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***Inventory management model for Protection  
Manufacturers***

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## EXECUTIVE SUMMARY

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The following document is the provisional project report of the final year project done for the Industrial and Systems Engineering department at the University of Pretoria. The project is currently being done at Profection Manufacturers in Silverton. In the introduction, the company background is given with an indication to what is to be followed in the document. This company faces trouble in the inventory section of the sheet metal manufacturing. No inventory facility, system or control is currently in working order.

The project aim and scope are identified, hereafter is a literature study been done on the methods, concepts and designs of other researchers. Main topics that are examined in the study are facilities planning, information systems, operations research and business engineering. Appropriate designs, concepts and methods are selected at the end of the literature review to develop a conceptual design for the project.

This leads to the building of an inventory management model to control the warehouse and its functions and operations. By implementing this model, Profection company will now have the ability to increase their profits. Through continuous improvement at the inventory warehouse, the company can and will stay one of the leading manufacturing job shops in the country.

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## LIST OF ACRONYMS

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CNC	Computer numerical control
CAD	Computer aided design
CAM	Computer aided manufacturing
ERD	Entity relationship diagram
ERP	Enterprise resource planning
FIFO	First in – First out
GA	Genetic algorithm
IDEF0	Integrated definition language 0
IDEF1x	Integrated definition language 1 extended
IDEF3	Integrated definition language 3
IMS	Inventory management system
IQIS	Integrated quality information system
KPI	Key performance indicator
NC	Numerical control
PC	Personal computer
QIS	Quality information system
RF	Radio frequency
RFID	Radio frequency identification
RFQ	Request for quote
ROI	Return on investment
SCOR	Supply chain operations reference model
SPC	Statistical process control
SQL	Structured query language
TQM	Total quality management
WIP	Work in process

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# 1. INTRODUCTION

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Profession Manufacturers developed to a great extent when getting the contract from Cell C South Africa 4 years ago, to build the Community Chat containers. The company had to manufacture 5600 containers for this project. Today the company has many other projects to keep up with making it one of the largest job shop manufacturing companies in South Africa.

The company has a fabrication process where raw materials, usually sheet metal, are changed into some specific form. They follow a make-to-order process and have a process flow structure of a job shop type, where small batches of a large number of different products are produced. The management faces trouble with the manufacturing inventory storage control. Because all successful companies have integrated functionality within the whole facility, it requires looking at a few aspects around the problem to manage the flow of production. This problem initiated a project to apply certain Industrial Engineering tools to solve successfully.

A literature study was done to gather appropriate methods, designs and concepts for solving the problem, which after a conceptual design shows a solution to the problem. An inventory warehouse model is built with key aspects such as a business modelling, facility planning and operations management. The following few chapters in the document explain the problem, scope, objective, literature study and then the solution as proposed.

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# 2. PROBLEM STATEMENT

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The company came to realise that inventory costs are definitely too high and something needs to be done to decrease these costs. As one walks through the production area, the first of many problems are visible. Sheet metal (inventory) is lying unorganized against the side walls. Off cut sheet metal can also be classified as inventory, because it can be re-cut. Inside the existing inventory warehouse, there is a lot of inventory piled on to each other and not enough racks for inventory. This situation makes it difficult to find the item needed. More and more off cut sheet metals are the result when the picker can not find the most appropriate item for the job then takes a new full sheet. A more disorganized facility is therefore created, pickers not knowing where to begin searching. When not using the off cut sheet metal as efficiently as possible, the inventory costs will increase. These problems only occurred because production in the company took a big leap forward leaving certain processes behind.

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# 3. PROJECT AIM

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The AS-IS state of the raw material storage facility is not structured and well managed as desired. Through implementing an inventory management system (IMS) and new layout at the storeroom, the following project aims will be addressed:

- Inside the storage facility
  - Restructuring the current storeroom layout.
  - Classification of material types, sizes and quantities into storage locations.
  - Reducing the order picking time in storeroom.

- Reducing inventory costs.
- Continuous record updating of inventory quantity.
- Ensuring that the control procedures and processes are adhered to.
  
- Outside the storage facility
  - Controlling WIP and inventory in the storeroom with the IMS.
  - Reducing material waste (off cuts) by selecting the appropriate stock material for the specific job.
  - Improving the flow of raw materials on site.
  - Continuous tracking of inventory.

An objective that is very important to any company is the financial analysis, only after this analysis the company can decide whether to implement the project or not.

Another objective of the project is to demonstrate to the company how they can improve facility operations in the future. This project is only the ground phase to many future developments. Only a broad overview will be given to applicable suggestions.

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## 4. PROJECT SCOPE

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As soon as the carrier is parked in front of the inventory warehouse with the raw materials, the facility operations start to take action. The whole warehouse management is part of the project, up to where raw materials are picked and moved into manufacturing. After manufacturing, there is a possibility that excessive materials (off cut sheets) are present. These excessive materials will return to the inventory warehouse and will be used at a later stage on another job in the manufacturing area or otherwise classified as scrap material which is thrown into a bin.

There is a certain probability that an off cut sheet will be used for another job. Therefore looking at the financial side of inventory the following question arise, do the company need to classify the off cut as inventory which will be stored and used for a next job or as scrap metal and be sold. Another aspect which is outside the inventory warehouse but will be addressed is the product nesting application for the laser cutter. Reasons for this being part of the inventory warehouse design and procedures, is because the off cut figure needs to be standardized to achieve a quality storage policy.

The warehouse needs to be operated and managed in a qualitative manner through useful material- and information flow. To summarise the scope, one can say that the warehouse need to be designed, functioned, managed and sustained as best as possible, through looking at all possible scenarios and side effects impacting the warehouse.

## 5. LITERATURE REVIEW

### 5.1 FACILITIES PLANNING

Facilities planning have changed from a science to a strategy in the past ten years. The global industry has become more competitive, resulting in more advanced planning. All facilities strive to achieve Supply Chain Excellence. According to *Thompkins, White, Bozer and Tanchoo [15]*, Supply Chain Excellence can be achieved with a six step process, where one of the steps is visibility. All departments share information to better understand the organization's position therefore minimizing supply chain surprises. Applying total integration of material and information will give the organization a holistic approach to all elements [15].

When an organization plans a facility, they must keep in mind the effect the facility will have on their supply chain partners. Therefore the facilities in the supply chain need to have important characteristics such as flexibility, modularity, upgradability and adaptability. To have flexibility the facility should handle a variety of requirements. Systems that cooperate efficiently are known to be modular. The upgrading of a facility should always be possible, whether large or small, because technology is always a factor. The facility needs to be adaptable to any changes for example, the supply and demand which will cause fluctuations of the inventory level [15].

A facility design project can be analyzed with the seven management and planning tools method to achieve success. The following diagram is taken from *Thompkins, White, Bozer and Tanchoo [15]*, figure 2.24 on page 70, to show the procedure of design.

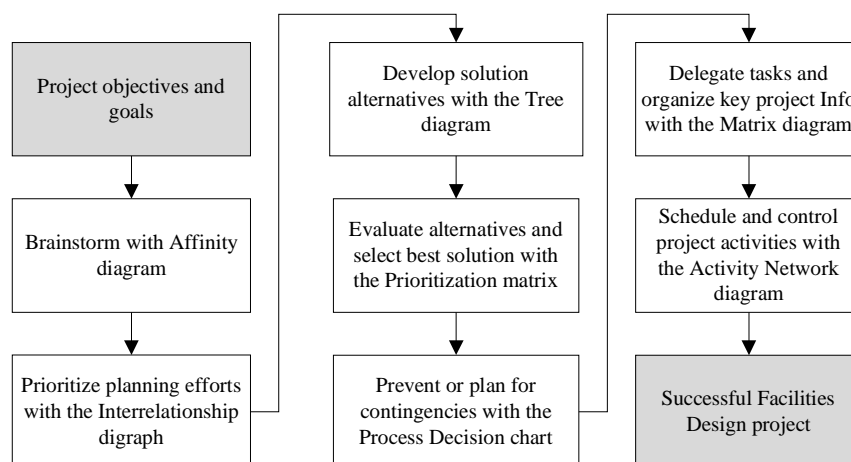


FIGURE 1: SEVEN MANAGEMENT AND PLANNING TOOLS [.9]

### 5.2 LAYOUT DESIGN

Simulation models are commonly used to determine the outcome of warehouse operations, for example confirming the warehouse design and material handling equipment used [16]. By determining the optimum storage locations (number of racks) it can aid in the improvement of operations [16]. When simulating such a warehouse operation, a discrete event simulation should be modelled [16]. The model contains three main elements, the database, list of events which occur in a certain distribution, and then the simulator clock [16]. The database contains all the orders received. The model stores all the events that occurred during the run of the simulation, to study further the

effect of different scenarios [16]. Examples of such an integrated optimization-simulation model are found in *Gue* [10] and *Ruiz* [24].

People in any organization tend to make numerous estimates of the space required in the facility [15]. After many calculations to determine the true space requirements, the following law comes to the front, *Parkinson's Law* [15]; it states that all things will expand to its full capacity sooner than expected. After determining the required space for the facility, the planning and implementation is done. Near the end of the project you come to realise that the space requirements has surely increased since the beginning phases [15].

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### 5.3 STORE OPERATIONS

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The first function of the warehouse operation cycle is the receiving and inspection operation [15]. After offloading of the requested materials the quantity and quality is checked to confirm an acceptable order [15]. Inspection can be done in various ways, from basic visual check to laboratorial testing. The inspection costs increase as the inspection methods improve. Therefore raw materials with much lower value than finished goods would only be checked visually [15].

The put away operation is the physical movement of products into the allocated storage location. This process involves identifying the product, by means of bar code scanning, RFID (radio frequency identification), optical character recognition, magnetic stripes, machine vision or manual labelling, then identifying a location and moving the product. Thereafter the inventory database is updated, showing the product quantity and location [19].

A few strategies exist in storage operations. Products are allocated to a fixed location; this strategy is known as dedicated storage. Classed-based storage is a strategy where products are stored in specific zones or areas in the store or warehouse [16]. *Gagliardi, Renaud, Ruiz* [16] say that "...warehouses require much more than choosing storage and picking strategies. In fact, even given a basic storage model — dedicated storage, for example — many decisions must be made: what type of equipment should be chosen (e.g., racking), whether certain equipment (e.g., handling devices like conveyors) should be used, and which products should be assigned to which storage locations."

Order picking is considered to be a very important activity in a store. The throughput time of an order is an important measure, the faster the order picking is done the more efficient the store is considered [21]. *Gagliardi, Renaud, Ruiz* [16] state four basic procedures for order picking, where one of it is discrete picking. Discrete picking is when one person picks a single order at a time, this strategy is known to be basic but also easily implemented. The other procedure is batch picking, one person picks many orders at a time. Provide the picker with an easy to read picking document, so that no confusion is created [15]. The document should contain the necessary information to identify the item [15].

The storing of raw materials and semi finished goods is classified as long term storage. Because it involves less risk of storing these goods, less-complicated storage facilities are required [19].

Store the most popular products in the most easily accessed area of the storeroom, eliminating unnecessary travel time of the picker [11]. Validating this point we can look at *Heskett's* [11] excellent work on locating the most popular products close to the foundation area. Congestion of pickers when picking in the same area could be a huge problem. Smaller sized items (cubic dimensions) also need to be stored close to shipping area, which will reduce picking time [19].

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## 5.4 MATERIAL HANDLING

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The definition is given from *Thompkins, White, Bozer and Tanchoo [15]*, “Material handling is the art and science of moving, storing, protecting and controlling material.” A very common saying that describes the ideal system is to get the right amount of the right material, in the right condition, in the right sequence, in the right orientation, at the right place, at the right time, at the right cost, with the right method [15].

The material handling system equation [25] analyses a checklist to determine the recommended system. After answering all questions in the checklist, the materials, moves and methods are added together, to get the ideal material handling system.

The counterbalanced lift truck also known as the fork truck is the standard storage/ retrieval vehicle [15]. Many different fork truck models exist but the most widely used type can lift a load of up to 2500kg and has a lift height of up to 2.6m. When using the fork truck for operations the aisle width necessary for vehicle manoeuvrability is between 3m and 4m [15].

Many different picking carts are available to pick all sorts of items. Picking carts are designed with dividers to carry many different items at once without mixing them. A flat bed on top of the cart is useful for doing paperwork and measuring [15].

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## 5.5 STORAGE EQUIPMENT

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The single-deep selective rack is a metal frame used for storage and provides easy access to goods [16]. It is not necessary for goods to be stacked onto each other when stored. Pallet spaces can be built into the frame, to slide the pallet with goods into the open slot. The pallet rack is considered to be the most standard equipment in industry. The pallet rack can easily be built to preferable standards.

A manufacturing company from Austria, *Stahlbau Zeidhofer GmbH* wrote an article on “Storage system that speeds work” [28]. Excellent material flow is achieved through the *TruStore* storage system. This storage system can supply the laser cutter at a continuous rate, also eliminating the need for any human attendance. Raw material can be put onto the cutting bed by the service system, and after cutting the parts and material waste are picked up and put into separate bins. *Zeidhofer* says: “A laser cutting machine with a service unit accomplishes far more than two laser machines alone.” [28].

