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Applying a Lean Analysis to Process Flow

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Dissertação de Mestrado

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Abstract

The conversion to Lean or Lean-ism, has become a worldwide phenomenon rapidly spreading into all business sectors. Its success has and continues to draw the attention of companies of all sizes. With an enormous number of organizations following the Lean philosophy, boast of experiencing vast improvements in quality, production, customer service, and profitability. This is made possible as Lean Manufacturing offers a systematic approach to identifying and eliminating waste through continuous improvement.

The purpose of this study is to conduct a Lean Analysis of Dinis de Oliveira & Filhos (DOF), processes, identify opportunities for improvements and the potential benefits to be obtained from improvements.

To accomplish this objective, it involved mapping activities for each of DOF products, analyzing both its supplier, production and demand variability, classifying the waste which is affecting their process, identifying opportunities for improvement and identifying lean tools that can be implemented to fine-tune their production process, to reduce waste and bring about improvements of DOF operation.

The results from the analysis showed that within DOF operation there are several forms of waste: overproduction, excessive inventory waiting and movement, not only waste but also experience high variability at both supplier and customer end of its operation. All these factors collective contributes to a low value adding time for all products and long lead times.

The lean tools proposed to help counteract these waste were, VSM, pull production, Kanban, Heijunka, 5S, Visual management, Streamlining unit conversion and layout. There is great potential benefit to be gain from the implementation of lean: such as; reduction lead time, inventory, material movement, increase in unit conversion and pallet size optimization, better production control that matches customer demand.

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List of Abbreviations

ABC	Activators, Behavior and Consequences
Bales	60kgs compressed grains for shipping
BB	Big bags equivalent to 162kg
CG	Compressed Grain
DOF	Dinis de Oliveira & Filhos
FG	Finish Goods
FIFO	First in First Out
FOM	Frequency of Movement
FPS	Ford Production System
HRM	Human Resource Management
JIT	Just in Time
LT	Lead Time
MC	Manufacturing Cell
MTO	Make of Order
MTS	Make to Stock
OM	Operation Management
PAM	Process Activity Mapping
PC	Production Control
RM	Raw Material
SD	Standard Deviation
SME	Small to Medium Enterprise
SMED	Single Minute Exchange of Die
TPM	Total productive management
TPS	Toyota Production System
TQM	Total Quality Management
UCG	Uncompressed Grains/lose grains
VA	Value Added
VSM	Value Stream Mapping
WIP	Work In Process

1. Introduction

In this chapter we present an introduction to the report, introducing the reader to the host company and the work conducted. The chapter is divided into five parts firstly we present a brief description of the host organization which provided the opportunity to carry out this dissertation at their facility, then the motivation, objective of the work, the methodology applied to accomplished the objectives, limitations faced during the work and finally we give an outline of the report.

1.1. Presentation of the company

Dinis de Oliveira & Filhos (DOF Cork, hereafter referred to as DOF), is a private limited company founder by Mr. Dimas Dinis de Oliveira Alves in 1987, which operates in the Cork sector of Portugal. Nested in the heart of the cork industry in Mozelos, DOF is a SME with a human resource capital (HRC) of 21 employees which are shared between the Production and Administration of the company.

Presently its operations is centered on transforming cork into green products, with a product range that includes cork boards (CortiPAN), cork rolls (CorkROLL) and granulated cork (CorkGRAN). These products are sold both locally and internationally, with their customer based spanning as wide as Europa, Latin America and the Middle East.

DOF products are employed by several industries such as: automotive, construction and manufacturing; being used for thermal and acoustic insulation, as final coating (finishing), manufacturing of lightweight concrete and other derivative products e.g. seals used in cars.

From its inception up till now DOF has undergone several organizational changes, where were milestone in its development, allowing for growth over time, below we highlighted some of the significant milestones in DOF evolution to the organization that exist today.

1953	Mr. Dimas Dinis de Oliveira Alves founded Fernando de Oliveira & Irmão, Lda with his brother, which was dedicated to cork preparation, production of cork stoppers and natural planks.
1987	The company was separated between the brothers with Mr. Dinis Dimas Alves founding Dinis de Oliveira & Filhos. Continuing with the cork preparation, production of blades, adding Granulated cork to serve markets such Brazil, Mexico and Argentina
1990's	The company abandoned the production of sheets of cork and increased its capacity in the production of Granulated cork.
2001	The company changed its statutes to anonymous society.
2008	Dedicated its production of Crushed, Granulated and CortiPAN (chipboard).
2012	New management, with ideas, changing the company's direction, focusing on entry into new markets, developing HRC; employee's competencies, incorporating their knowledge in areas of marketing and human resources management and quality

Currently the company is manage by Dr. Rosa Maria Alves and Mr. Dimas Manuel Alves successors of the founder figure 1 shows the organization chart of DOF; illustration its four departments Administrative and Financial, Purchase and Production, Commercial and Marketing and Maintenance and Quality Control.

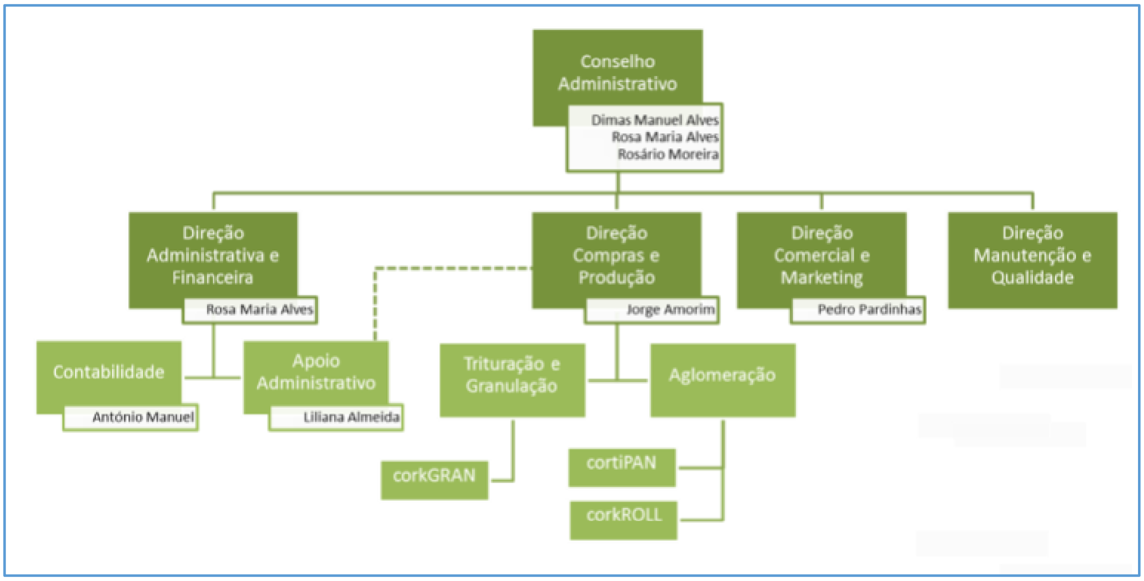

Figure 1The organizational structure of DOF

1.2. Motivation for Project

DOF is a small traditional company which to date has executed its operation in a very traditional manner in that, work is pushed through the manufacturing process unrelated to demand, stocking large quantities of inventory. However the cork sector which DOF operates in is a highly competitive sector with 247[1] companies' all competing for market shares, DOF new management team in understanding this competition in sector, aim to increase their competitiveness: by looking at techniques that can help them cut cost, elimination of waste and improve performance, and market share by enter new markets internationally and also locally. As a result they've decided to take the required steps to improve their internal processes, product quality, etc.

The Cork industry is one of the most important industries of the Portuguese economy, having 62% of the world market, constituting to 70% of export trade and 16% of the export income of Portugal.

Despite the success of the cork industry there over hangs, a dismal past and a daunting immediate future, in the Global economy as a result of the long period of economic uncertainty, in much of the world's developed economies. This is a warning for all companies to being more efficient in the operations and activities, to stay productive and react to any side effects in their business actives due to uncertainty in the global economy?

[1] Association Portuguese Cork

1.3. Objective

The purpose of this study is to conduct a Lean Analysis of Dinis de Oliveira & Filhos (DOF), processes, identify opportunities for improvements and the potential benefits to be obtained from improvements.

1.4. Methodolgy

To conduct this study we look at the problem from systematic point of view, incorporating suppliers, customers and internal behavior of DOF. This approach was used based on the understanding that a system is made up of parts, all of which should work in tandem with each other, any deviation in one would affect the others, and to improve the system we must address the individual parts

The research is presented as a case study where we'll conduct an in-depth analysis of DOF operation, exploring for irregularities, describing these irregularities and identifying possible solution explaining the gaps. To complement the case study method, we utilize a small cross section analysis to identify similar work accomplish in other industries, to glean some insightful information from their work, such as solution or barriers in implementing Lean Tools in SME, which is very useful to this study, such as DOF is an SME which aims at improving the process with the application of Lean Tools.

All the data used/analyzed in conducting this dissertation consist of both primary and secondary data, because of the age of DOF's operation, some of the equipment employed don't have any capacity ratings therefore in some case we had to used induction to estimate the capacity rating or operation information of the machinery. All sales records quoted in the report were secondary data obtain for the accounting department in most case the rest of the data was primary data retrieved during the thesis. Below shows the process followed during this study, however it should be noted that in most case the process was iterative one.

