipped via sea
else it is zero where $j=\{1..m\}$

Decision Variables:

$x_{ij} =$ is 1 if product i is sourced from vendor j where $i=\{1..n\}$ and $j=\{1..m\}$
else it is 0

$z_{ij} =$ is 1 if product i sourced from vendor j is shipped via air freight where $i=\{1..n\}$
and $j=\{1..m\}$
else it is 0

$y_{ij} =$ is 1 if product i sourced from supplier j is shipped via sea freight where
 $i=\{1..n\}$ and $j=\{1..m\}$
else it is 0

1.2 Objective function

TC = total cost

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m [\text{Total variable cost of an individual product per year}] + \sum_{k=1}^q \text{Fixed cost per country per year}$$

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m \text{Total variable cost of an individual product} * \text{demand per year} * x_{ij} + \sum_{k=1}^q \text{Cost per HAWB per country} * 52 \text{ weeks}$$

Note: x_{ij} confirms whether product i is bought from vendor j . If x_{ij} is 1, all variable costs are charged else if it is 0, no costs are charged.

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m (\text{Unit Cost} + \text{Variable Transport Cost}) * d_i * x_{ij} + \sum_{k=1}^q r_k * 52$$

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m (p_{ij} + \text{Air freight cost}[z_{ij}] + \text{Sea freight cost}[y_{ij}]) d_{ij} * x_{ij} + \sum_{k=1}^q r_k * 52$$

Note: z_{ij} and y_{ij} indicates which mode of transport will be taken. Only the costs of the mode of transport used will be charged.

$$\text{Air freight cost} = a_j * g_i$$

$$\text{Sea freight cost} = s_j * v_i$$

$$\text{Min TC} = \sum_{i=1}^n \sum_{j=1}^m (p_{ij} + ((a_j g_i)[z_{ij}] + (s_j v_i)[y_{ij}]) d_i * x_{ij} + \sum_{k=1}^q r_k * 52$$

1.3 Constraints

A product can only be sourced from one vendor:

$$\sum_{j=1}^m X_{ij} = 1 \quad (i = 1, 2, \dots, n)$$

(1) Vendor constraint

Products can only be imported by either air or sea freight but not both.

$$X_{ij} = (z_{ij} + y_{ij}) \quad (i = 1, 2, \dots, n; j = 1, 2, \dots, m)$$

(2) Transport system constraint

A part can only be imported by air or sea if that option is available.

$$z_{ij} \leq e_j \quad (i = 1, 2, \dots, n; j = 1, 2, \dots, m)$$

$$y_{ij} \leq f_j \quad (i = 1, 2, \dots, n; j = 1, 2, \dots, m)$$

(3) Transport availability constraints

Parts can only be imported from a specific country if a 20ft container can be filled over a period of 3 months i.e.132 cubic metres per year.

$$\sum_{i=1}^n \sum_{j=1}^m v_i * d_i * y_{ij} * c_{jk} \geq 132 * [\sum_{i=1}^n \sum_{j=1}^m v_{ij} * c_{jk}] \quad (k = 1, 2, \dots, q)$$

(4) Container constraint

2. The LINGO model

Model:

```
TITLE Nissan_decision_tool;
```

Sets:

```
Products: d, g, v;
```

```
Vendors: a, s, e, f;
```

```
Countries: r;
```

```
Arcs(Products, Vendors): p, x, z, y;
```

```
Arcs2(Vendors, Countries): c;
```

endsets

```
! Import data from Access;
```

```
! @ODBC('Database_name', 'Table_name', 'Attribute_1', 'Attribute_2');
```

Data:

```
Products, d, g, v =  
@ODBC('Nissan_decision_tool', 'X_product', 'Material_ID',  
'Demand', 'Weight_final', 'Volume');
```

```
Vendors, a, s, e, f =  
@ODBC('Nissan_decision_tool', 'X_variable_cost', 'Vendor_ID', 'Cost_kg',  
'Cost_volume', 'Air_possible', 'Sea_possible');
```

```
Countries, r =  
@ODBC('Nissan_decision_tool', 'X_fixed_cost', 'Country_name', 'Cost_HAWB  
');
```

```
Arcs, p =  
@ODBC('Nissan_decision_tool', 'X_price_vendor', 'Material_ID', 'Vendor_I  
D', 'Price_R');
```

```
Arcs2, c =  
@ODBC('Nissan_decision_tool', 'X_vendor_country', 'Vendor_ID', 'Country_  
name', 'c');
```

```
ENDDATA
```

```

! The objective function;
[OBJ] MIN = @SUM(Countries(k):r(k)*52) +
           @SUM(Arcs(i,j): (p(i,j)+(a(j)*g(i)*z(i,j))+
           (s(j)*v(i)*y(i,j))*d(i)*x(i,j)) );

!The vendor constraint;
@FOR (Products(i):
      @SUM (Vendors(j): x(i,j) )=1);

!The transport system constraint;
@FOR (Products(i):
      @FOR (Vendors(j): x(i,j) = z(i,j) + y(i,j) ));
!The transport availability constraints;
@FOR (Vendors(j):
      @FOR (Products(i): z(i,j)<=e(j) ));

@FOR (Vendors(j):
      @FOR (Products(i): y(i,j)<=f(j) ));

!The container constraint;
@FOR (Countries(k):
      @SUM (Arcs(i,j): y(i,j)*v(i)*d(i)*c(j,k))
      >=132*@SUM(Arcs(i,j):y(i,j)*c(j,k)));

!Decision variables are binary;
@FOR (Products(i):
      @FOR( Vendors(j): @BIN(x(i,j))));
@FOR (Products(i):
      @FOR( Vendors(j): @BIN(y(i,j))));
@FOR (Products(i):
      @FOR( Vendors(j): @BIN(z(i,j))));

! Export data to Access;
Data:

      @ODBC('Nissan_decision_tool','Solution','Material_ID','Vendor_I
D','Chosen','Air','Sea') = Arcs, x, z, y;

ENDDATA
END