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## 5.6 SHEET METAL OPERATIONS

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Sheet metal is basically metal that has been rolled into a sheet [8]. The English word “metal” is derived from the Latin word “metallon” meaning “metal, mine, product of mining” [8]. Many different types of metal can be used in sheet metal fabrication. Sheet metal can be used to make almost any size or shape of product [8]. Operations such as cutting, bending, punching etc. are used to work with sheet metal. Sheet metal is bendable and easy to shape.

Although metal operations started thousands of years ago, it is still in process today with more advanced machinery such as CNC (computer numerical control) machines and laser cutting, making it more interesting than before [7]. A couple of years ago NC (numerical control) machines became CNC machines through the development of microprocessors which were installed into NC machines [1]. This provided on-board computer functionality for the operator. The processor has all possible inputs one can think off. Functions such as program storage, tool balance and tool compensation, program control capability and sending/receiving of data are some of the on-board functions available [1].

Computer-aided design (CAD) is the design of a part, which can be modified and analysed on the computer software. Computer-aided manufacturing (CAM) involves the manufacturing, production planning and scheduling of making the product [1]. CAD and CAM are widely present in the manufacturing industry nowadays. It is called a CAD-CAM system [30].

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## 5.7 LASER CUTTING: NESTING OF PARTS

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To decrease the cost of laser cutting, nesting is applied to the sheet metal. Nesting is the process of combining all the orders and placing it on the sheet to minimize the waste material. Many researchers (Murtey, [22]) (Farley, [5]) have developed algorithms for this cutting stock problem, using linear programming techniques. More recently the irregular shape problem acquired more attention, where heuristics were used to minimize the sheet waste [30].

Stock size and shape need to be considered as to optimize the utilization of any shape [6]. A basic way of handling nesting problems is to use a rule-based heuristic. Taking all the shape profiles to be nested and placing it in a rectangle [21]. GA (genetic algorithm) is probably the more general method to get the most sufficient solution to this problem [6]. The algorithm only seeks a near optimum solution because infinite solutions are possible. Algorithms are only accepted in practise when they present good results. The boundary nesting algorithm is very appropriate in this situation [6]. The algorithm searches for the best possible position for the part on the initial shape along the boundary [6]. After the position is identified the algorithm searches for the best position for the next part, along the new shape, which is the area of the first part subtracted from the initial shape. The algorithm continues until no more parts can be fitted onto the shape [6].

The measurement of effectiveness on the sheet metal is the ratio of the total area of the shapes over the area of the sheet metal [21]. We want to maximise the usage of stock, therefore when selecting an irregular shape sheet from the store by random for nesting certain parts, it will have a small probability of effectiveness. Effectiveness will be maximised when a specific irregular shape sheet is identified, thereafter nested and cut.

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## 5.8 AUTOMATIC IDENTIFICATION

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Bar code technology is mostly used when it comes to automatic identification, and it will stay certain for quite some time [29]. More and more industry sectors are applying the bar coding system as the prime identification of products [29]. Warehouses today are highly dependent on bar coding technology, to keep track of their inventory, the in- and outflow and managing of inventory, therefore proving to be very effective in inventory control [17]. The bar code development and implementation process is summarized in a diagram, where aspects such as preliminary analysis, system analysis and system design, and implementation is the main focus to develop a complete bar coding system. The diagram can be seen in the journal of Vassiliki Manthou\*, Maro Vlachopoulou [29], figure 2. System design depends solely on the organization's environment, budget and amount of information to be sent to the database [29]. To select appropriate hardware and software for the organization, the integration and compatibility of the system need not be overlooked [29]. In the case studied in Vassiliki Manthou\*, Maro Vlachopoulou [29], they achieved a decrease in cost and human error after the bar code implementation.

RF (radio frequency) coded tags are highly efficient in difficult environments, where data needs to be received [14]. Antennas and interrogators need to be installed for frequency recognition, this result in very high cost of this automatic identification method. Tags can carry a lot of information and also be detected from a long distance and at high speeds [14]. This method has shown an increase in popularity in the industry, especially where WIP (work-in-process) is present. You now know the

exact location of the item, making continuous data updating on the tags possible [14]. Doer et al. [2] examines the cost involved when RFID (radio frequency identification) is implemented, and whether it is feasible to actually have a ROI (return on investment).

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## 5.9 LEAN JOB SHOPS

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The lean enterprise vehicle best describes how lean is applied to any business. The vehicle consists of 4 wheels. Each wheel represents a business principle. When ever one of these wheels is smaller, larger or broken compared to the others, the business won't run as smoothly as wished [9].

Wheel number one symbolizes the business principle [9], *Total quality management* (TQM). TQM consists of many key indicators which are measured against the business goal, namely best practices, statistical process control (SPC), waste reduction, 5's workplace organization, information flow etc.

Edward Deming has written, "It is good management to reduce the variation in any quality characteristic, whether this characteristic be in state of control or not, and even when few or no defectives are being produced." [12].

Control charts are commonly used among management to strive towards an ideal state for a process. These control charts hold control limits, which are also called *three sigma limits* ( $3\sigma$ ). These limits indicate the allowable range of variation from the mean. The out of control points, which states the data points above the upper control limit and the data points below the lower control limit, should be identified and carefully assessed to determine the cause. To achieve greater quality in the process, continuous improvement through control chart application is necessary [12].

Advantages of reaching a stable process through statistical process control (SPC) are; productivity will be optimised and costs will be minimised; management will have total control over change and performance in the system.

Seven types of wastes (or also known as "*muda*" in the Japanese literature) are commonly visible in businesses. Shigeo Shingo identified these types of waste as part of the Toyota Production System, over production, waiting, transporting, inappropriate processing, unnecessary inventory, excess motion and lastly defects [23].

A valuable concept thrown away is the workplace organization. The writer [33] stipulates the importance of "a place for everything and everything in its place". To achieve the excellence, these 5 pillars of workplace organization are adhered to; sort, shine, standardise, set in order, sustain.

Wheel number two symbolizes the business principle [9], *Lean manufacturing techniques*. Key indicators followed underneath are, facility layout, handling reduction, pull system, right sized equipment etc.

Wheel number three symbolizes the business principle [9], *Sales, Production and Inventory Management*. These three management aspects are closely integrated with each other. Important key indicators to attend to are inventory turn, standard work in process (WIP), visual pull signals, "*kanban*" etc. "*Kanban*" (another term originated from Japan) signals visually the requirement for a product or to move as such.

The last wheel, number four, symbolises the business principle, *Total Organizational Buy – In*. It relates to the company culture, the management of your people. As important as the other resources in your business environment.

## 5.10 BUSINESS MODELLING

Business modelling is a framework that consists of economic, social and many other forms of value that represent core aspects of a business [13]. IDEF methods and techniques are used to compile a business model.

During the earlier years the U.S. Air Force Program for Integrated Computer Aided Manufacturing (ICAM) developed a series of techniques known as IDEF techniques. The IDEF0 (integrated definition language 0) technique, developed by Douglas T. Ross and SofTech, Inc, is used for a functional model. The following definition is given in the document Draft Federal Information Processing Standards Publication 183 [3]. “A functional model is a structured representation of the functions, activities or processes within the modelled system or subject area”.

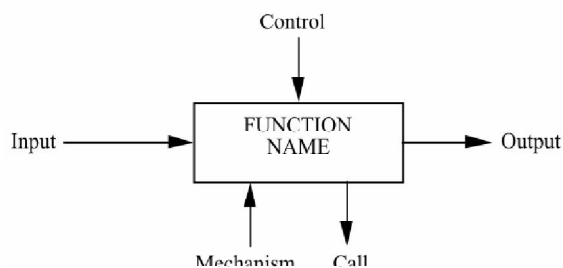


FIGURE 2: ICOM BOX

The box (in figure 2) represents a function within the hierarchical schematic model, which is called the ICOM (Input, Control, Output, and Mechanism) box.

The IDEF1x (integrated definition language 1 extended) techniques is used for an information model. The following definition is given in the document Draft Federal Information Processing Standards Publication 183 [3]. “An information model represents the structure and semantics of information within the modelled system or subject area”.

information within the modelled system or subject area”.

Another modelling language the IDEF3 (integrated definition language 3) is particularly designed to capture descriptions of sequence of activities [26]. Objective of this language is to provide a structural method to explain the operation of a specific system.

The functional-, process- and information models are integrated with each other to form the business model as a whole.

## 5.11 INFORMATION SYSTEM

System development is a process with a few steps, namely system analysis, system design, system implementation [20]. System analysis is the gathering of the required data with applicable methods. System design is the structuring of the database model from data flow diagrams. An example of a database language that can be used by the end user is SQL (structured query language) which is compatible for complete database construction and usage [20].

*Pilkington PE (PPE)* [31] manufacturing company began a transition into paperless quality. During continuous improvement stages the company realized that data control became more complex, therefore some changes had to be implemented. A quality information system (QIS) was introduced to the company, which resulted in an integrated system [31]. Data can now be analysed and performance measures be taken, even more time is available for data capturing than before. During developing of the QIS, the relations between paper forms were built into the system logic. Now only one action is performed on the system, and everyone in the company is aware of it. The paperwork between departments is eliminated [31]. This system resulted with a high payback to the company, increased process quality of 40%, over ten paper systems substituted, increased productivity and warranty costs reduced by 70% [31].

One of the earlier information systems are described by *Cope, Kamel and Kamel [18]*. The PC (personal computer) serves as the central server of the system and also at the same time receiving information from different terminals. It then updates the SQL database, allowing other users to access the information. This system will result in greater productivity and efficiency, allowing the company to follow actual inventory levels [18].

Today more companies have ERP (enterprise resource planning) systems set up, therefore by developing an IQIS (Integrated quality information system) to share data, it is necessary to integrate the IQIS with the ERP [32].

To develop a complex product, such as an information system, the Zachman framework is very useful [27]. The framework is useful in identifying the information system's components. The framework concentrates on all aspects within the system, but not throwing away the holistic overview [27].

A method useful for system analysis is the ERD (entity relationship diagram). It describes data in relationship with the entity, where in this case an entity is something where data can be stored by the organization [20].

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## 5.12 JOINT AND BY-PRODUCT COSTING

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Several products that are the output of a specific process are called joint products [4]. Products which are dependant from the same process but with much less value are called by-products [4]. These by-products have little or no effect on the selling of the joint products. Only after the split-off point can you distinguish between these two types of products. The net realizable value method can be used to determine whether the further processing after the split-off point is feasible or not [4]. This method takes the value at the split-off point and deducts it from the sales revenues at the point of sale. Normally the by-product costs are subtracted from the joint products sales [4]. But if any revenues that can occur from further processing of the by-product after split-off point, it should be deducted from the by-product's costs [4].

Drury [4] explains the difference between waste, by-products and scrap. Waste has no value at all and isn't included in inventory value. By-products have little value, definitely less than the primary product sales value, but can be further processed to increase possible value. Scrap is the leftovers that you get from manufacturing products and has a small value.

Some distinction comes into costs and revenues when making a decision whether to continue processing the product or to store the product. There are relevant and irrelevant costs and revenues when the choice is to be made [4]. The relevant costs and revenues are the potential costs that will be affected by the decision.

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## 5.13 REVIEW CONCLUSION

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So many methods and ideas exist in the literature study, but only a few selective topics can be studied further and developed in the end. No studies were found on exactly this project's problem, but this literature study can be twisted to solve the particular problem.

The design of facility, material handling and operations will be done to accommodate the sheet metal manufacturing. The literature study on the nesting of parts is done not to develop a heuristic for nesting, but only to better understand the process and to make a few changes in the nesting operation to get more standardised off cut sizes. Future development can include a heuristic which is integrated with the storage facility.

Many problems exist in choosing an automatic identification system for sheet metal parts, because of the robustness. Only the logic of identification is used to develop something unique to this company.

As nowadays all enterprises strive toward lean implementations, this topic is very wide and unique to each business. By taking some of the lean techniques and approaches which were researched by specialists, and integrating them with other fundamental study areas, such as facility planning, a quality inventory management model can be obtained.

Business engineering can clearly be at the core of any business, to prudently manage all functions, processes and information. Schematics can show the integrated holistic view of the business.

## 6. CONCEPTUAL DESIGN

After examining the literature review and considering the problem definition, the following conceptual design schematic is structured. This inventory management model can be seen in the diagram below (figure 3).



FIGURE 3: INVENTORY MANAGEMENT MODEL

Through addressing every aspect in the above diagram in detail, a productive inventory warehouse facility will be the result. The following few chapters analyse the current AS-IS system and provide the company with the TO-BE system. Additional information is presented in the appendices at the end of the document.

## 7. OPERATIONS MANAGEMENT

### 7.1 DATA CAPTURING

A wide variety of materials are available for industrial use nowadays [8]. The most commonly used materials are mild steel, stainless steel, aluminium, high tensile steel. These materials differ in weight, composition etc. Sheets can have a thickness ranging from 0.05mm to 150mm, and different sheet formats, with a medium format of 1250 x 1500mm [8].