- Visit the company – discuss company's operation, aim and outcome of this study
- Literature review – to identify tools which can be used in to analyze the operation and also tools to be applied at DOF.
- Analyze DOF Cork operation – using tools such as VSM, PAM, ABC etc.
- Share findings with management to ensure accuracy of results obtained.
- Identifying areas of Improvement
- Review improvements suggestion with management - Iterative step
- Identify final possible improvements and quantify benefit to be gain.

1.5. Limitation of Study

While carrying out this dissertation there were several limitations faced, which in one way or another influence the execution of the study. In this section we'll identify all limitations which were encountered during the course of the dissertation.

Lack of available data – this presented itself in the form of lack of equipment/machinery capacity ratings making it difficult to identify where constraints equipment resources exist and where not. This is due to the fact that some of the equipment utilized was manufactured/created in house by factory workers, adapted to their specific needs and constrictions (such as space, etc.).

Access – essential to the success of this study is attaining the operative facts of the process: accessing the practical knowledge of the factory workers, however access to this information was limited to the availability of one individual within the company, because of a language barrier between the workers and myself at the factory.

Longitudinal effects – because of the time limitations given for the study, which was greatly reduced by delayed start of the work (March 27th) due to the difficulty encountered in finding a host company, it wasn't possible to implement solution and measure change/stability within the time constrained specified by FEUP for submission of dissertation. To overcome this limitation we quantified the projected result to be obtained if the solutions were implementation. Another element of the longitudinal effect is seasonal natural of DOF operation which is very dynamic, with systems constraints changing with the season. One example: during this study the bottleneck was determine as the dehumidifier, which is the case during the cold months of the year, however during warm months when the raw material is less humid there is less demand on the dehumidify and as such the system constraint changes. However was impossible to investigate this due to the time limit.

Fluency in a language – this study was conducted in a Portuguese company where only two individuals were able to communicated professionally in English, neither was I fluent in Portuguese, thus creating barriers, that hinder direct communication between workers and myself.

1.6. Outline of the report

To help provided clarity to the layout of the report, making it easy for the readers to identify specific chapter in the report, we present here the content of the report.

Introduction: This section gives an insight/brief history into the company where the project was conducted, the reasoning for commissioning this study, the expected outcomes and finally the methodology used in executing the dissertation.

Literature Review: analyzes the State of the Art in the field of Lean covering areas such as the history and evolution of Lean philosophy, what constitutes lean and the lean tool proposed for use in this case study.

DOF Operation: gives an in depth look at the products, production lines and its resources.

Critical Analysis and Problem defining: here we present the analysis of DOF's operation, its VSM, PAM, ABC Sales and Suppliers.

Proposed Solution: in this chapter we present our recommendation based on the analysis and Problem identified in the preceding chapter, quantifying the expected benefits to be grain from the proposed solution.

Conclusion and Future Work: here we present the conclusion for the work conducted, problems faced, benefits to be gain from solution suggested and also recommendation for future work.

References: In this section includes a list of the literature used during the study.

Appendix: Complementary data and information, that wasn't possible to fit into the body of the work.

2. Literature review

This chapter reviews the state of the art on Lean philosophy, we'll start with a brief history on the evolution of Operation Management, after which we'll look at TPS and Lean working our way through the history of Lean, into the lean concepts defining and explore the different dimensions of lean manufacturing, exploring the relevance of lean, some critical views of lean philosophy and its shortcomings and finally finishing up the literature review with some case studies which carry out similar work as this, presenting the ideas and findings of these articles which we'll believe are central and interesting for our further work.

2.1. The Evolution of Operation Management History

Operation Management (OM) is define as the design, operation and improvement of systems that create and deliver the firm's primary products and services (Chase et al. 2004), another definition I found interesting was offered by Chopra et al. (2004) which define OM as the design and management of any transformation processes that creates value for society. The transformation process is the conversion of inputs or raw material such as labor, equipment, raw material, information and capital resources into outputs goods and services, not forgetting the flow of information or feedback from the end customer to the Inputs via the improvement process or directly to the Inputs. This definition encompasses the normal view of OM as a manufacturing discipline, but its evolution into areas of Service, Marketing, Logistics, etc. Due to this expansion of the boundary of OM it's difficult to define the boundaries of OM (Hayes, 2000).

Several authors such as Chase et al. (2004), Erkan Bayraktar et al. (2007) and Nankervis et al. (2005), states that the field OM has its origin in 1910's, thus being at least 100 year old. During this 100 years there have been several milestones along the way which has contributed to the shaping of OM has we know it now. We'll briefly explore this evolution,

Scientific ERA – Erkan Bayraktar et al. (2007) suggested that OM started in the western world in 1913 with Henry Ford and his idea of creating the world's first assembly, however Skinner (1985) OM first came to being during the time frame 1890-1920, is a better referred to as the Scientific Management era, with works by W. Taylor, Frank and Lillian Gilbreth and Henery Gantt.

Golden ERA – During this time 1930 to 1960 the main focus was developing algorithms and methodologies to solve optimization problems (Chopra et al., 2004). Some of the main contributor were Walter Shewhart 1924 (statistical sampling and quality control), also during this time frame Information Science was integrated into OM setting the foundation for the development of Total Quality Management (TQM) given by Deming in 1947, and the Japanese innovation, with Kanban, JIT which was a part of Toyota Production System, other tools introduce are Material Requirement Planning (MRP) 1960, and Material Resource Planning (MRP II) 1970.

Expansion of OM – During the 1980s there was a wider acceptance of OM, as a functional field in the organization (Erkan Bayraktar et al., 2007), this was due to the increasing competitiveness driven by the Japanese, who focused on cost reduction during early 1980s, later shifting to quality through collaboration of information systems and leanness (Heizer and Render, 2006). Here again it was observed that the internet provided again opportunity for more development in the field of new tools to function and connect with customers. Such as, Customer Relation Management

(CRM), Supplier Relation Management (SRM), Supply Chain Management (SCM) and Knowledge Management (KM). Finally Concluding with E-commerce or Collaborate commerce as the final innovation in OM.

2.2. Toyota Production System

Toyota Production System (TPS), was given birth out of a need of the Japanese's industry to succeed despite shortage in both Capital and Resources after the Second World War (Erkan Bayraktar et al. 2007). With Taiichi Ohno being accredited as the originator of the TPS, TPS model has two main concepts which are;

1. Reduction of Cost by the elimination of waste and,
2. Full appreciation and utilization of the workers capabilities.

The motto if you like to say was "High Quality but low cost". Thereafter TPS emerged as the dominant production model, allowing the Japanese automotive industry to experience tremendous success outperforming its western counterparts (Womack and Jones 1996). The capabilities of TPS was made popular by Womack and Jones (1996), in both their Harvard Business School Case Studies and also in their book The Machine that Change the World and also with work conducted by the International Motor Vehicle Program by MIT's. The Toyota Production System as its name suggest is a system constituting several concepts and facets, developed during the 1950's, by Taiichi Ohno incorporating such concepts as, Kanban, JIT, quality cycles, Continuous Flow, just to mention a few. Shah and Ward (2007) in their article suggested that the TPS, however found its roots in the Ford Production System (FPS), developed by Henry Ford in the 1937, with Ohno, Kiichiro and Eiji perfecting the principle concepts and tools within the FPS. Later on during the 1980's TPS was documented and shared to the westerner world via books and joint ventures between Japanese Companies and Western Companies one such example is NUMMI between Toyota Motors and General Motors.

2.3. Lean Production

Lean Production is a direct descendant of the TPS model, the term was coined by Womack and Jones in the book the Machine that change the World (Hineset et al. 2004) and like its predecessor Lean Production philosophy aims on waste elimination by reducing the cost of the overall production process, while utilizing production labor through continuous improvement process (Womack et al., 1990). Which provides an alternative to the capital intensive mass production (with large batch sizes dedicated assets and hidden waste) offered my Henry Ford (Hines et al. 2004). A key of Lean Production ability to eliminating waste in a production process is its focus on the value stream of the product during its manufacturing process, with the intention to identify and eliminate non-value added operation for example storage, transportation and inspection. By following these five steps (Womack and Jones 1996)

- Identify the Specific value as defined by the customer.
- Identify the value stream: the core set of actions required to produce a product.
- Make the value flow the method of aligning the processes to facilitate the critical path.
- Let the customer pull: the customer should begin to 'pull' product on an 'as needed' basis.
- Pursue perfection: develop and amend the processes continuously in pursuit of perfection.

In the academic world today there isn't any one accepted definition of Lean Production, this is because unlike during the early days of Lean introduction, when only the Japanese used the philosophy and there was limited published books, today there are hundreds of books and thousands of articles which have review and documented TPS and Lean Production, each offering slightly skewed different definition and concepts that are integrated into their philosophy. This therefore bring the question what is really Lean Production and what integrates?

Shah and Ward (2007), debated that currently there are many terms for both TPS by extension Lean Production which have be ingrained into the academic world, being it, from scientific studies or business reviews resulting in semantic discrepancies being introduce into this subject area. Sighting that there aren't any precise and agreed way for defining the concept of Lean Production. They however highlighted two perspectives that can be used to build a definition for lean production, i.e. philosophical and practical perspective.

- ✓ A philosophical perspective related to guiding principles and overarching goals (Womack and Jones, (1996); Spear and Bowen, 1999),
- ✓ A practical perspective of a set of management practices, tools, or techniques that can be observed directly (Shah and Ward, 2003).