```

3. Data input

The following data is an illustration of how data is imported into LINGO. All imported variables are represented. Codes starting with a 1 are Material_IDs and those that start with a 2 are Vendor_IDs. A sample of the tables from which this data was imported appears in Appendix D, Chapter 3.2.

d_i = is the given demand for product i where $i=\{1001..1003\}$

D(1001)	10400.00
D(1002)	52.00000
D(1003)	10.40000

g_i = is the given weight of product i in kg where $i=\{1001..1003\}$

G(1001)	0.3000000E-01
G(1002)	28.75000
G(1003)	600.0000

v_i = is the given volume of product i in cubic metre where $i=\{1001..1003\}$

V(1001)	0.5000000E-05
V(1002)	0.1725000
V(1003)	1.072500

a_j = the given variable cost (per kilogram) of shipping a product from vendor j via air freight where $j=\{2001..2003\}$

A(2001)	72.30000
A(2002)	200.3000
A(2003)	384.0000

s_j = the given variable cost (per cubic metre) of shipping a product from vendor j via sea freight where $j=\{2001..2003\}$

S(2001)	6.098837
S(2002)	7.107558
S(2003)	21.19186

e_j = is given as 1 if a product sourced from vendor j can be shipped via air else it is zero where $j=\{2001..2003\}$

E(2001)	1.000000
E(2002)	0.000000
E(2003)	1.000000

$f_j =$ is given as 1 if a product sourced from vendor j can be shipped via sea
else it is zero where $j=\{2001..2003\}$

F(2001)	1.000000
F(2002)	1.000000
F(2003)	1.000000

$r_k =$ the given fixed cost of shipping a product from country k via air freight where
 $k=\{\text{Europe, Japan, USA}\}$

R(USA)	25.00000
R(JAPAN)	57.00000
R(EUROPE)	96.00000

$p_{ij} =$ is the given price of product i sourced from vendor j where $i=\{1001..1003\}$ and
 $j=\{2001..2003\}$

P(1001, 2003)	1000000.
P(1001, 2002)	24.00000
P(1001, 2001)	24.00000
P(1002, 2003)	4000.000
P(1002, 2002)	1000000.
P(1002, 2001)	2400.000
P(1003, 2003)	192000.0
P(1003, 2002)	1000000.
P(1003, 2001)	80000.00

$c_{jk} =$ is given as 1 if vendor j is situated in country k where $j=\{2001..2003\}$ and
 $k=\{\text{Europe, Japan, USA}\}$
else it is 0

C(2001, EUROPE)	0.0000000
C(2001, JAPAN)	0.0000000
C(2001, USA)	1.0000000
C(2002, EUROPE)	0.0000000
C(2002, JAPAN)	1.0000000
C(2002, USA)	0.0000000
C(2003, EUROPE)	1.0000000
C(2003, JAPAN)	0.0000000
C(2003, USA)	0.0000000

4. Data Output

All exported variables are represented here i.e. the decision variables.

x_{ij} = is 1 if product i is sourced from vendor j where $i=\{1001..1003\}$ and $j=\{2001..2003\}$

else it is 0

X(1001, 2003)	0.0000000
X(1001, 2002)	0.0000000
X(1001, 2001)	1.0000000
X(1002, 2003)	0.0000000
X(1002, 2002)	0.0000000
X(1002, 2001)	1.0000000
X(1003, 2003)	0.0000000
X(1003, 2002)	0.0000000
X(1003, 2001)	1.0000000

z_{ij} = is 1 if product i sourced from vendor j is shipped via air freight where $i=\{1001..2003\}$ and $j=\{2001..2003\}$

else it is 0

Z(1001, 2003)	0.0000000
Z(1001, 2002)	0.0000000
Z(1001, 2001)	1.0000000
Z(1002, 2003)	0.0000000
Z(1002, 2002)	0.0000000
Z(1002, 2001)	1.0000000
Z(1003, 2003)	0.0000000
Z(1003, 2002)	0.0000000
Z(1003, 2001)	1.0000000

y_{ij} = is 1 if product i sourced from supplier j is shipped via sea freight where $i=\{1001..1003\}$ and $j=\{2001..2003\}$

else it is 0

Y(1001, 2003)	0.0000000
Y(1001, 2002)	0.0000000
Y(1001, 2001)	0.0000000
Y(1002, 2003)	0.0000000
Y(1002, 2002)	0.0000000
Y(1002, 2001)	0.0000000
Y(1003, 2003)	0.0000000
Y(1003, 2002)	0.0000000
Y(1003, 2001)	0.0000000

The results appear in the table "solution". See figure 1.

Figure 1: "Solution" table after the LINGO model was executed

	Solution_ID	Material_ID	Vendor_ID	Chosen	Sea	Air
	231	1001	2003	0	0	0
	232	1001	2002	0	0	0
	233	1001	2001	1	0	1
	234	1002	2003	0	0	0
	235	1002	2002	0	0	0
	236	1002	2001	1	0	1
	237	1003	2003	0	0	0
	238	1003	2002	0	0	0
	239	1003	2001	1	0	1