The measurements of the generated off cut was analysed in the most realistic manner. Through visual inspection at the laser cutting department a definite trend can be seen. Previous data shows a probability of about 80% for an off cut to be generated from using a full sheet for a job, and a probability of about 90.5% for an off cut to be generated from using an off cut sheet. Now this last probability can be misleading, but going back to the shop floor, the cause becomes clear. The incorrect sheet is collected for a job, and this leads to generating multiple off cuts over and over again.

The off cut shape follows the following contours, shown in figures 4 and 5. Either an L-shape off cut or a square off cut. There is a higher probability that an L-shape off cut will be generated than a

square. Length (L1) and width (W1) is the original length and width before cutting, which is also the longest length and width. Length (L2) is the second longest length, and width (W2) is the second widest width. This measuring technique was used to collect data for analysis, and will be used during implementation of the project. This is the easiest way to approximate the area of the off cut shape, without confusing the operator.

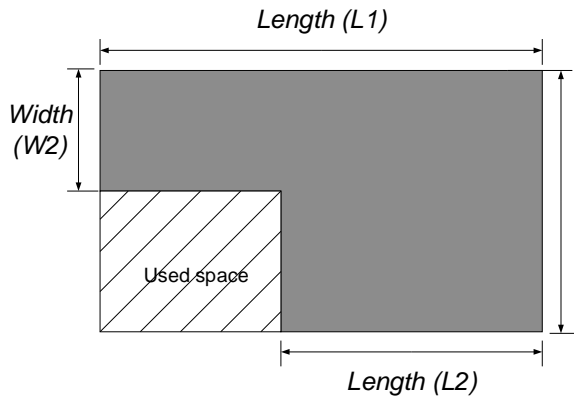


FIGURE 5: OFF CUT SHAPE 2

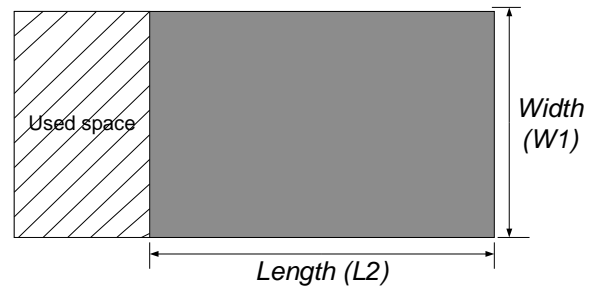
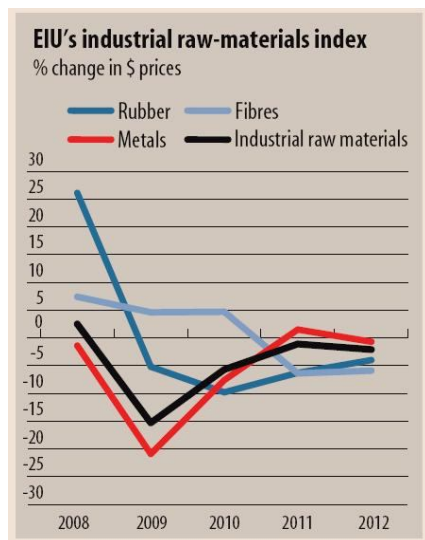


FIGURE 4: OFF CUT SHAPE 1

Data viewed from the setup schedule when send to the *Trumph* laser cutter is very useful to determine the different size off cut sheet metal and also finding an average. The minimum blank size minus the blank size gives the off cut size. The nesting software, either *Sigmanest* or *TruTops* give a percentage scrap. This isn't always an exact indication of the true off cut size, because the unusable material between the nested parts is also taken into account. This setup schedule data was captured and can be seen in Appendix B.

## 7.2 INVENTORY CONTROL



The overall big picture for the sheet metal industry, states a fall in price during 2009, where after it will steadily rise over the next 3 years. This will have an effect on the amount of raw material inventory Protection will store. This shows that a large warehouse containing all the different types, sizes and shapes of sheet metals are really unprovoked, for it will only increase inventory costs.

FIGURE 6: EIU'S INDUSTRIAL RAW MATERIAL INDEX

These are the reasons why Protection requires inventory storage space:

- To meet the variation in product demand of the customer. Therefore buffer or safety stock is required.
- To allow flexibility in manufacturing scheduling. The factory has a capacity at which it operates. High setup costs favour manufacturing a larger number of units.

- To take advantage of economic order quantity from the supplier.

The short lead time from the supplier to the warehouse of 1 day is hugely in favour to Profection. Profection has built an extremely good relationship with their raw material supplier over the past ten years. This eliminates the larger safety stock levels which are actually compulsory to any warehouse operations. Small amount of full sheet metals are stored in the warehouse. The main use of the warehouse will be for the storage of off cut sheet metals.

The inventory ordering model for Profection is unique to their operation. The fixed- order quantity (Q-model) or fixed-time period (P-model) inventory systems can not be used to manage inventory control, because of the huge variation in demand. The figure below illustrates the TO-BE inventory ordering model for Profection warehouse.

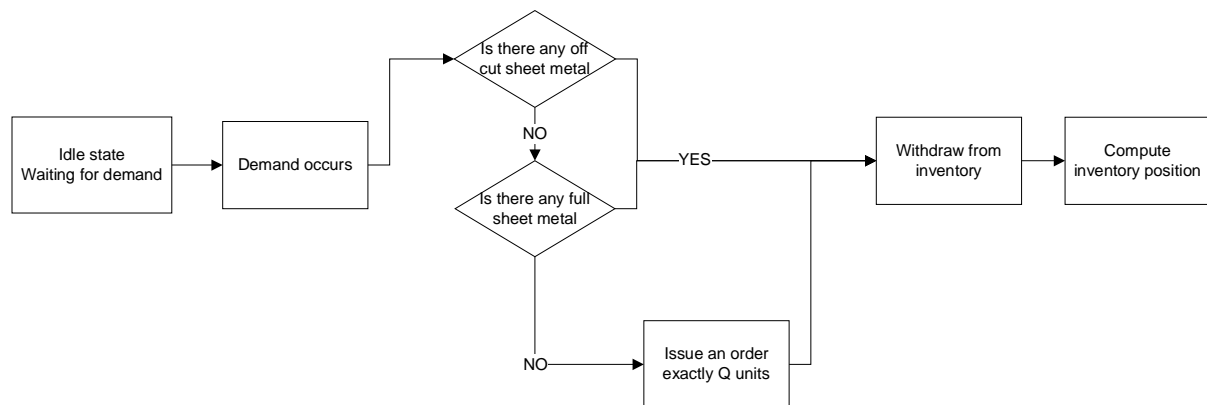


FIGURE 7: INVENTORY ORDERING MODEL

Still the costs of designing, implementing and maintaining a warehouse are significant. Analysis is done to determine whether to keep the off cut sheets or not. Is it feasible to store these off cut sheets and for what period? What is the probability that these off cuts in the warehouse will be used for manufacturing?

The following assumptions are made for calculation purposes:

- Average type and size of sheet metal in warehouse – 4mm Stainless steel
- Price for 4mm Stainless steel sheet of 1250mm x 2500mm is R5843, R55/kg.
- Lease income of R24m<sup>2</sup> per month when warehouse is not used by Profection
- Warehouse property value of R1600/m<sup>2</sup>.
- Property tax of 0.07% per year.
- Property depreciation of 5% per year.
- Employment salary of R120 000 per annum.
- Interest rate of 11%.
- Maintenance on the warehouse of R3000 per year.
- Electricity of R12000 per year.



FIGURE 8: KEEP VS SELL GRAPH

Results show that, if the off cut sheet metal is not used after 22 years from storage entry date it will yield as no benefit to the company. Sell the off cut sheet metal instead to create open space for other raw materials which can be of more benefit to the company. During the first 22 years, keep the off cut sheet metals to optimise profit for Protection warehouse. If the probability exist in which case the off cut sheet metal will not be used in the next 22 years, then it will be the best option to sell the off cut sheet as scrap metal before storing it into the warehouse.

### 7.3 WAREHOUSE COSTS

The warehouse improvement costs are a once off payment to implement the TO-BE system. These costs are a minimum compared to the actual return on investment (ROI) the company would gain. The ROI will be depended on the customer demand and the profit gained on each job. The more customers and profit the higher the ROI. An assumption can be made by saying that the payback period can be within one year from implementation of the project.

Cost analysis:

#### Warehouse improvement costs

Cost item	Description	Per unit	Quantity	Total
<i>Off cut racks</i>				R 90 280.04
Square tubing (40mm)	500m	R133.81/m		R 66 905
Sheet metal (2mm Stainless)	25m <sup>2</sup>	R55/kg	8 sheets	R 23 375.04
<i>Trolley (x2)</i>				R 7 198.08
Wheel	8 wheels	R200/w		R 1 600
Sheet metal (2mm Stainless)	1250 x2500mm	R55/kg		R 2 921.88
Square tubing (40mm)	20m	R133.81/m		R 2 676.20
PC				R 4 000
Office equipment				R 2 000
Labour	3 workers/3days	R40/h		R 2 880
				<b>R 106 358.12</b>

The operational costs of the warehouse are categorised into fixed costs and variable costs. As seen in the analysis below, the labour costs are the highest expenses.

### Warehouse operations costs per month

	Cost item	Description	Per unit	Quantity	Total
<b>Fixed costs</b>	Labour	1 manager	R45/h	160h	R 7 200
	Overhead	Electricity			R 3 000
	Maintenance				R 500

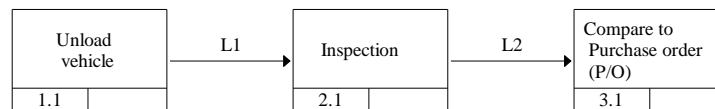
#### Variable costs

	Marker pen	85 sheets	R 0.1/s		R 8.50
	Masking tape (45mm x 40m)	85 sheets	R 0.07/s		R 5.95
					<u>R 10 714.45</u>

## 8. FACILITY PLANNING

### 8.1 WAREHOUSE OPERATIONS

The *receiving* operation is done at no specific time. The uncertainty in the low volume high variety job shop creates an unstable ordering policy from the supplier and also an unstable generation of off cuts which need to be brought to the warehouse. Therefore the receiving operation needs to be flexible as any other operation in the company. The warehouse operator needs to be informed when receiving is about to happen, to ensure a spacious area for unloading, determining the location of the sheet placement beforehand if possible and inquiring the invoice.



The *put away* operation of the new sheets from the supplier and the off cut sheets from the shop floor should be dealt with accordingly. A new entry is created in the database system for the particular sheet, containing all information regarding the sheet. The database classifies the product ID and storage location for the particular sheet. Masking tape and marker pen are the product identification equipment to be used for the sheet metal. A 45mm x 120mm masking tape strip is stuck onto the right hand corner of the sheet metal, then with the marker pen the product identification number and the storage location code is written, separated with a dash bar (figure 9 shows an example of such an identification code). Reason for this identification method; the low raw material unit cost, the disposable code strips, the high inventory turns increases the need for frequent change of identification, the most reliable and effective method for this particular robust environment.

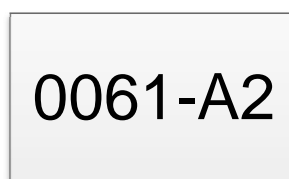
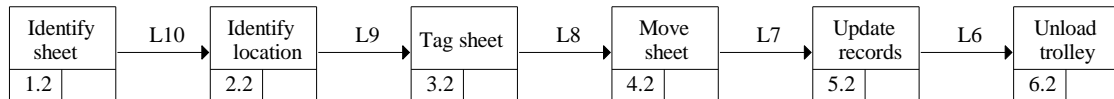
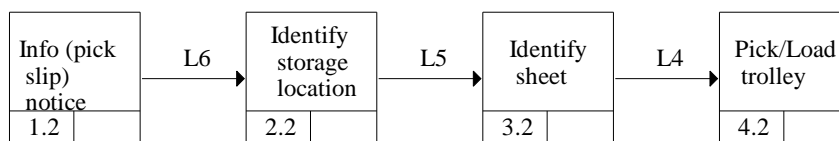


FIGURE 9: IDENTIFICATION CODE



*Order picking* operation in the warehouse is done as follows. A pick slip is received from nesting and planning department that contains either the specific sheet to pick or just a specification. With this specification the warehouse operator searches the inventory database for the most appropriate sheet for the job to be done. The database points out the storage location of the sheet. The trolley operator now picks the sheet from the bin and loads it onto the trolley, whereby it is moved to the fabrication department indicated on the pick slip. The database is updated to show the output from the warehouse.



*Stock taking* is the process of comparing actual inventory in the warehouse against the database system. Previously the company had no specific figures on how much and which types of materials were stored. No official stock taking was done to determine the unknown, only a few operators had an idea of the inventory that was stored. As when the warehouse and all of its operative systems are in place the stock taking should be done once or twice a year, especially just before the financial year end. As many counters (workers) as possible are needed to complete this task, to ensure a fast and effective count.