Since this dissertation is more gear towards the process improvement, with the implementation of lean tools and techniques, I've decided to opt for the practical perspective. Therefore I'll adapt the definition offered by Shah and Ward (2007).

"Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability."

This definition brings together two important points, Waste and Variability. Waste in Lean jargon is referred to as 'muda'; muda can be define as "anything other than the minimum amount of equipment, material, parts, space and time which is absolutely essential to add value to the product" (Russell and Taylor, 2000). The core of the lean production philosophy is the focus of avoiding waste and also on respecting customers, employees and suppliers (Schonberger, 1986). Lean philosophy however has deconstructed waste into seven fundamental forms, better known as the seven form of wastes. These seven fundamental waste have been widely identify and agreed upon by the academic body and are known as;

Table 1 Several forms of waste

Types of Waste	Description
Over production	Producing more, sooner or faster than is required by the next process.
Inventory	Purchasing or making products before they are needed
Transportation	Refers to physical items and data (rather than the movement of people) and excessive motion between work stations.
Over Processing	Doing extra work which the customer doesn't require.
Waiting	Referring to people or things waiting around for next action.
Movement	Refers to the physical movement of people
Defects	Producing of bad parts, which would requires repairs, reworking, scrapping etc.

In Addition to the seven fundamental waste, there is an expansion to incorporate other forms of sevens such as confusion (any missing or misinformation), unsafe or ergonomic (workplace working condition which can cause discomfort such as eye fatigue, pain etc. and finally underutilized human potential/waste of creativity.

Variability is customer, supplier or internal operations are perilous to any companies operation.

- Demand variability can ripple through the entire production process and cause havoc to daily production schedule.
- Supply variability occurs when suppliers fail to deliver the right quantity or right quality at the right time or the right place (Womack et al., 1990).
- Internal variability that is process time variability is third aspect which can affect the productivity of company and by extension the ability of the company to meet customer demand and also their profitability.

These three variables are codependent on each other, making it of vital importance that they work in an interactive tandem with each other to achieve the goal of Lean Production, because any fluctuation or variation experience by either of these would cause a domino effect in the others, thereby reducing the effectiveness of the others variability. Causing havoc on a company's operation, resulting in failure to meet customer demand and also affecting both the productivity and profitability of the company.

2.4. Lean Tools

Thus far we have mention the origin of Lean, as the successor of TPS and also explore the element which lean production aim to address, these are the seven waste and also variability within a operation be it supply, demand or internal variability. In order to attack these seven forms of muda and variability, Lean Production offers several tools and techniques which can be implement and utilized, to help corporation's reduce and eliminate their waste and achieve a stable operation. Again however, like in the definition of the concept of lean production there exist chaotic state when referring to lean tools, Shah and Ward (2007) in their critical analysis of the subject matter Lean Production try to address this chaotic state in the academic world about lean tools.

First let's explore where the problem exist, several other author beside Shah and Ward (2007) such as Sakakibara et al., (1993) McKone and Weiss, (1999), and Cua et al., (2001) also mention this Shah and Ward (2003), give support to the idea that there is a chaotic state within the theory of Lean Production, as a result of three issues which they have limit to the following.

- First problem arises because some concepts have undergone a change in status over time. Preventive maintenance for example, in most of the early research, it was used as one of the underlying dimensions of JIT but it is now established as an independent construct and is used to predict manufacturing performance.
- Second problem occurs when identical items are used to operationalize vastly different concepts and finally,
- The reverse case in which different items are used to operationalize the same construct.

As a result of this chaotic state in the academic world with reference to Lean Production concept and the tools integrated into its philosophy Shah and Ward (2007, 2003) conducted a critical analysis of the subject matter with the goal to bring some order and clarity to the body of knowledge. Their studies conclude some interesting ideas: in the first study Shah and Ward (2003) investigated the application of 22 lean practices and categorized them into four “bundles”, i.e. just-in-time (JIT), total quality management (TQM), total productive management (TPM), and human resource management (HRM), in a variety of industries in the US, and observed that 23 percent variation in operational performance attributed to the use of lean bundles. They also observed a strong influence of plant size on lean implementation and a less influence on plant age and unionization. In the subsequent study Shah and Ward (2007) argued that lean is a multi-dimensional construct and developed ten distinct factors/dimensions to characterize lean production system.

The 10 factors identified in their study, can be grouped into three, Supplier Involvement (related) consisting of three measure, Customer Involvement, consisting of one measures, and finally Internal firm Involvement, consisting of six measures. Together, these 10 factors constitute the operational complement to the philosophy of lean production and characterize 10 distinct dimensions of a lean system Shah and Ward (2007).

Table 2 showing Shah and Ward 10 factors constitute lean philosophy

Underlying construct	Operation Construct	Description
Supplier Related	SUPPFEED (supplier feedback)	Provide regular feedback to suppliers about their performance
	SUPPJIT (JIT delivery by suppliers)	Ensures that suppliers deliver the right quantity at the right time in the right place.
	SUPPDEVT (supplier development)	Develop suppliers so they can be more involved in the production process of the focal firm.
Customer Related	CUSTINV (customer involvement)	Focus on a firm’s customers and their needs.
Internally Related	PULL (pull)	Facilitate JIT production including kanban cards which serves as a signal to start or stop production.
	FLOW (continuous flow)	Establish mechanisms that enable and ease the continuous flow of products.
	SETUP (set up time reduction)	Reduce process downtime between product changeovers.
	TPM (total productive/preventive maintenance)	Address equipment downtime through total productive maintenance and thus achieve a high level of equipment availability.
	SPC (statistical process control)	Ensure each process will supply defect free units to subsequent process.
	EMPINV (employee involvement)	Employees’ role in problem solving, and their cross functional character.

NB: Please refer to Shad and Ward (2003 and 2007) for further detail and diagrams

It should be noted the seamless correlation between the objective of lean production and the 10 factors of lean exist, for example as stated in the lean definition, the objective of lean production is to eliminate waste while at the same time reducing variability related to supply, processing time, and demand. The three of which are accounted for and addressed by these factors. However a point of vital importance in implementing Lean production to address the aforementioned issues is, reducing variability related to only one source at a time helps a firm in eliminating only some of the waste from the system; not all waste can be addressed unless firms can attend to each type of variability concomitantly. That is, processing time variability cannot be eliminated unless supply and demand variability is also reduced Shah and Ward (2007). The work conducted by Shah and Ward (2007, 2003) was cited by several authors in academia, for the contribution to the scientific body of knowledge such as Ahmed M. Deif (2010), AndreasHu¨ ttmeir (2009), Alireza Anvari e al. (2011) and Er. Rajesh Kumar (2012), just to name a few, hence the reason we'll deem it important to be included here.

2.5. Why is Lean needed!

At this time we'll explore the significance of lean and match it with the reality in which we live today, to give a different perspective and reaffirm its relevance today before we explore further Lean production and its tools. The Global Competitiveness Report 2012–2013 focused on Measuring Competitiveness; the report started with a reminder of the dismal past and a daunting immediate future, as a result of the long period of economic uncertainty. Highlighting that global economy is facing a number of significant challenges that is hampering a genuine improvement as economic crisis continuous, already half a decade long in much of the world, most advanced economies (Klaus Schwab et al., 2013).

This uncertain global economy has several ramifications, and sustained structural reforms aimed at enhancing competitiveness is necessary to ensure stabilize economic growth. Although this is happening at a global level these effects would trickle down into the all sectors of the global economy, and as the global economy slows there is a greater need to company's and businesses to tighten their belt, to ensure their survival during time economic uncertainty.

Added to this global economic insecurity there is another factor which intensifies the need for companies to become more competitive, this is their customers. With the introduction of ecommerce, this has revolutionized business and one side effect of that is, customer's expectation has increase. Today customers have higher expectations from their purchases, such as greater customization, faster delivery/response time etc. and manufacturers need to meet these expectations by increasing a product's quality, reducing delivery time, and minimizing product costs or a combination of the three (George, 2002).

With these two combine, companies need a systemic approach that can help improve their competiveness while at the same time be customer focused. Lean offers a solution, to this scenario, TPS was able improve the Japanese competitiveness during their time of difficulty when capital and resources were difficult to acquire, (Erkan Bayraktar et al., 2007) and now again it seems that history has repeat itself and the situation is right for Lean Production to help company's navigate their way out of this bleak presents into a brighter more productive future the Lean way.

2.6. Lean Tools

There are several tools and techniques which belong to the philosophy of Lean production in this section I aim at giving an insight only to the tools integrated into lean which would be used during the thesis, the other tools would only be stated for recognition purposes.

2.6.1.Value Stream Mapping

Value stream Mapping (VSM) is an extension of the Toyota's Material and Information Flow (MIF) technique, which maps all activities, value added as well as non-value added required to bring a product or a group of products through the main flows, from raw material to the end customers (Rother and Shook, 1998). VSM has become an enterprise improvement tool that helps in visualizing the entire production process, representing both material and information flow, which is occurs within the door to door activities of a company's operation, (Bhim Singh et al. 2010). This technique was evolved from Toyota Material and Information diagram, Rother and Shook, (1998) in their book "Learning How to See' illustrates VSM as a pencil and paper tool aim at helping individuals to see and understand the flow of material and information as a product makes its way through the value stream. Womack JP et al. (1990), emphasized that VSM has to be carried out as the first step towards lean implementation.