The process model in appendix D shows how the warehouse operations fit into the overall model.

## 8.2 LAYOUT DESIGN

Profexion already has a building structure on site available which can serve as an inventory warehouse. By efficiently utilizing the space the company own, the company's costs can decrease and eliminating the requirement of additional infrastructure. The total available space to carry inventory has an area of  $230m^2$  and cubic space of  $1320m^3$ .

Figure 10 illustrates the layout of the warehouse with all the operating equipment. The full sheet metal racks will be placed near the entrance of the warehouse to easily accommodate the fork truck movement. The fork truck dimensions are  $4.8m \times 1.2m \times 2.2m$ . The punch machine ( $6m^3$ ) needs to be situated in the warehouse because the shop floor space is up to capacity. The isle in the middle of the warehouse is divided into two parallel lanes which is necessary for off cut sheet picking on both sides. The isle of  $6m$  is wide enough to facilitate trolley movements. The office space required for the warehouse operator with his desk and computer is round about  $6m^3$ .

The receiving and sending operations are done through one warehouse entrance. The operator is placed next to the entrance to supervise these receiving and sending operations.

Inside the current facility there are a few machines that occupy some of the space. It is requested from the company that these machines cannot be moved out of the facility, but can be shifted about. Measurements of these machines are according:

- Machine 1 and 2 - 1 x 1 x 2m
- Machine 3 – 1 x 2 x 2.5m
- Machine 4 – 3 x 2 x 2m

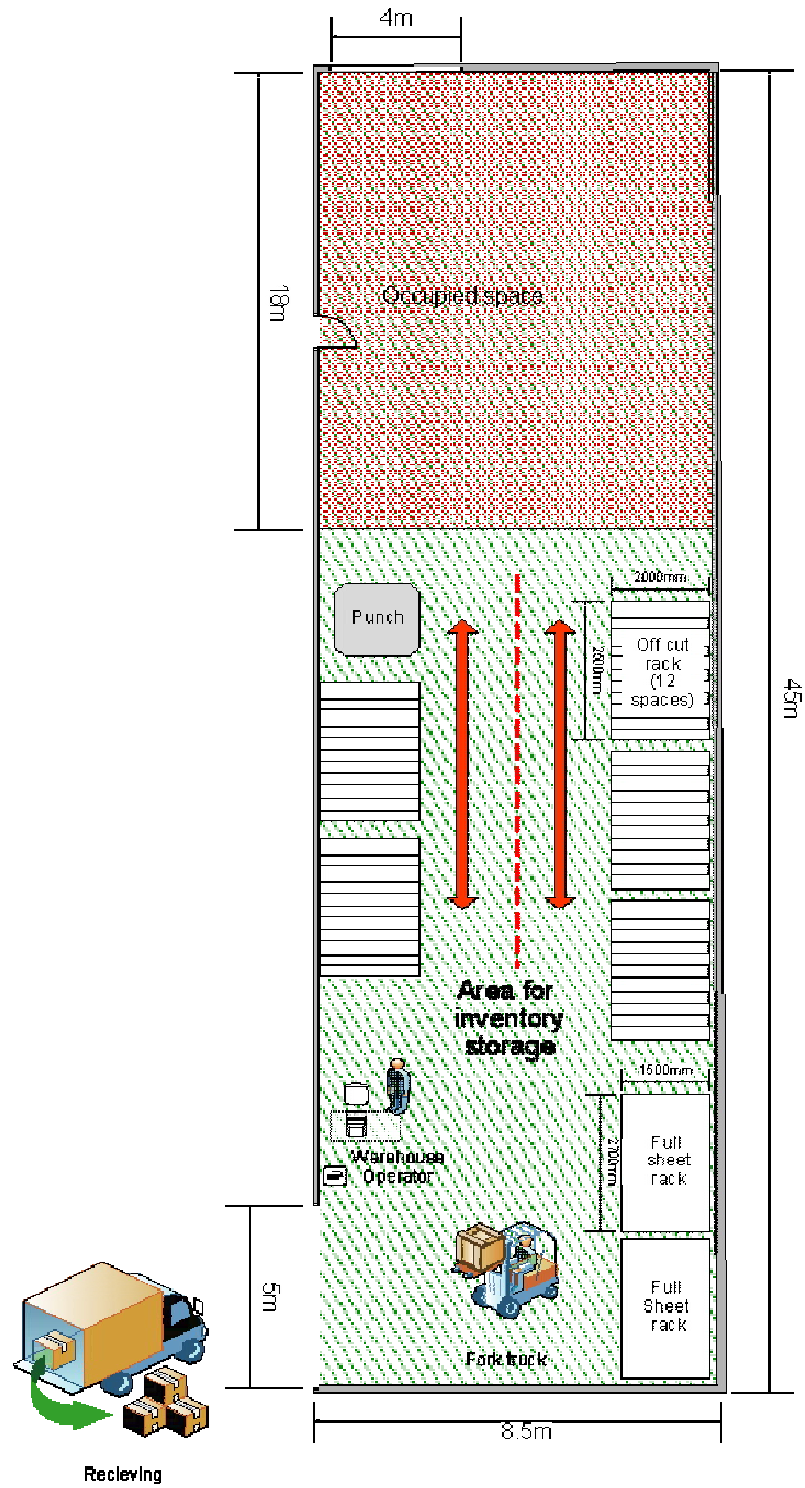


FIGURE 10: WAREHOUSE LAYOUT

## 8.3 STORAGE EQUIPMENT

Because Profecion specializes in manufacturing, they have the capability of building their own storage equipment. Mild or low carbon steel is used to construct this equipment, for this common steel price is relatively low. The following material is used to build the full sheet rack:

- square tubing of 75mm x 75mm, about 30m for one rack
- square tubing 50mm x 50mm, about 15m for one pallet
- angle bar 70mm x 70mm, about 15m for one rack

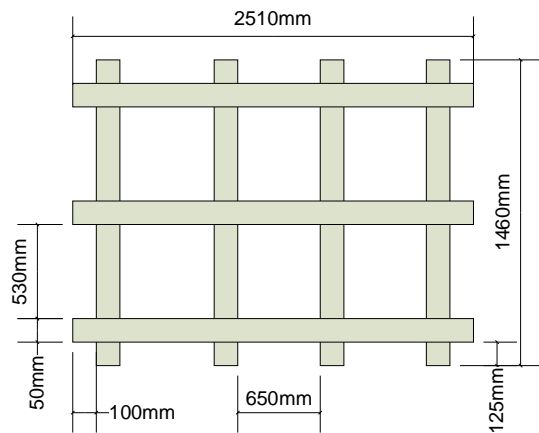


FIGURE 11: SHEET PALLET

The full sheet metal will be stored on the pallet (see figure 11) into the rack shown in figures 12 and 13. The height of the rack is up to maximum, because the warehouse roof and fork truck lift limits the height storage. The unused space beneath the rack is open for any other storage of goods, because the job shop is mostly unpredictable; therefore space is available for this kind of occurrences.

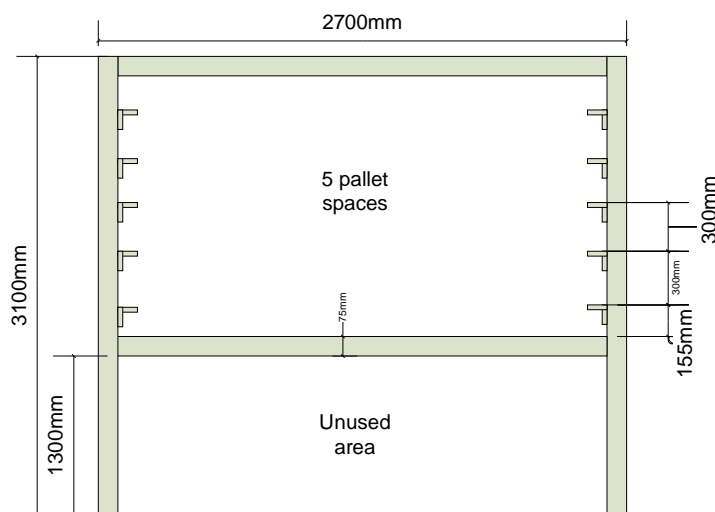


FIGURE 13: SHEET RACK (FRONT)

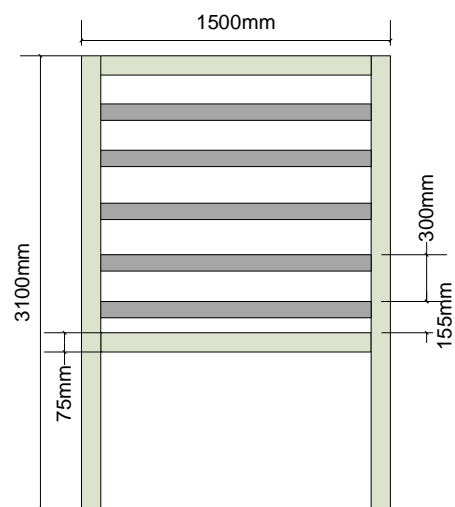


FIGURE 12: SHEET RACK (SIDE)

The off cut sheets will be stored in an upright position into the rack shown in figure 14. This rack is also built from mild steel with the following configuration:

- square tubing of 40mm x 40mm, about 95m
- sheet metal of 2mm, about 5m<sup>2</sup>

The rack exists with 12 open spaces to store off cut sheets.

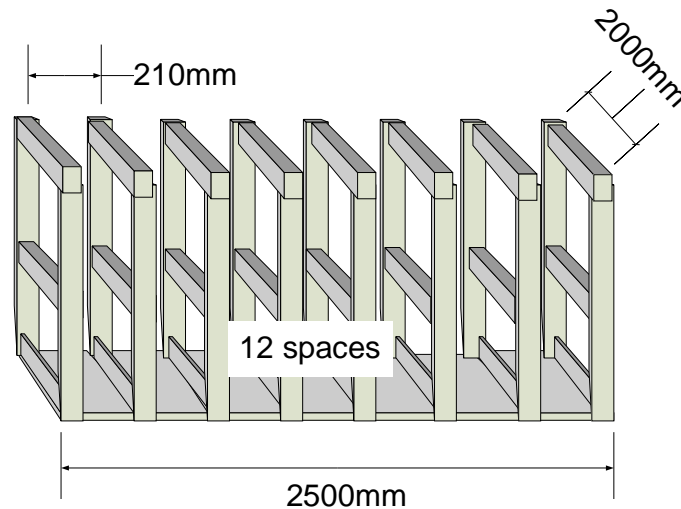


FIGURE 14: OFF CUT RACK

## 8.4 MATERIAL HANDLING EQUIPMENT

To improve material flow within the manufacturing company the common trolley will support as such. Protection can build the trolley themselves to their own specifications with the following material:

- square tubing of 40mm x 40mm
- sheet metal of 2mm
- 4 wheels with diameter of 100mm

The trolley's purpose is to move the off cut sheets between the shop floor and the warehouse. The trolley is well balanced and ergonomically designed to accommodate the operator when off cut sheets are transferred. The trolley serve as a quality management feature when off cut sheets are being delivered just in time and with no hassle. Another quality feature is the minimum sheet residual after a job, because now the operator can remove unwanted sheet material with this trolley.

One forklift is in use at the job shop. Size dimensions of this vehicle are 4.8 x 1.2 x 2.2m

## 8.5 WAREHOUSE STORAGE CAPACITY

The most common type of sheet metal to be stored in the warehouse is stainless steel. The graph below shows the most common stainless steel thickness to be stored, with an average of 3.14mm and a standard deviation of 2.05mm. To next round up number from 3.14mm is 4mm. Therefore an assumption is made that 4mm stainless steel sheets are mostly stored in the warehouse.

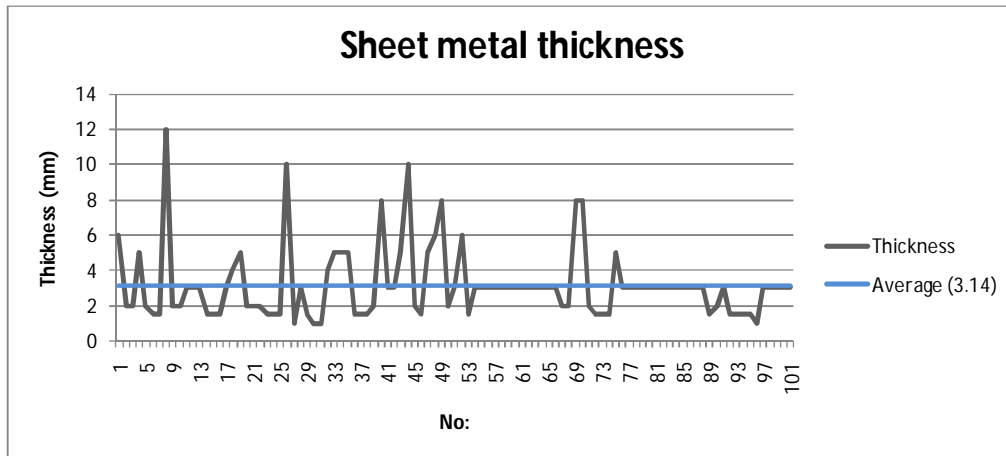


FIGURE 15: SHEET METAL THICKNESS GRAPH

One full sheet rack has a storage space of 1250mm x 1250mm x 2500mm, which result in storing 312 stainless steel 4mm sheets. The total average storage capacity for full sheets is 624. Presenting it in an average weight capacity, the result is about 66 ton, when stainless steel has a density of 8.5 g/cm<sup>3</sup>.