'*Whenever there is a product for a customer, there is a value stream.*
The challenge lies in seeing it.'
(Rother and Shook, 1998)

There are essential four steps within this technique, which are;

1. Select Product Family
2. Construct current state map
3. Design the future state map and finally
4. Work plan and Implementation

In mapping the value stream, one thing that must be noted is what constitute value and what doesn't, all activities can be grouped into the following categories,

- Value Added Activities – these are activities that transform the product or service into something the customer wants and is willing to pay for.
- Non-Value Added – Pure waste: all activities which consume resources but add no value, e.g. rework, non-productive meetings, etc.
- Required Non-value activities - this are activities that create no value but at the same time can't be eliminated for the company, based on law, existing technology, equipment etc. also activities required to keep the company operating such as vehicle maintenance, training etc.

It is estimated that all work done in a product stream only 20% contributes to Value Adding, with 50% being non-value added activities (pure waste) and finally the required non-value activities making up the remaining 30% of the value stream.

A key element in the design of the future state map is the Takt time, which is used to synchronize the pace of production with the pace of sales, particularly at the pacemaker/drum process.

$$Takt\ time = \frac{available\ working\ time\ per\ day}{customer\ demand\ rate\ per\ day}$$

We can look at the annex C figure 21& 22 for examples of current VSM of DOF. Rother and Shook, (1998). Hines P, Rich N (1997), identify and classified several other mapping tools which, bear some similar characteristics of VSM, these tools are; Process Activity Mapping (PAM), Supply Chain Response Matrix, Production Variety Funnel, Quality Filter Mapping, Demand Amplification Mapping, Decision Point Analysis and Physical Structure Mapping. However we'll not be going into any details with these tools.

2.6.2.Heijunka (Uniform Plant Loading)

Variability internal or external of the companies operation isn't good at all, Shah and Ward (2007) however stated that stability in operation, supply and demand are much more desirable factors. Uniform plant loading or Heijunka is a tool that focus on protecting the producer from variability in the sequence of jobs to be processed, AndreasHu¨ ttmeir (2009). Coleman et al. (1994), states that the concept Heijunka incorporates both concepts of leveling and line balancing, in that it matches the capacity of a process to its capability and in most of the literature review Heijunka concept was closely related to Kanban, with authors mentioning a Heijunka Kanban system. Heijunka is not only to level production volume, but also level the product mix by having the same order of products for each production cycle (Demand leveling), Judith Matzka (2012).

The are two primary goals of Heijunka;

- To supply one or more customer processes with a constant flow of small lots of different parts and at the same time generating a constant demand of parts for upstream processes. Thus reducing or eliminating the need for spare capacity or stocks to cope with peaks of demand.
- To reduce the bullwhip effect.

2.6.3. Visual Management/Control

When trying to identify the source of problems within an organization which could result in excessive waste, long lead time and other despises characteristics, information availability is usually not the problem; rather it is the communication of this said information which seems to be ineffective (Bilalis et al. 2002). Clear, visual communication ensures information such as customer requirements, production schedules, and the objectives set by management are effectively disperse and understood across an enterprise (G. C. Parry et al. 2006).

This ties to one of the keys principles of lean thinking, which is, every employee should be able to see and fully understand the different aspects of the process and the status of activities, so that he or she will be able to take appropriate action (Womack and Jones 1996 and G. C. Parry et al. 2006). Therefore we see that visual tools form an important part of the communication process which drives lean factories, making processes transparent, highlighting errors/faults and allowing for immediate feedback about areas where adjustment may be required to ensure the process fulfils customer pull (Womack and Jones 1996). Visual Tools aim at influencing workers behavior, as explained by Bilalis et al. (2002) ABC model, A - Activators are environmental cues that give direction to the behavior, B - Behavior is the sequence of observable actions sometimes brought about by the activator. C - Consequences are outcomes that follow behaviors and determine the probability of that behavior occurring in the future.

Thus it's evident that visual control can help keep process and workers in check with regards to the customer demand. When thinking about visual control tools to implement 5S is an excellent place to start. 5S principle drivers' workers or their behavior towards a clean, organized workplaces, by ensuring all raw materials (RM), work in process (WIP) and finish goods (FG) are located neatly in well label spaces. Another tool that can be very useful is Visual Management Control Boards, whereby management can track work at each stage in the process to ensure that the task remain on schedule.

2.6.4.5S

5S is a program which aims at improving the productivity, quality, and safety, by applying techniques such as visual order, organization, cleanliness, and standardization. 5S is define as a structured program to systematically achieve total organization, neatness, cleanliness, standardization and discipline in the workplace, ensuring that the workplace is well organized for optimal worker performance, (Abhijeet S. Deshpande,et al., 2012; Tushar K. Acharyaa 2011; Alireza Anvari et. al., 2011). As the motto goes 'a place for everything and everything in its place' is the governing principle of the 5S tool. The 5S are five Japanese themes which are;

Table 3 5S tools

5S	Description
Seiri (sort)	Separate what is needed or not needed in the work area
Seiton (set in order)	Organize what remain in the work area
Seiso (regular maintenance)	Clean and inspect the work are
Safety	Create a safe place to work
Seiketsu (standardize)	Standardized cleaning, inspection and safety practices.
Shitsuke (sustain the improvements)	Make 6S a way of life.

The emphasis is on seeking out areas where work processes can be improved and implementing and standardizing the new improvements. Alireza Anvari et. al., (2011) suggested that there is an evolution of the 5S tool, into 6S (5S + 1S = Safety), 6S is an extension of the 5S model to incorporate safety "safe work environment "the six S, which was added by Universal Coordinated Time to emphasize safety in the work place. The 5S/6S tool help reduce defects, make accidents less likely, reduce costs and increase productivity. Fostering a culture of continual improvement and employee engagement that is essential for successful implementation of Lean.

2.6.5.Kanban cards

Kanban is a Japanese word for card, which was develop with the JIT philosophy to achieve pull production flow, which is the opposition to the common and dominant push production found in many industries; this being said Kanban cards as a twofold function (Shaojun Wang et. Al., 2004), which is;

1. Production control to tie different manufacturing processes and to ensure that the delivery of necessary amounts of material and parts at the appropriate time and place.

2. Process improvement: includes improving the operations in the production process with emphasis on reducing inventory costs.

A kanban usually includes the information such as part number, description, container, unit load (quantity per container), stock location (from), end process (to), and some other optional information such as lot size, number of kanbans per lot, machine number of final operation, individual kanban. The role played by kanbans in a supply chain system has a general purpose in the sense that it is not only an information carrier, but also material carrier (or transporter).

2.7. Limited Success of Lean

The success of lean has be well document and publish by many authors and researchers in books, journals etc. However in this section we aim not to focus on the success of lean implementation, rather to explore some of the contrary views in the academic society with reference to the lean philosophy. Despite the bulk of author supporting and crediting the success that organization can achieve at the hand of lean philosophy, there are a few who disagree with the wider population about the lean philosophy successfulness.

One such places where lean has be criticized is the Job shop, which is characterized by high variety and low volume, opposite to that manufacturing industries thus success experience here is limited. James-Moore and Gibbons, (1997) stating that lean focus on optimizing value-added activities, however these activities doesn't consider the size, complexity or manufacturability of a product, facts which become important in the Job shop environment, therefore suggesting that the universality of lean must is questionable. Bamber and Dale, (2000) suggested three reason for this:

- Huge product portfolios mean that each "job" is likely to be different and therefore production approaches cannot be standardized.
- The products' characteristics create production constraints.
- The job-shops or smaller firms simply cannot match the dominance or resources that the larger firms enjoy, allowing them to be inflexible along their supply chains

Parker and Slaughter, (1994) viewed lean as being pro-company, not pro-employee, has such employees feel a sense of insecurity, perceiving lean as a redundancy threat. Cusumano and Nobeoka (1998) examine the Toyota product development processes by multi-project management, suggesting that it indirectly implies that one of the limitations of the lean principles is single-project focus, which can cause wasteful designs and products contradicting the concept of eliminating waste. Lamming (1996) suggests that a truly lean system may lack the flexibility necessary for it to function in a competitive business world, for instance, providing no extra time and space to think and experiment respectively.

Some author gives reason for the lack of success, Hancock and Zayko, (1998) argued that there seem to be lack of understand, direction and commit from managers when lean philosophy is transferred into environments different from is origin. M.P.J. Pepper et al. (2008) suggest that some miss the fundamental building blocks of lean, such as employee empowerment and cultural change, approaching lean in with the wrong goals. Lean requires and relies on these cultural changes to occur because in itself is key to sustainability of lean. Without this we see an adverse effect on morale, increasing levels of worker unhappiness and withdrawal, ultimately leading to operational failures (Hines et al., 2004).

2.8. Practical Analysis

In this section we'll look at several case studies from industries such as garment, auto and wood manufacturing, highlighting the implementation of lean in small to medium enterprises (SME), to gain some insight from similar works conducted. The knowledge glean from these cases shared several vital information such as, barriers for implementing lean, be it human or organizational barrier.

Several authors (Golicic and Medland (2007), Pirraglia et al. (2009), Ramune Ciarniene and Milita Vienazindiene (2013) Beitinger (2012)) suggested there is a need for behavior change within the organization, aim at improving workers motivation and participation, which would help reduce the resistance to change from employees and middle management, and improve communication, this behavior changed should be fostered by proper organizational values. Additionally management should have knowledge and knowhow for implement lean to prevent backsliding into pre lean operation state.