One off cut sheet rack can store about 630 off cut sheets, resulting in a total of 3150 stored off cut sheets in the TO-BE warehouse layout. Again, the average 4mm stainless steel sheet is used for calculations. One rack will have an average weight of 67 ton when stored up to full capacity. Giving a total average weight capacity for off cut sheet metal of 334 ton in the warehouse.

## 9. TOTAL QUALITY MANAGEMENT

### 9.1 STATISTICAL PROCESS CONTROL

It will be of great value to the company to reduce the variation in off cut sizes and scrap metal. The process output of the laser cutters and process input of the warehouse will be known with greater assurance.

When analysing the graphs in figures 16 and 17, a definite trend can be seen. Each sheet is cut and the percentage size off cut and the percentage size scrap is noted down. After a sample size of one hundred jobs, the graphs below are drawn. Upper and lower control limits (UCL and LCL) which are the  $3\sigma$  limits are shown on the graphs. Points that are out of control are the points that are above the UCL and below the LCL. Because this is a job shop operation the variation is extremely high. Definite trends can be seen on the graphs that too many points are above the UCL in figure 16 and too many points are below the LCL in figure 17.

The inventory management model's aim is to increase the actual scrap size percentage per sheet and decrease the off cut size percentage per sheet. This will result in fewer off cut sheets, fewer inventories stored in the warehouse and increase in profit.

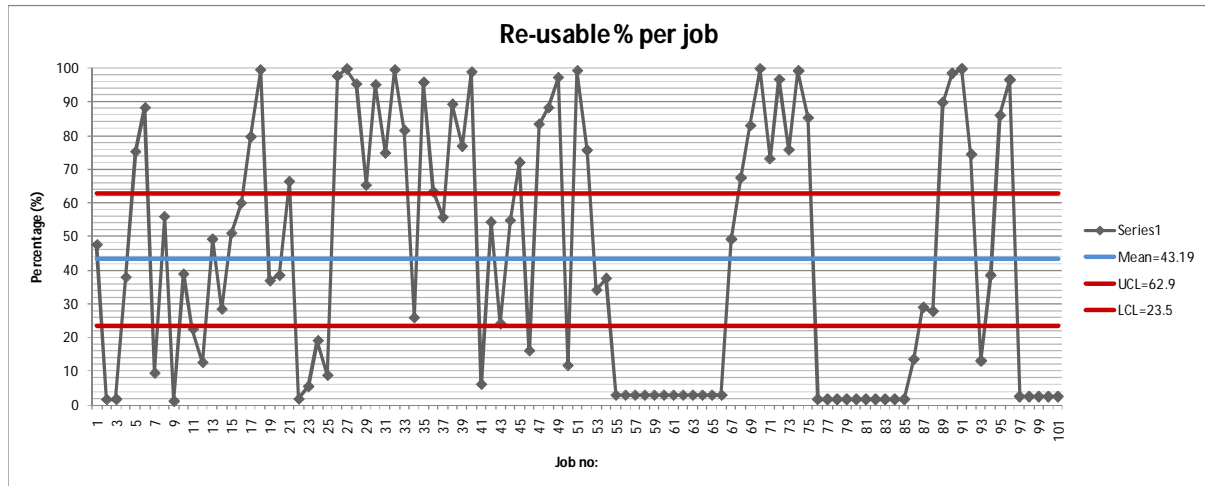


FIGURE 16: SPC-REUSABLE % PER JOB

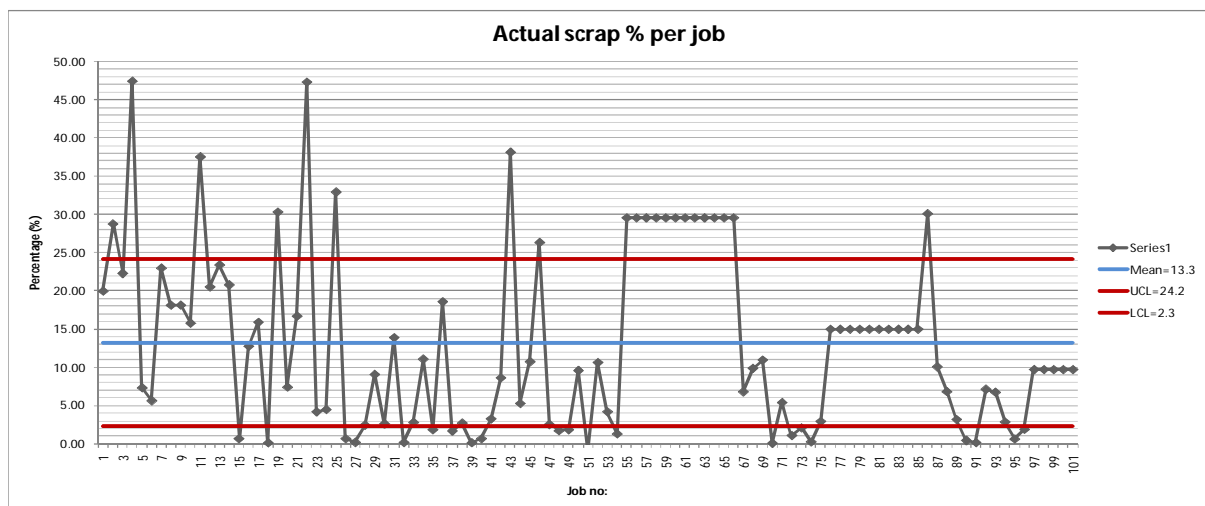


FIGURE 17: SPC-ACTUAL SCRAP % PER JOB

## 9.2 5'S WORKPLACE ORGANISATION

Any quality system states the truth of “doing it right the first time”. To sustain a quality inventory warehouse the 5’s workplace organization principles should be focused on.

*Sort* – identify all inventory that are not in the correct place. Inventory should either be in the warehouse in the correct storage location, or in transit to the job shop, or in the job area, waiting to be processed. Newly generated off cuts should be moved back to the warehouse.

*Set in order* – Because off cuts appear in almost every size, shape and type, product families need to be identified to store these off cuts into standards. A type and size off cut sheet will be ranged into either a small range or big range, for example, a 2mm stainless steel off cut sheet will be stored either in bin location A1 or A2, depending on the size off cut compared to the original sized sheet. Smaller than half of 2500mm x 1250mm will be stored into A1 and off cut larger will be stored in A2. This location is easily accessible to the operator and a unique range for an off cut sheet.

*Standardize* – Continuous sorting are necessary to maintain a standard. The database contains the different storage locations available for storing a sheet. Above each bin location a tag is placed to indicate the type and number of the bin below. This standard decreases the time of the put away

operation, operators will know exactly where to go, no time will be wasted by searching and speculating.

*Shine* – Clean the warehouse on regular basis. Not just cleaning but also inspect through cleaning, where equipment is checked for problems to prevent any further damages. Preventative maintenance is an important factor of achieving quality in the work environment.

*Sustain* – The warehouse manager will approve 5's implementation through filling out the check sheet provided (see appendix B). Worker performance and warehouse performance are measured to continue improving quality management.

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### 9.3 ROLES AND REPSONSIBILITIES

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Insights into one's own work determine the operator's effectiveness. Their performance depends on how well they understand their roles and responsibilities and their response on dilemmas in the work place. The following points present the roles and responsibilities of warehouse employees.

*Warehouse chief operator:*

- Unlock and lock inventory warehouse before and after a working day.
- Update inventory database, inputs and outputs of the warehouse.
- Manage the shine principle in the warehouse, by keeping all sheets in correct locations.
- Complete the warehouse quality performance sheet at the end of each week to reflect the weeks work.
- Manage the stock counting procedures every 6 months as scheduled.
- Report to top management on a regular basis the performance status of the warehouse.
- Do key performance measures and report to top management.

*Sheet metal picker:*

- Every working day the picker should check in at the warehouse chief operator, before starting with scheduled duties.
- Move sheet metal to and from the shop floor in an efficient and pro-active manner.
- Place identification code onto the stored sheets.
- Place all inventory in the correct storage location as indicated by the database software or by the labels above the inventory racks.
- Report any maintenance to be done on the trolley to the warehouse chief operator.
- Assist the warehouse chief operator in updating the inventory database.
- Assist in the receiving operation.
- Apply the shine principle in the warehouse, by keeping all inventory, tools and equipment in the allocated areas.
- Do stock counting every 6 months as scheduled.
- Receive pick slips from the warehouse chief operator.

*Fork truck driver:*

- Offload inventory from the supplier vehicle.
- Move the bulk sheet metal, which can not be moved by the trolleys, to and from the shop floor in an efficient and pro-active manner.
- Report any maintenance to be done on the fork truck to the warehouse chief operator.
- Load heavy scrap metal into the bulk bin outside the warehouse.

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## 9.4 BEST PRACTISES

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Best practices are a technique or methodology used to achieve a desired result. Through using all knowledge and technology, success in the warehouse can be sought after. It is the best possible way to manage the inventory warehouse, which will result in the most beneficial results for Protection as a company and entire supply chain. The best practices in this document are derived from the Supply Chain Operations Reference Model version 9.0.

- All key participants or strategic partners have full visibility of the demand to ensure optimised planning.
- Data accessibility is essential across the discrete business units of the company.
- Automated pick list received from the inventory database which generates pick lists based on picking rules.
- Clarify in advance the product storage location of material.
- Confirm all documentation and inspection requirements before movement of material.
- Continuous improvement by reviewing key performance indicators of processes, cause and effect analysis.
- Manage supplier network, to create and maintain multiple suppliers including services and information.
- Training and certification support for employees from the human resources department.
- Cross docking procedures to eliminate unnecessary storage of inventory. Move the inventory directly to the manufacturing area and processes.
- First in - First out (FIFO) principle applied to the inventory warehouse. The first entered materials in the warehouse should be used first in the manufacturing operations, thereby minimising the storage time of materials.
- Transportation visibility presents readiness at the receiving end.
- Organise warehouse management to enhance flexibility, which is the ability to respond to customer demand.
- Paperless inventory warehouse management refer to electronic processes.
- Periodic review of metrics and strategy compared to industry benchmarks.
- Removal of obsolete and scrap sheet metal.

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## 9.5 KEY PERFORMANCE INDICATORS (KPI'S)

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KPI's measure the different areas of performance in the functional process. Such measures help the company define and realise how successful their inventory warehouse functions. The warehouse KPI's are categorised into the following:

### *Process perspective*

- Unit count accuracy – the accuracy by which the suppliers deliver raw materials.
- Lead time – average time from receiving the pick slip to delivering to the shop floor.
- Obsolescence – Number of obsolete sheets per period in stock.

### *Financial perspective*

- Insurance – Insurance cost per unit in warehouse.
- Average cost per unit – Total warehouse costs applicable to one sheet.
- Lost sales analysis – Lost sales occurred when no inventory were available to supply the demand.

### *Storage efficiency*

- Inventory turnover rate – Cost of sales per average inventory level.
- Inventory levels – Comparison between the actual inventory level and the recorded inventory level.
- Space utilisation – Percentage occupied space per period.

### *Supplementary perspective*

- Staff satisfaction – Satisfaction rating per warehouse employee.
- Reported accidents – Health and safety feature. Quantitative and seriousness.

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## 10. BUSINESS MODELLING

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Business engineering is a framework for introducing change into a business system. The principle of this framework is a low volume, high variety business system. Business modelling is used as a method and technique to increase business productivity and expansion of the inventory warehouse. The business model for the inventory warehouse is categorised in the organizational structure, functional model, process model and the data model.

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### 10.1 ORGANIZATION STRUCTURE

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The organization structure (in figure 18) reflects the warehouse’s integrated business position within the Protection company structure. The warehouse function communicates with procurement, finance, planning and nesting, and fabrication to full strive toward the common company goal. Great success is achieved by letting your organization operate as a unit. The inventory warehouse leg of the company was broken and therefore this project restores that function to lift up the company, to achieve greater productivity.