Golicic and Medland (2007) said that SME would have limited success in the implementing of lean: if they don't have influence over supplier and customer behavior change. Suggesting 5 proposition concerning supplier, customer and internal influence, which would affect the result or ineffectiveness of implementing lean 1) Supplier behavior change is positively related to lean implementation success of SME. 2) Power of the supplier is negatively related to behavior changes of suppliers, similarly for customer demand and finally 5) Internal behavior changes are positively related to lean implementation success of SME.

Finally some organization barrier that can limit lean are hierarchy and cultural issues, high cost of implementation and lack of resources, weak link between improvement programs and strategy and a disconnection between management and shop floor (Marudhamuthu et al.2011). To overcome these barrier there is a need for leadership responsibility, committed management support, resource committed and finance, these should form the building blocks for lean implementation. Some of the lean tools utilized or implement within these case studies are; Value Stream Mapping (VSM), Single Minute Exchange of Die (SMED), Kaizen, 5S, Kanban, Cause and Effect diagram and Why-Why analysis.

3. DOF Operations

In this section DOF operations would be detailed, we'll explore its product range, the size of operation based on sales, its facility and equipment capacity, both its production lines and the human resource capital.

3.1. DOF Products

Dinis de Oliveira & Filhos, as the introduction indicates currently focus their operation activity on the production of CortiPAN, CortROLL and CorkGRAN, these however are grouped into two main product category as the product tree in figure 2 shows;

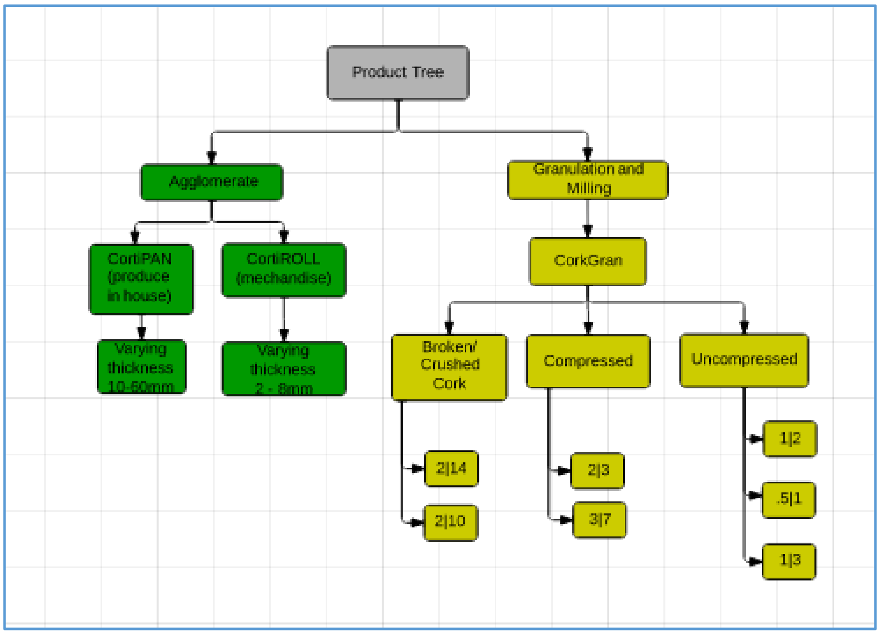

Figure 2 Showing the product tree/catalog for DOF

A description of each grouping is given below.

- Agglomerate section incorporates two products;
    - CortiPAN – this is produce with a standard length and width dimension of 100*50 cm and a varying thickness from 10mm up 60mm, increasing in increments of 10mm and finishing which can be either 50% or 100%. 50% finishing means only one side of the CortiPAN plate is polish and 100% both sides of the plate are polish.
    - CortROLL– varies in thickness from 2mm to 8mm, this product isn't however produced at DOF, they supply the granules need for the production of the rolls but the actual manufacturing of the CortROLLis outsource to DOF business associates.
- CorkGRAN includes three product streams;
    - Crushed cork – is internally referred to as Broken (hereafter refer also), and has specification range from 2mm to 14mm. This range is subdivided into two groups which are 2mm to 10mm (which can be referred to as fine broken) and the other is from 2mm to 14mm just broken.

- Compressed granules (Bales) – these grains are compressed and transformed into bales of 60kg for shipping internationally. The grains used in this product are 2|3 and 3|7 mm granules.
- Uncompressed granules (Lose grains) – these grains usually range in size from 0.5 to 4mm and is sold in the local market to the customer

However besides these main products, everything that exist DOF production process are sold, i.e. cork bark or poor cork, powder cork, etc. However during this study we'll only be focusing on DOF main products.

The raw material used in the manufacturing process is sourced from the waste products of other companies within the Cork Industry, such material as; apara desp. crowded, burnt chip, cork burnt (for CortiPAN), flour cork, bit of cork and yellow cork (for granules), Table 38 and figure 18 & 17 annex B, shows details about the raw material used.

To have an idea of the size of the operation, the table 4 shows the 2012 sales narrative for the main products sold by DOF.

Table 4 Sales quantities for 2012

Product	*Units*	*2012 Quantity*	*€*
Agglomerate	m^2	38837	212748.07
Broken	kg	927723	16102.44
Granules	kg	1379122	1457488.55
Total			1686339.06

3.2. Facility and Equipment

DOF facility is located in Mozelos on a plot of land covering an estimated area 6101 m^2. The facility consists of four main sections, the administrative building, raw material storage area, manufacturing section and warehouse. The current layout is shown in the figure 18 annex B of the report, table 5 gives a brief idea of the size of these section.

Table 5 Showing any estimate square meter allocation of DOF main buildings

Section			*Area (m^2)*
Administrative	A	Office	70
Manufacturing	A	Grain Processing Area	392
	B	Separation	360
	C	Compression/WIP/ Dehumidification	1060
	E	CortiPAN MC	546
Warehouse	F	FG material storage	1034
Raw Material	D1	Broken Storage	132
	D2	Raw for CortiPAN and Granulation storage	525
Total			4119
		Miscellaneous	1982

DOF is characterized as an SME, having an assortment of equipment at their disposal; however because the company is old and some of the equipment they used in their manufacturing were actually fabricated by the company, and it's difficult to determine the operating capacity, it's just left up to estimation to have an idea of the capacity. In the below table we aim and present a catalog of the machines available in the company and estimating the usability and productivity where possible.

Table 6 Illustrating the equipment and machine catalog of DOF

ID N⁰	*Section*	*Machine Description*	*Quantity*
	General	Fork lift	4
		Tractor	1
		3ton truck	2
		Material Transportation Truck	1
	Granulation	Dehumidifier	1
		Press	1
		Density tables	2
		Grain processing line	2
		Mills	6
	CortiPAN	Oven & Mixer	2
		Cooling duct and Cutter	1
		Polisher	1
		Packaging (small parcel and pallet)	1

3.3. Production Process

DOF offer main three product's family as the product tree illustrated in figure 2, however despite offering three products the company operates two production lines, with the initial stages of both performing very similar activities, as a result there exist 100% flexibility between these lines with either line have the ability to produce which ever product needed. Below describe the two production lines,

Production 1 as illustrated in the figure 3 below is for processing of the Granules needed for both the CG (bales) and the UCG (lose grains sold locally). The diagram shows a detail picture of the process, including information such as each activity individual cycle time[2] in minutes. .

To better explain the process diagram we'll divide it up into three main sections, corresponding to areas where the materials are being physically moved.

[2] The processing time indicated in the figure, is the actual measure time from starting activity till output was registered at the end of the activity

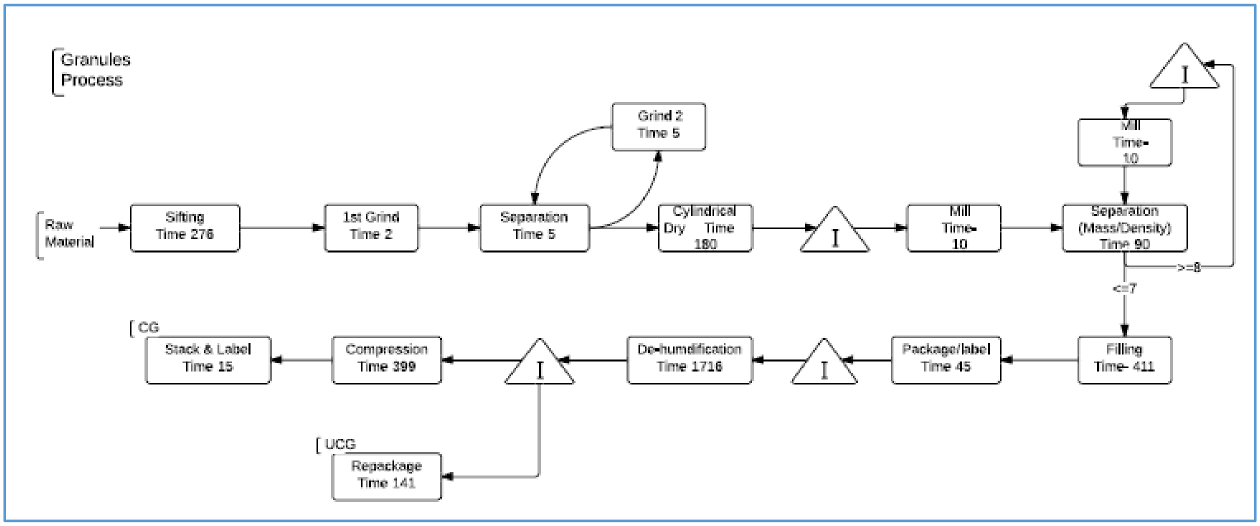

Figure 3 show the process diagram for the production of CG and UCG

- Section one – this covers everything from the beginning (sifting) to the package and label activity; raw material is feed into process where it is transformed, reducing its size 0.5 to 7mm. This is accomplish by passing the cork through a two stage grinding process reducing the cork to 10mm with a separation step in between, to remove unwanted cork bark. After the cork enters the cylindrical dryer to reduce it moisture content, exiting the dryer the cork enters a silo which acts as a buffer. Then onto the final milling stage reducing the gain size to the required dimension of 0.5 to 7 mm, anything at exceeds the 7mm size is recycled back through the process. Finally this section concludes with the product being filled into bags of 27kgs, packaged and labeled, specifying the grain size according to the product tree.
- Section two – here the package grains are placed on pallets (according to their size) for transportation to the dehumidifier via a fork lift. Once at the dehumidifier the pallet is off load, unpackaged and empty into a dehumidifier (6bags at a time), to further reduce its moisture content to 5-6%. After dehumidification the grains are placed into BB which are equivalent to 162kg, and transported to WIP inventory.
- Section three – this third section the process diverge grains placed in the WIP inventory would either being used for:
    - Compression (grain size 3|7 and 2|3) and
    - Repackage into the 27kgs (0.5|1, 0.5|2, 1|3, etc.)

NB: section 2 (dehumidification activity) is weather and seasonal dependent, i.e. it is more used during the winter season and less used during the summer.

Production line 2 is for the manufacturing of the CortiPAN and Broken product (with the Broken being completed end of the 1st section), however if you'll look closely the initial stages of the production process is exactly the same, as that for the granules described above.

This diagram also illustrates the cycle time at each activity in minutes Similar to the approach used in the description of production 1 would be applied here:

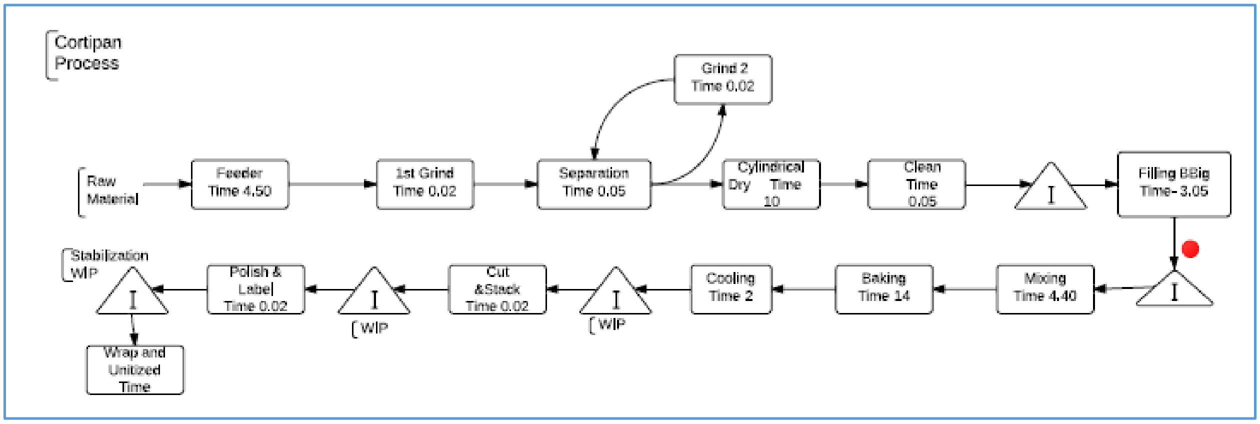

Figure 4 showing the process diagram for the production Broken and CortiPAN

- Section one – this area encompasses all activities from the start of the process to the second inventory icon (show above by the red dot.) In this section of the process, raw material (cork waste) is transform by passing it through two grinding/milling stages, separation, the dryer to reduce the moisture content of the cork, and then clean, to remove any remaining unwanted segment of the cork bark, reducing its size to a range of 2 to 18mm, which is then pack into BB according the size variation (check product tree) and stored as WIP.
- Section two – involve the manufacturing of the CortiPAN product, beginning at the WIP inventory and ending at Polish and Label activity. The broken cork taken from the WIP inventory area is transformed into the CortiPAN, the broken cork is first mix with adhesive and then bake in an oven (the baking time is proportional to the thickness of the CortiPAN, refer to table 40 annex B for more detail). After which the bake CortiPAN board is cool in an air duct with natural air, then cut into pieces (1*0.5m), temporary stack to build batches before being polished, labelled and stack onto pallets.
- Section three – the pallets built at the end of section two are moved to the warehouse for stabilizing, this activity is critical to ensure the quality of the product before final packaging which occurs in the CortiPAN manufacturing cell (MC). There after stabilizing the CortiPAN is move back to the MC for final package and then back to the warehouse for storage as finish goods (FG).

3.4. Human Resources Analysis

DOF employees a total of 21 employees, with a mixed work force including both genders, with female accounting for 33% of the workforce and men 67%. The average age of DOF human captial (HC) is 45 years with 67% of all employees above this average age. The 21 employees are disperse between the office, manufacturing and security activities, with the office utilizing 20% of the HC and the manufacturing process 76% and security the remaining 4%. The 76% HC used by manufacturing is shared between three categories of work; granulation, cortipn and maintainence. Granulation (CG+UCG) utilizes 40%, CortiPAN 32% (plus broken) and the remain 4% is utilized for maintenence. Finally DOF records shows that 62% of the HC can be consider as unskill or semi skilled workers. Futher detail of DOF Human Resource analysis can be seen in table 39 annex B.

4. Analysis and Problem Definition

In this section we'll present the analysis conducted and the findings obtained. This analysis covers several areas such as: the operation, value stream, productivity, sales analysis and supplier analysis. At the end of the section we'll scope and describe the problem which we believe is being faced by DOF operation. To begin we'll start with the VSM tools.

4.1. VSM Tools

To examine DOF operation, we'll utilized three value stream mapping tools which are: Value Stream Mapping (VSM), Process activity mapping (PAM) and Demand amplification. VSM was introduce in the literature review as a method to map the material and information flow within an organization, both other tools were mentioned additional mapping tool.

The results obtained from the PAM analysis are presented in table 7. This results shows a very high total time recorded for CortiPAN, which was attributed mainly to the large stocks of FG in the WH awaiting shipment, for in excess of 5months. Despite the long waiting time, the VA for CortiPAN was highest of all products at 8%, this is a result of one activity within CortiPAN production process stabilization; which requires three (3) full day to be completed, an equivalent of 4320 min, which represents 98.42% of the total VA time. Since stabilization is viewed as a needed activity to ensure product quality[3] it was included as an operational activity. However if this wasn't the case, the actual VA % would be 0.12%. Another point to note is: the CortiPAN has a total distance travelled, recorded as 722m (for every pallet FG shipped) representing the largest number in the group of products.

Table 7 showing the result from the Process Activity Mapping

Product	# of Steps	# Operation steps	Total distance travel (m)	Total Time (min)	Operation time (min)	% VA	# of person	Operator
CortiPAN	28	17	722	57384.57	4389.37	8	21	2
CG	32	16	266.5	5425.16	57.41	1.06	27	1
UCG	29	15	207.5	2766.11	52.56	1.79	21	1

UCG showed the high total time 2766.11 relative to its operation time, recording VA at 1.79%; similar results was observed for CG showing a high total time of 5316.16min and a comparatively low VA at 1.06% being the lowest of all the products.

All results from the PAM showed that for the majority of time products are with DOF internal supply chain no value is being added, as we see the extremely low operating time to total processing time for all products. Additional many delay points along each product flow was identify as pools of WIP and FG inventory, in all cases the time delay at these pools exceeded the total operating time. A full list showing at the steps/activities for each product is shown in annex C, table 41 to 43.

[3] Production Manager stated

VSM results table 8 offer us another view of DOF operation, the results showed that for all products, their VSM exhibits high LT in excess of a month; with CortiPAN having the highest LT at 55.63 days (due to the sales of CortiPAN decrease during the past years), CG has the second highest LT of 32.93 days, (due to high FG inventory, because shipping occurring only twice/month) figure 5. Finally UCG has the shortest LT comparative to other products of 29.14 days, this can be attributed to the fact that 49 % of the FG for UCG are outsourced and resold. Table 8 shows the contribution of each form of inventory to the total LT. Full VSM diagram for CortiPAN and UCG are can be found in annex C figure 21 and 22.