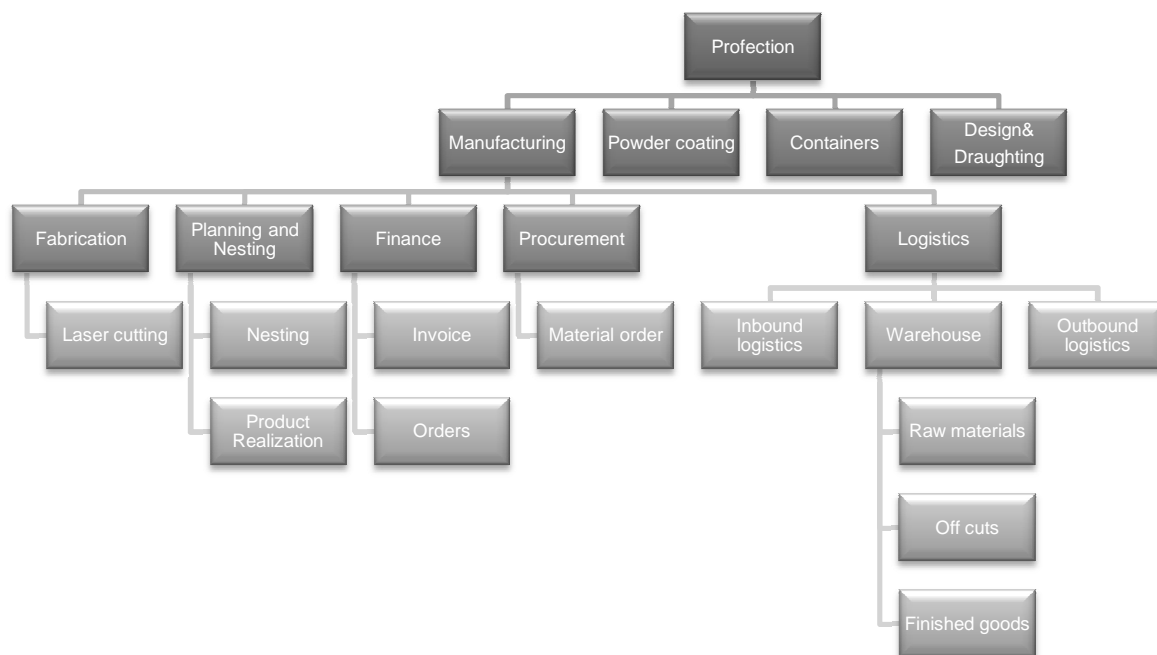
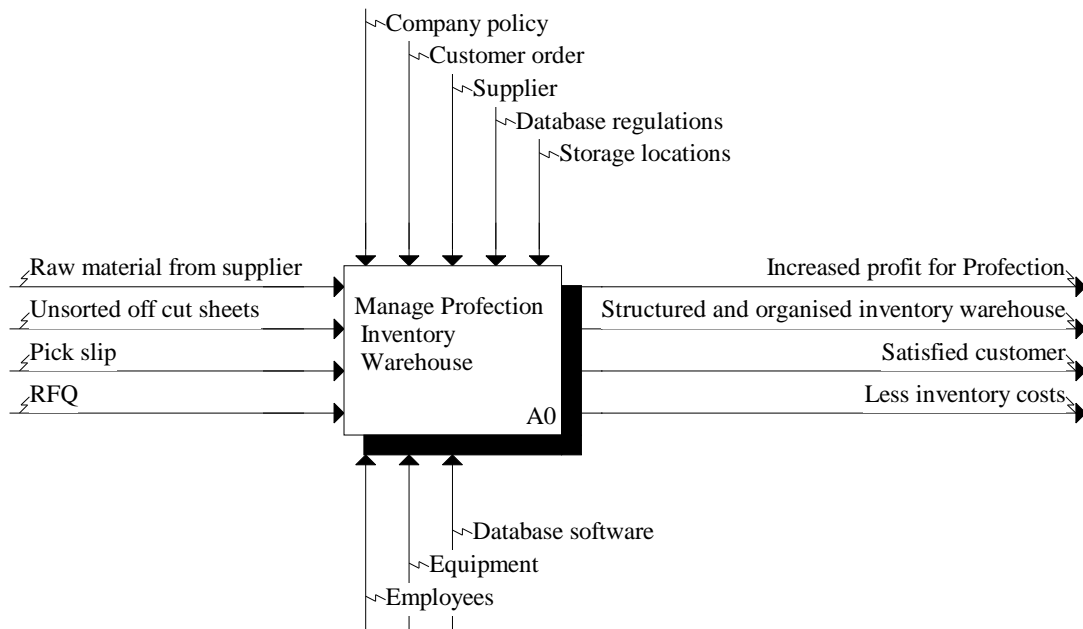


FIGURE 18: ORGANIZATION STRUCTURE

## 10.2 FUNCTIONAL MODEL

The diagram contains the top level functionality of the warehouse with factors such as inputs, outputs, mechanisms and controls that influences the warehouse activities.



The completely decomposed functional model with all its levels is shown in appendix F.

## 10.3 PROCESS MODEL

The process flow of the organization is done using the IDEF3 software to illustrate how things work. The objective of this specific process model is to demonstrate the proposed functionality of the warehouse and how the processes around the warehouse interact as inputs and outputs on the warehouse.

Any job in this organization begins with the customer, if no orders are placed the warehouse won't function, after all the company will lose business. So the customer requests a quote, and places the order if satisfied. Immediately the next steps are taken to create a job card and planning the manufacturing of the product. To manufacture the product the company requires a particular sheet metal. The inventory warehouse is checked through accessing the inventory database whether the required sheet metal is present.

Then if the particular sheet metal is at hand, the warehouse activities are triggered to supply the shop floor with the sheet metal at an efficient schedule. The warehouse operations are described in further detail under section 8, facilities planning. The sheet metal arrives at the shop floor where it is placed onto the laser cutter bed. The setup schedule is compared with the correct job card to eliminate imperfection. After fabrication the sheet metal is split into two, one side is the customer product and the other is the generated off cut sheet. The product is stored or processed further and then delivered to the unique customer. The off cut sheet is loaded onto the trolley and moved to the inventory warehouse, where it is stored into the appropriate bin location. The inventory database keeps track of all inputs and outputs of the warehouse.

If the required sheet metal is not at hand in the warehouse, the procurement procedures take place. When receiving the acquired raw material, the warehouse identifies the invoice, and inspects the raw material. Offloading is done by the fork truck and the raw material is put away in correct bin location. Again the inventory database is updated. This procured raw material now is order picked and then sent to the shop floor to take on fabrication, as described in the previous paragraph.

If any uncertainty in process flows occurs, the process model diagram can assist in understanding the warehouse processes.

## 10.4 DATA MODEL

### 10.4.1 MODEL

The standard used to construct the data model is the integration definition for information modelling (IDEF1x). The model's objective is to give an overall understanding of the inventory warehouse's data resources.

The first step in doing the information modelling is to construct a use case diagram, in figure 19, which illustrates the relationships between the inventory warehouse system and the external agents. After receiving information about the stakeholders and their expectations from the system, an entity relationship diagram (ERD) is built to define the business requirements.

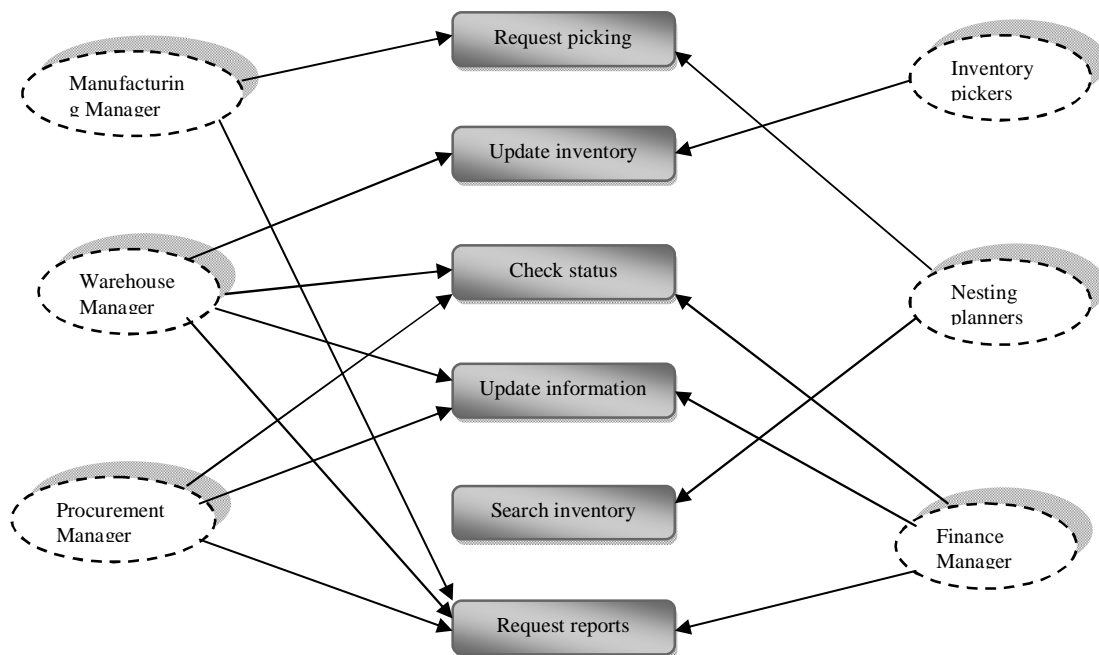


FIGURE 19: USE CASE DIAGRAM

The ERD in figure 20 makes the following statements:

- Data needs to be stored within the six entities.
- The supplier delivers many materials and of different types to the warehouse.
- Each material received has a unique shape, and are classified into either a square shape or an L-shape.
- The inventory warehouse contains many stored materials.

- These materials all have only one storage location according to their size, shape and type.
- The warehouse has one or more employees which are assigned to their duties.

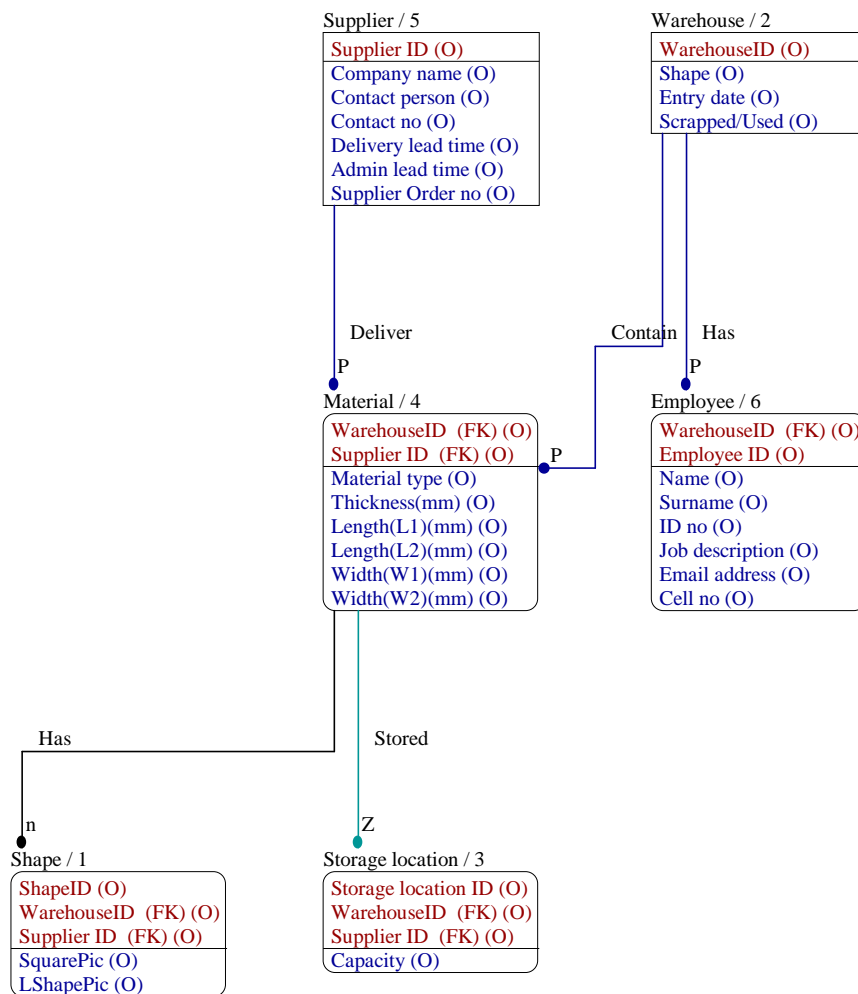


FIGURE 20: ENTITY RELATIONSHIP DIAGRAM (ERD)

#### 10.4.2 PROFECTION INVENTORY DATABASE

The statement of purpose of this inventory management database is to control the flow of materials and information, resulting in decreased costs and decreased operation times.

The scope of the data model contains the following key aspects:

- Procurement
- Receiving of materials
- Storage allocation
- Issuing to shop floor
- Supplier and employee information

The inventory database model is built in Microsoft Excel 2007 to accommodate the required user compatibility. Although this inventory database forms only a small section of the project, it remains highly essential. Microsoft Access 2007 software is not used, because of certain programming complexity regarding this inventory database.

A few screen shots are shown in appendix E just to give a slight demonstration of the user interface. The full database program is attached to the document on disc.

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### 10.4.3 OPERATIONAL MANUAL

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Basics for how to use the inventory database:

*Getting started* – Open the program on a Microsoft Excel enabled pc. Once the program is opened, click on options to enable the macros. Click on the “Menu” tab to start working.

*Receiving materials* – In the main menu section click on the “Add entry” button. If the material is an off cut sheet, go to the off cut sheet picture, on the right hand side of the screen and type in the dimensions. If the material is a new sheet, go to the left hand sided picture and type in the dimensions there. After the dimensions had been typed in, complete the type of material and thickness information by selecting from the drop down list in the allocated block. When finished click on “Submit”.

*Warehouse materials* – Click on the “Warehouse” tab to see the current inventory status. To print the list, click on “Print preview”. Where after the print button will be present in the top left corner. When finished printing click on the “Close” button, where the user will be taken back to the warehouse list.

*Search materials* – In the main menu section click on the “Search” button. Now the user can search according to the criteria longed for by clicking on any of the drop down lists. Select the check boxes to show in the remaining list. Click “OK” to see the filtered list.

*Scrapping materials* – In the main menu section click on the “ Remove entry” button, this will take the user to the warehouse list. From the drop down list in the scrap/used column, choose yes. This highlights the row to indicate the removal of the entry.

*Storage location* – The storage location ID will be shown automatically after a new submission. Choose one location. Click on “ Enter storage location” , which will take the user to the warehouse list. Type in the correct row/column the storage location ID.

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## 11. CONTINUOUS IMPROVEMENT

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Continuous improvement also known as “Kaizen”, a term originated from the Toyota production system. “Kaizen” is where a company strive to improve manufacturing processes by working together as a team. In order to change processes, the people need to understand the implications and intentions of the overall company strategy. The current proposed TO BE state specified in this document need to be tested, analysed and understood. Only then a future state can be defined and implemented. During the study of this project a number of future state changes were identified. This processes need to be studied further to ensure practicality.

*Bar code scanning* – Shelf/rack scanning upon put away and picking. No bar codes on the sheet metal itself, as stated in the document, only on the shelf/rack.

*Automatic storage system* – Additional equipment integrated with the Trumph TruLaser, namely the Trumph TruStore, which speeds up the work. This machine continuously feeds the laser cutter. It is a fully automated system, which requires no labour at all.

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## 12. CONCLUSION

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The industrial engineering tools studied during the degree made it possible to address the problem, Profecion manufacturers had. The basis of any industrial engineering project would be to balance man, machine, material and money to ensure a sustainable business through using business processes.

Profecion manufacturers are in the process of implementing the project at their inventory warehouse. So far, the inventory warehouse changed significantly, from the AS-IS state to the TO-BE state. Effective results of the project surfaced in a short period, showing additional income from doing a job, without purchasing raw material. The off cut materials on hand were used to complete the orders, no need to obtain new sheet metal. The results are highly depended on the demand from the customer, but every time when off cut sheet metal is used to complete a job it simply doubles the profit per sheet.

The uncertainty of customer demand made this project rather challenging to design, implement and maintain. Many assumptions and practical applications were made to even out the uncertainty to create a flexible basis for fast and effective manufacturing.

Through continuous improvement and effective management at the inventory warehouse, the company can and will stay one of the leading manufacturing job shops in the country.



## APPENDIX C

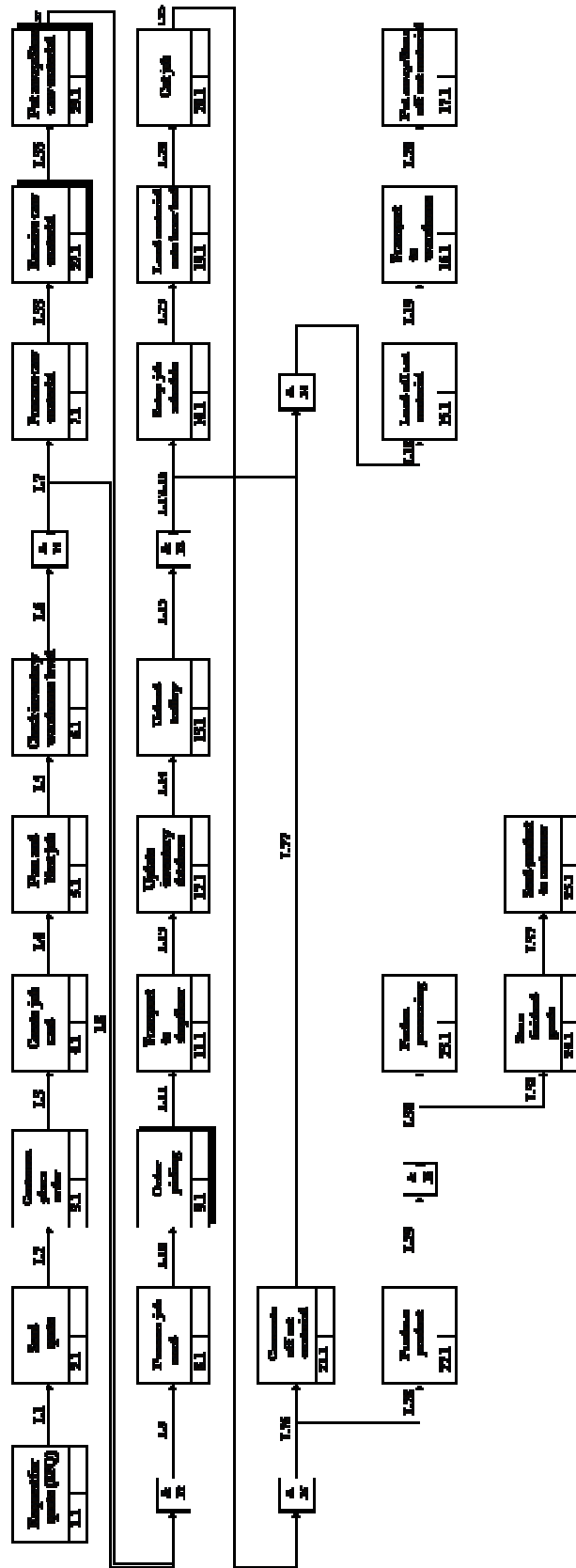
### TRUTOPS Set-up schedule General Data

	Job name	Blank		Rotated Blank		Off cut used	Min Blank required		Scrap(%)	Reusable sheet(%)	Storage Range	Actual scrap(%)
		Thickness	Length	Width	Length		Width					
1	2221	6	890	110	offcut	471.15	109.07	67.49	47.51	5	19.98	
2	2217	2	2450	1230		2445.13	1212.66	30.4	1.61	1	28.79	
3	2217	2	2450	1230		2447.28	1210.83	23.98	1.67	1	22.31	
4	2222	5	570	270	offcut	353.93	270	85.39	37.91	4	47.48	
5	2216	2	1250	970	offcut	970	310.9	82.46	75.13	8	7.33	
6	Kapilaan	1.5	2500	1250		1250	295.6	93.81	88.18	9	5.63	
7	Kapilaan	1.5	2500	1250		2363.6	1197.54	32.44	9.42	1	23.02	
8	2209	12	2500	1210	offcut	1202.92	1110	73.99	55.86	6	18.13	
9	2205	2	2500	1250		2488.11	1242.26	19.25	1.09	1	18.16	
10	2205	2	2500	1250		1529.64	1250	54.6	38.81	4	15.79	
11	Asblik	3	2450	1229.4	offcut	2419	965.79	60	22.44	3	37.56	
12	2183	3	2450	1220	offcut	2360.25	1106.98	33.12	12.59	2	20.53	
13	2183	3	2450	1220	offcut	1245.87	1220	72.59	49.15	5	23.44	
14	Kapilaan	1.5	2450	1225	offcut	1753.35	1225	49.24	28.43	3	20.81	
15	2194	1.5	2500	1250		1732.23	885.48	51.59	50.92	6	0.67	
16	2194	1.5	2500	1250		1732.23	723.68	72.67	59.89	6	12.78	
17	2218	3	2450	1230		1065.07	578.02	95.47	79.57	8	15.90	
18	2220	4	2450	1200	offcut	143.2	120.96	99.54	99.41	10	0.13	
19	2223	5	400	300	offcut	336.35	225.29	67.19	36.85	4	30.34	
20	2224	2	1250	1000	offcut	1210.87	635.5	45.87	38.44	4	7.43	
21	2225	2	2450	1230		1230	825.92	83.01	66.29	7	16.72	
22	2225	2	2450	1230		2444.4	1211.35	49.1	1.74	1	47.36	
23	2228	1.5	1250	850	offcut	1224.47	820.22	9.65	5.47	1	4.18	
24	2229	1.5	1150	170	offcut	958.48	165.07	23.56	19.07	2	4.49	
25	2229	1.5	740	520	offcut	734.23	478.07	41.74	8.78	1	32.96	
26	2231	10	2000	1000	offcut	259.7	188.2	98.23	97.56	10	0.67	
27	2230	1	2500	1250		141.87	67.47	99.87	99.69	10	0.18	
28	2232	3	2450	1250		1067.68	138.46	97.62	95.17	10	2.45	
29	2226	1.5	2500	1250		1250	870.37	74.26	65.19	7	9.07	
30	2234	1	2450	1200	offcut	561.3	262.18	97.61	94.99	10	2.62	
31	2235	1	2020	610	offcut	610	510.73	88.61	74.72	8	13.89	
32	2233	4	2450	1200	offcut	143.2	120.98	99.57	99.41	10	0.16	
33	2219	5	2500	1210	offcut	915.15	614.03	84.24	81.42	9	2.82	
34	2219	5	2500	1210	offcut	2440.15	918.89	36.96	25.88	3	11.08	
35	2227	5	2450	290	offcut	290	105.15	97.54	95.71	10	1.83	
36	2237	1.5	2500	1250		1250	919.71	81.8	63.21	7	18.59	
37	2238	1.5	1160	510	offcut	640.07	409.97	57.33	55.64	6	1.69	
										50.94	average	14.78
										33.59	stdev	12.96

The highlighted numbers in the column, reusable sheet %, is values that are less than 10%. An assumption was made to consider this sheet metal as scrap, because of the very low reusable sheet percentage.

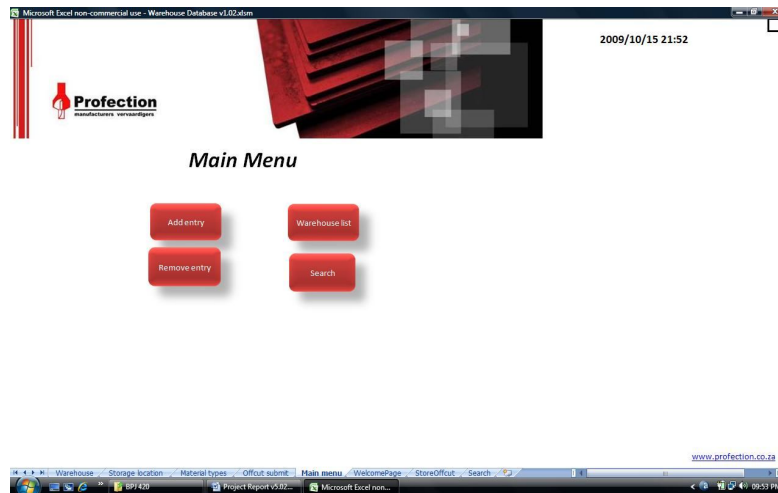
## APPENDIX D

The diagram below shows the entire process model of the inventory management model. The decomposition entities are illustrated by a shadowed block. These entities are *Receive raw material*, *Put away/Store raw material* and *Order picking*. The decomposition entities' processes are shown earlier under the topic Warehouse operations on page 14.