Table 8 Results of the VSM

Production	*Lead Time (LT)(days)*	*RM inventory*	*WIP inventory*	*FG inventory*	*Processing time (sec)*
CortiPAN	55.63	10	10.83	34.8	3064
CG	32.93	19.19	6.76	7.79	2709
UCG	29.14	10.40	14.46	4.28	2427

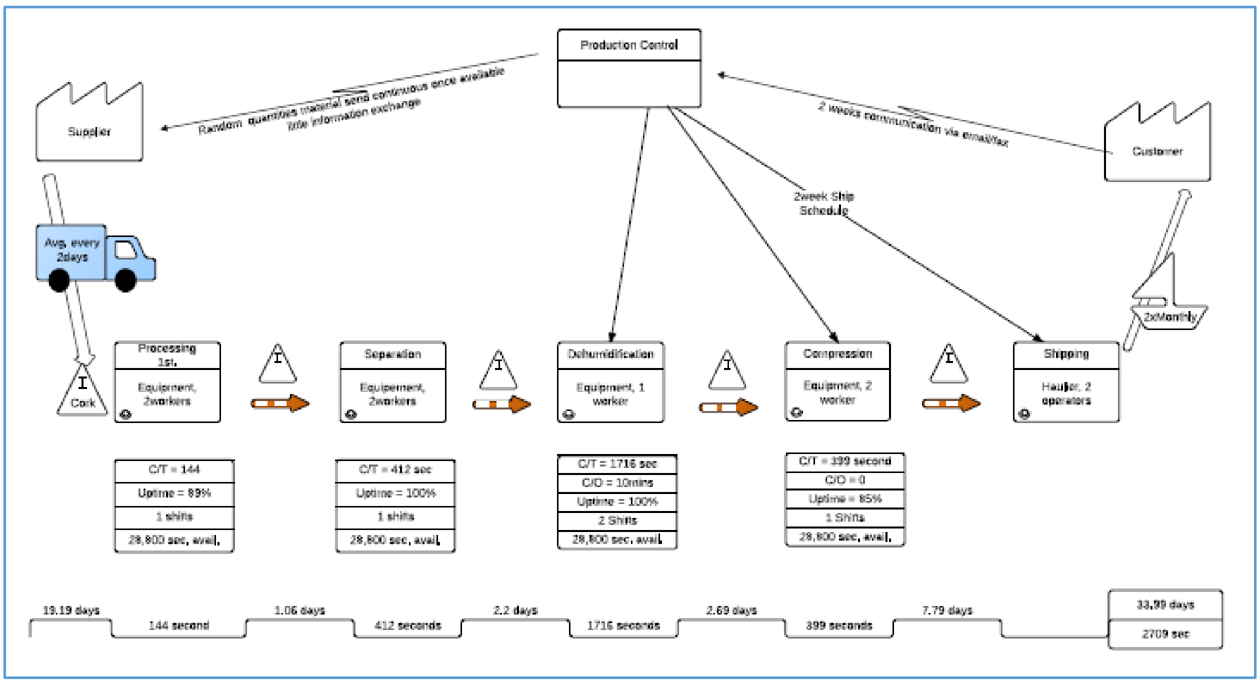

Figure 5 VSM current map CG

Present View of DOF production system.

Currently at DOF there isn't a ridged production control for each product; below we provide a brief input as to where production controlled is applied for each product.

- CortiPAN – Production is executed in long runs with large batch sizes, the Production Manager controls three activities within the manufacturing process 1. Processing 2. Baking (oven inside MC) and 3. Shipping. At the processing activity production is usually conducted for one day a week, during this day large quantities of one broken grains size (e.g. 2|10, 2|18 or 6|18) is produced to fulfill production of CortiPAN when needed.

Because there are three grain sizes, each used for a specific dimensions of CortiPAN, production of the CortiPAN boards are also accomplish in long runs also, with changes in the dimension of the CortiPAN occurring every 3/4 days.

- CG – Production control for the CG enters the manufacturing process at three locations, 1. Dehumidification, 2. Compression and 3. Shipping as seen in figure 5. At compression the input is sporadic as work is accomplished repeated base on the average composition of a container, which is usually 160 bales of 3|7 and 31 bales of 2|3 with production runs equally to the quantities needed, 2.5 days for 3|7 and 0.5 days 2|3, then the cycle is repeated, unless there is a change in demand ratio.
- UCG – Production control for UCG is executed that four locations also which are: 1. Separation, 2. De-humidification, 3. Packaging and 4. Shipping. Here the production managers instructs the operators what quantity and product type to produce e.g. at the separator the production manager would instruct which gain size (0.5|1, 0.5|2 or 1|2.) to be produce, also when they are to be combine and package or when they are separated and package. Within this process work is executed continuously at each activity.
- Dehumidifier is presented separately because it's a shared activity PM inputs control indicating the work to be accomplish e.g. either 0.5|2, 2|3 or 3|7. Currently work is executed at 2days for 3|7 and 3 days for 0.5|2. Please refer to annex C figure 21 & 22 for current VSM of CortiPAN and UCG.

4.2. Sales Analysis

To begin a three year narrative of the sales is shown to identify sales trends which would provide a bases for interpretation of the result presented below.

Table 9 Sales Analysis for past three years

Sales Analysis for a three Year period (2010-2012)			
Products (kg)	2010	2011	2012
CorkGRAN (CG)	727,357.00	540,724.00	682,500.35
CorkGRAN (UCG)	390,253.00	340,481.00	697,997.00
CortiPAN	84,114.12	54,144.28	38,827.41
Broken	27,865.00	32,812.00	21,163.50
Total	1,229,589.12	968,161.28	1,439,049.26

The narrative shows that in 2011 there was a decrease in granulation sales (CG & UCG) and then an increase in the follow year. Broken shown the opposited, with an increase and then decrease and finally CortiPAN shows a continuous decrease in sales over the narrative period.

Next an ABC analysis of DOF products was conducted, thereafter we'll extent the analysis into the main product groups, examining their mean and standard deviation for the year 2012. The product ABC analysis is presented in table 10 showed that Granulation is main contributor of revenue therefore the A product, while the CortiPAN is B, with Broken and CortROLLthe C product.

Table 10 Sales analysis of DOF main products

Main Products	*Total quantity*	*Total value*	*%*
Broken (kg)	21,163.50	16,102.44 €	1%
Cork roll (m2)	16,661.08	34,732.91 €	2%
CortiPAN (m2)	38,827.41	179,102.70 €	11%
UCG (kg)	697,997.00	516,447.76 €	31%
CG (kg)	682,500.35	894,681.69 €	55%
		1,641,067.50 €	
ABC Analysis	A	B	C
	86%	11%	3%

ABC study identified Granulation as the product A, however from the total sales volume of granulation it is estimated that 73% of demand was met by in-house production, 4% from inventory carry over from 2011 and 23% is purchase grain.

Table 11 Shows the contributing elements to the 2012 sales volume

Year	*2012*	*% of Sale (2012)*
Production Grains	1007419.97	73%
Used from Inventory	26,658.00	4%
Purchase Grains	343,067.72	23%
Sales	1,380,027.35	

The 23% purchase grains were divided between the CG and UCG having the following contribution sale volume.

Table 12 Showing the division of purchase grain to either granulation products

	Sales	*Purchase grain contribution to final sale*	*%*
UCG	682500.4	332693.72	49%
CG	697997	10374	1%

Further analysis of the sales was completed to determine the variability of DOF product demand, by checking the monthly standard deviation for the year 2012. The result of this showed that all of their products exhibit high standard deviations with values exceeding 39% table 13, shows the obtained results. This high standard deviation indicates that there is great variation with demand, which we can recall as being a characteristic of process variation that is unwanted quality of any process.

Table 13 Showing the results for the standard deviation of Sales Analysis

Product	*Units*	*Annual 2012*	*Mean (monthly)*	*Standard Deviation*	*Standard Deviation %*
CortiPAN	m^2	38837.41	3236.45	1676.80	52%
CG	kg	682500.35	56875.03	22389.81	39%
UCG	Kg	697997	58166.42	29877.77	51%
Broken	Kg	21163.5	1763.63	1344.57	76%

To analyze how the company was responding when faced with this high standard deviation, a demand amplification maps[4] was constructed on a monthly bases

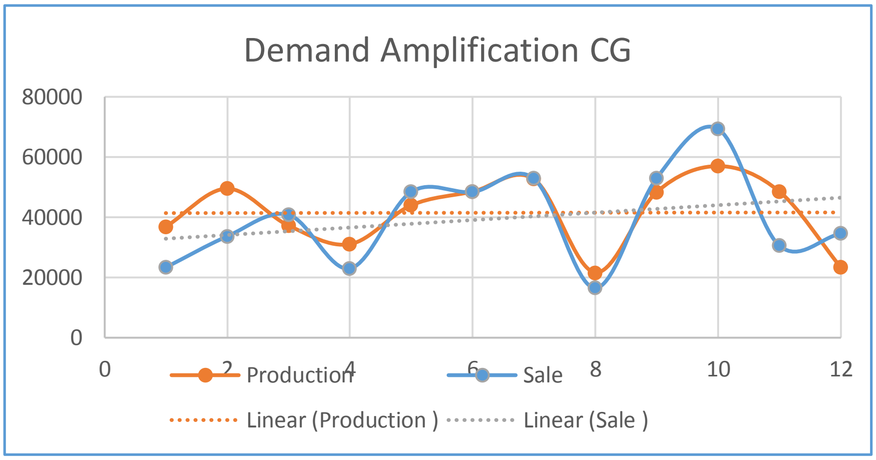

Figure 6 Demand Amplification CG

The demand amplification diagram figure 6, compares side by side production and demand for CG during the year 2012. The map shows that in most cases beside the beginning and the end production of CG closely tracking the demand. Liner trends shows on average for 1st seven months production was ahead of demand and for the last 5 months this was reversed. Table 13 also shows that CG has the lowest standard deviation for all products for the year 2012.