## APPENDIX E

### Main Menu page



### Warehouse inventory list page

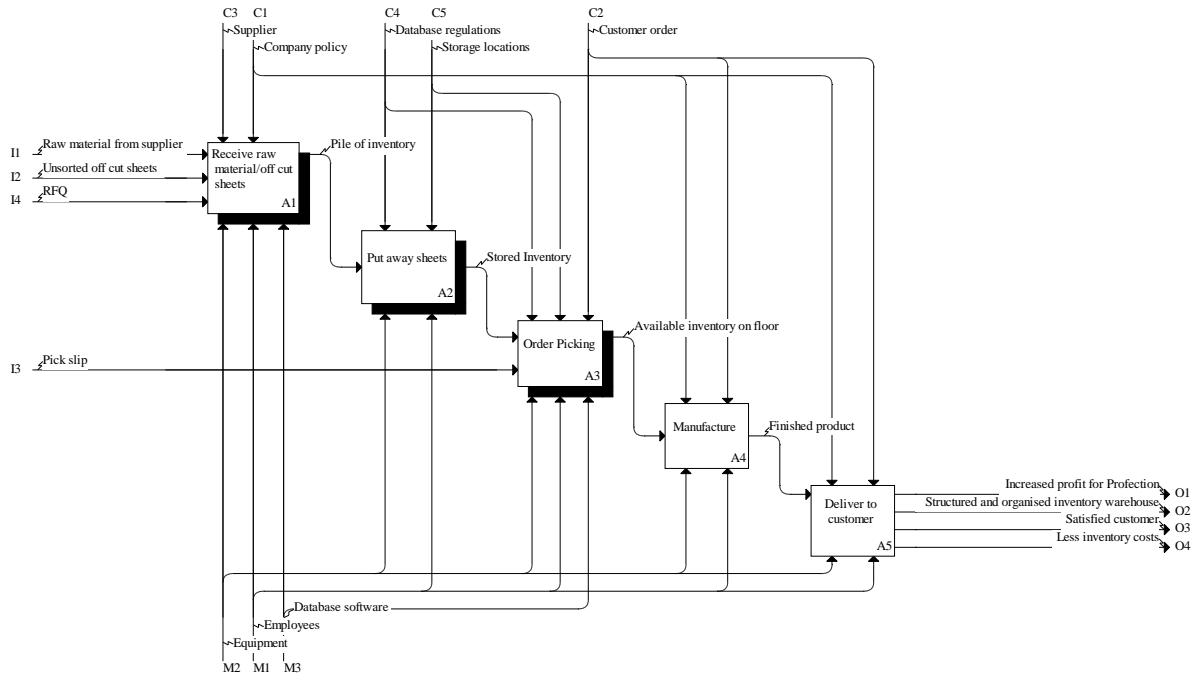
Sheet Code	Material type	Thickness (mm)	Length (L1)(mm)	Length (L2)(mm)	Width (W1)(mm)	Width (W2)(mm)	Storage location	Scrapped/Used
1	Mild steel	1	2500	0	1250	0	B8	Yes
2	Aluminium	2	1000	80	300	10		
3	Aluminium	2	1000	0	1000	0		
4	Aluminium	2	1000	0	1000	0		
5	Stainless steel	3	1	0	1	0		
6	Stainless steel	14	222	0	222	0		
7	Stainless steel	7	444	0	40	0		
8	Aluminium	2	999	0	99	0		
9	Aluminium	1	111	0	111	0		
10	Stainless steel	6	1224	0	123	0		
11	Stainless steel	6	111	0	222	0		

### Off cut sheet metal submission page

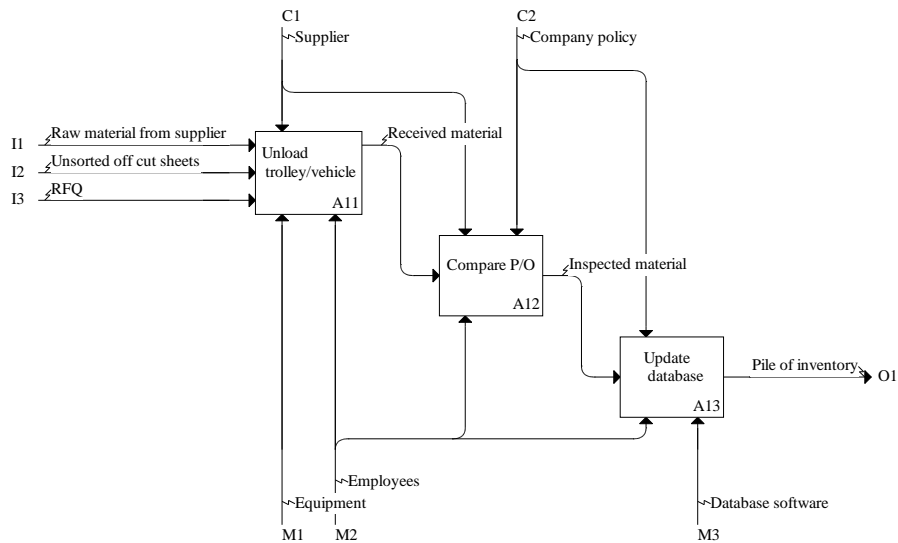
## APPENDIX F

The decomposed functional model for the inventory warehouse:

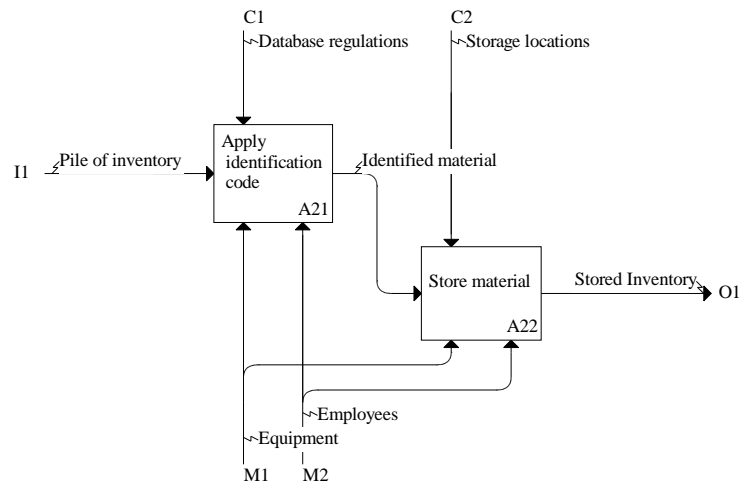
Level 1 of A0



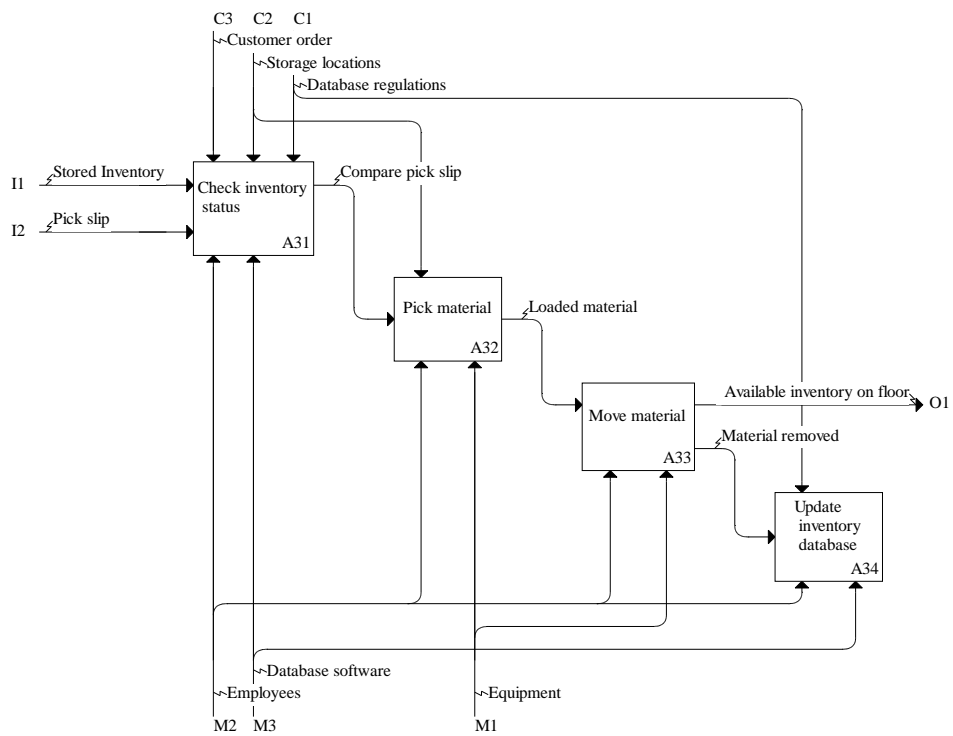
Level 2 of A1



Level 2 of A2



Level 2 of A3



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## REFERENCES

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- [1] [1]DeGarmo E.P, Black J.T, Kohser R.A, *Materials and processes in manufacturing 9<sup>th</sup> edition*, ISBN: 0-471-42944-9
- [2] [2]Doer, K.H., Gates, W.R., Mutty, J.E., 2006. *A hybrid approach to the valuation of RFID/MEMS technology applied to ordinance inventory*. International Journal of Production Economics, 1–16.
- [3] Draft Federal Information Processing Standards Publication 183, *INTEGRATION DEFINITION FOR FUNCTION MODELING (IDEF0)*, 1993 December 21
- [4] Drury, *Management and Cost Accounting 6<sup>th</sup> edition*, ISBN: 1-84480-028-8
- [5] Farley, A.A., *Mathematical programming models for cutting stock problems in the clothing industry*. J. Oper. Res. Soc., 1988, 39, 41–53.
- [6] Francis E.H. Tay\*, T.Y. Chong, F.C. Lee, *Pattern nesting on irregular-shaped stock using Genetic Algorithms*, Engineering Applications of Artificial Intelligence 15 (2002) 551–558
- [7] Fries-Knoblach, J., *Sheet-metal working in Bronze Age and Iron Age in Southern Central Europe*, in Proceedings of 7th International Conference on Sheet-Metal 1999, pp. 23–36.
- [8] Gabriela Buchfink, *Fascination of sheet metal*, 1<sup>st</sup> edition 2006, ISBN-10 3-8343-3071-X
- [9] Gary Conner, *Lean manufacturing for the small shop*, ISBN: 087263520 -1
- [10] Gue K.R., R.D. Meller and J.D. Skufca. 2006. *The effects of pick density on order picking areas with narrow aisles*. IIE Transactions, 38, 859-868.
- [11] Heskett J.L. 1963. *Cube-per-Order index – A key to workhouse store location*. Transportation and Distribution Management, 3, 27-31.
- [12] Howard S Gitlow, Alan J Oppenheim, Rosa Oppenheim, David M.Levine, *Quality Management*, 3<sup>rd</sup> edition, McGraw Hill International edition
- [13] [http://en.wikipedia.org/wiki/Business\\_model](http://en.wikipedia.org/wiki/Business_model)
- [14] Ian C. Smith, *AIM-an industry activity group for automatic identification*, COMPUTING & CONTROL ENGINEERING JOURNAL JANUARY 1990
- [15] James A. Thompkins, John A. White, Yavuz A. Bozer and J.M.A. Tanchoo, *Facilities Planning 3<sup>rd</sup> edition*, 0-471-41389-5
- [16] Jean Philippe Gagliardi, Jacques Renaud, Angel Ruiz, *A Simulation Model to improve Warehouse operations*, Proceedings of the 2007 Winter Simulation Conference, S. G. Henderson, B. Biller, M.-H. Hsieh, J. Shortle, J. D. Tew, and R. R. Barton, eds.
- [17] J. Jesitus, *Bar coding control inventory*, Hotel and Motel Management 210 (11) (1995) 30}38.
- [18] John Cope, Eman Kamel, Khaled Kamel, *Multidrop PC network/database server for material flow and inventory control*, Proceedings of the 9<sup>th</sup> IEEE Intemat~onaSI ywtposiusn on Intelligent Control 16-18 July 1997, h t ~ n b dT,u rkey
- [19] John J. Coyle, Edward J. bardi, C. John Langley Jr., *The Management of business logistics: A supply chain perspective 7<sup>th</sup> edition*, ISBN 10: 0-324-00751-5
- [20] Lonnie D. Bentley, Jeffrey L. Whitten, *System Analysis and Design for the Global Enerprise 7<sup>th</sup> edition*, McGraw-Hill International edition, ISBN-10: 0-07-110766-5
- [21] Mengfei Yu \*, René B.M. de Koster , *The impact of order batching and picking area zoning on order picking system performance*, European Journal of Operational Research 198 (2009) 480–490
- [22] Murty, K.G., *Linear Programming*, 1983 (Wiley: New York)

- [23] Professor Peter Hines & David Taylor, *Going Lean, January 2000*, ISBN: 0 9537982 0 8
- [24] Renaud, J. and Ruiz, A. 2007. *Improving Product Location and Order Picking Activities In a Distribution Center*, Journal of the Operational Research Society, forthcoming.
- [25] Richard B. Chase, F. Robert Jacobs, Nicholas J. Aquilano, *Operations Management for Competitive Advantage 11<sup>th</sup> edition*, 978-007-126048-0
- [26] Richard J. Mayer, Ph.D., Christopher P. Menzel, Ph.D., Michael K. Painter, Paula S. deWitte, Ph.D., Thomas Blinn, Benjamin Perakath, Ph.D., *INFORMATION INTEGRATION FOR CONCURRENT ENGINEERING (IICE) IDEF3 PROCESS DESCRIPTION CAPTURE METHOD REPORT*, September 1995
- [27] Rladen Varga, *Zachman Framework in Teaching Information Systems*, 25th Int. Conf. *Information Technology Interfaces ITI 2003*, June 16-19, 2003, Cavtat, Croatia
- [28] Triumph, Express 1/09, *Magazine for sheet metal processing*
- [29] Vassiliki Manthou\*, Maro Vlachopoulou, *Bar-code technology for inventory and marketing management systems: A model for its development and implementation*, Int. J. Production Economics 71 (2001) 157}164
- [30] Verlinden B., D. Cattrysse and D. Van Oudeheusden, *Integrated sheet-metal production planning for laser cutting and bending*. International Journal of Production Research, Vol. 45, No. 2, 15 January 2007, 369–383
- [31] *Quality without paper* , Manufacturing engineer, February 1997, IEEE Xplore
- [32] Zhen He, Qing'an Cui, Shuguang He, *Development of Integrated Quality Information System for Continuous Improvement*, IE Department, School of Management, Tianjin University, Tianjiin 300072, China
- [33] *5S for Operators -5 Pillars of the Visual Workplace*, Shop Floor Series, Productivity Press.