Unlike in the CG figure 6, UCG has third line which presents the Actual Demand; this is applied due to the fact that purchase grain contributed to 49% of UCG annual sales greatly offset the actual demand on the production system. To obtain the actual demand the monthly value of purchase grains was subtracted from monthly sales demand. The graph show that unlike CG where production which was tracking demand, UCG production for seven (7) months was leading the demand, and remaining five (5) months there were oscillation between leading and lagging

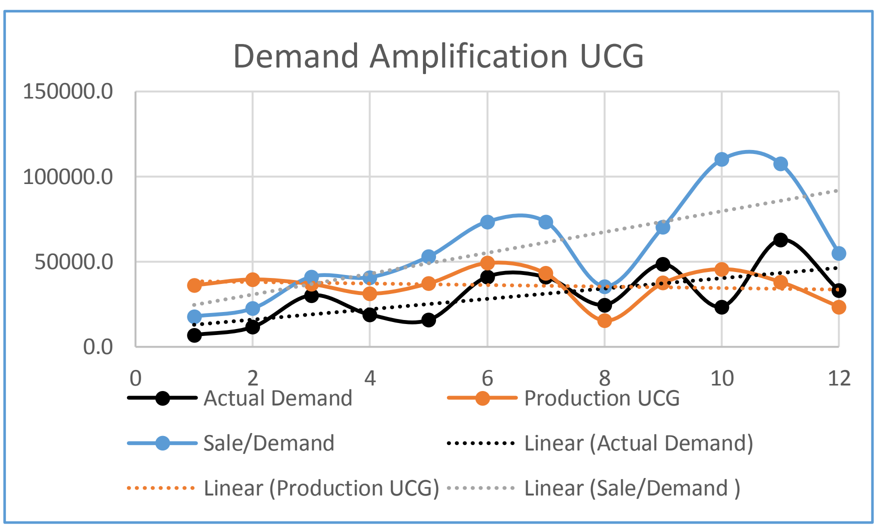

Figure 7 Demand Amplification UCG

[4] Demand amplification map is one of the techniques VSM

position figure 7. Therefore the demand amplification for UCG shows that there is a dislocation between production and actual demand, however for a short period during the year production appeared to be moving with demand months 7 to 9.

The CortiPAN despite have a high standard deviation of 52%, showed a steady liner trend for the duration of 2012, along which dynamic sales deviation occurs. Currently there isn't any production records for CortiPAN therefore we couldn't compare production rate to sale information, however the production manager stated that production usually is conducted on a daily bases, with the focus of replenishing FG, meeting specific demand if there isn't any FG and also geared at workers utilization[5], keeping workers active, which effectively would result in a push production system. Broken production is executed to match that of CortiPAN production because it's used in the CortiPAN manufacturing.

Since there isn't any production record, either for the broken and CortiPAN, and also because they're both utilized the same RM, the quantities of CortiPAN and broken were group together and compared to RM supply figure 9, which will be discussed in the next section with supplier analysis.

Thus far we've explored the PAM, VSM and Demand Amplification matching the variation in demand to production to gauge how internal operation reacts to the unstable demand and high variation. From the concept of variability as mention in the literature review avowing that variability: in internal operation, customer demand and suppliers are all interrelated therefore needs to addressed collectivity to achieve the goal of lean production. Thus in the next section the analysis was extended upstream of the supply chain to suppliers.

4.3. Supplier Analysis

The average quantity of raw material delivered monthly and its standard deviation was measured for both granules and CortiPAN and presented in the Table 14, this snap shot view indicates that RM supply has a SD of 24% and 36% for CortiPAN and granulation respectively. With no. of delivery and no. of days of deliveries having 25% and 22% for CortiPAN and 35% and 28% for granules raw material delivery.

Table 14 SD for raw material supply

		Raw Material					
		CortiPAN			Granules		
	Unit	Monthly Avg.	SD	SD as %	Monthly Avg.	SD	SD as %
No. of Deliveries/month		16.42	4.03	25%	27.50	9.63	35%
No. of days of deliveries/month	days	12.42	2.75	22%	14.00	3.88	28%
Raw Material	kg	56288.91	13739.96	24%	182435.2	67720.08	36%
Daily Mean		2601.23			8234.53		

[5] Production manager indicated

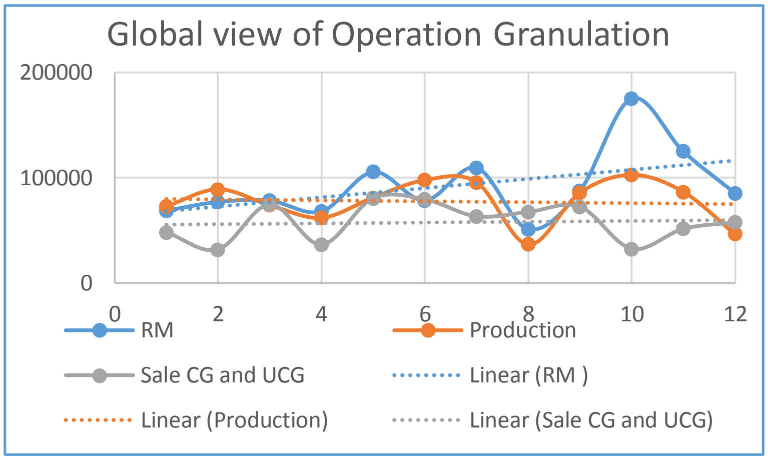

Figure 9 Global view of operation, comparing RM supply, production and sales 2012

Applying a similar comparison to suppliers and extending the analysis to include both production and actuals sale demand met from in-house production. This amplification of the three main elements of a production system (supply, operation and sales of FG) allows for the identification of irregularities within DOF operation, such as months in the year when either of the elements were starving or overwhelm with inventory. This complements to above work which look at the variation within individual products. Figure 8 shows collective/global view of the operation with granulation. The results illustrates that for the year 2012, production within the granulation section (CG and UCG) exceeded the actual sales demand on the manufacturing process, added to this the supply of raw material to the factory exceed both the actual sales demand and also the production rate for the year, as is confirmed by the linear trends for each.

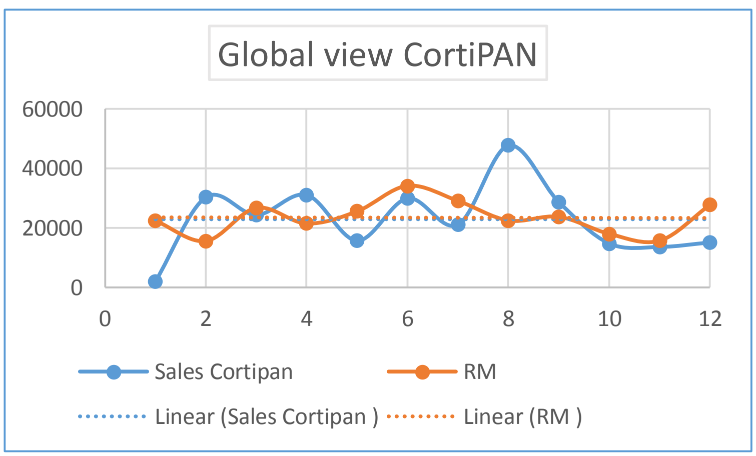

Figure 8 Global view of operation comparing RM and Sales (CortiPANd and broken)

Likewise the CortiPAN sales was matched against the RM supply figure 9, it was observed that both the RM supply and Sale shown variation between themselves; at one month Sales would lead RM supply and at another the reverse would occur, this persisted throughout the year. Regardless of the variation both their liner trends aligned perfectly suggesting that on average RM supply matches that of Sales.

Before and After: contrast show in Table 15, looks at the operational year 2102, showing that there were decreases in inventory level for RM CortiPAN, CortiPAN, Broken and UCG. While there was a recorded increase in RM Granulation and CG inventory.

Table 15 2012 Before and After look of products and raw material standings

Items (Units kg)	Start Inventory	End Inventory	Used Inventory	% used	Comment
RM CortiPAN	101,175	19580	-81,595	-80.6%	Decrease
RM (CG+UCG)	18,380	55241	36,861	200.5%	Increase
CortiPAN	30212	28968	-1,244	-4.1%	Decrease
Broken	6420	3175	-3,245	-50.5%	Decrease
CG	1917	7506	5,589	291.5%	Increase
UCG	53,740	11,500	-42,240	-78.6%	Decrease

The demand amplification for granulation (fig. 8) suggested that both RM and FG inventory is being accumulated in the granulation, which is confirm in table 15 CG. This is also in line with the results obtained in the PAM; low VA % of granulation products (table 7) due to delays within the process. VSM likewise illustrated that all products had very long LT. Whereas for the CortiPAN RM the result suggest RM purchase is tailored to match sales, however the before and after suggests that CortiPAN production exceeds the sales demand, as there is a massive in RM CortiPAN (confirm the comment that production is focus on work utilization), additional the large fairly unchanged FG inventory suggest then DOF hasn't adjusted their stock level despite continuous pattern of decreasing sales for the last years leading to the low VA % observed.

Finally to conclude this section we examine DOF suppliers, currently there is a 35 suppliers, which supplies the material needed for the manufacturing of all products, this analysis was conducted to identify DOF main suppliers and match time with a location analysis conducted also. The result showed figure 10 that A and B account for 78.3% and 16.35% respectively, a total 94.65% of all raw material supplied during the year 2012.

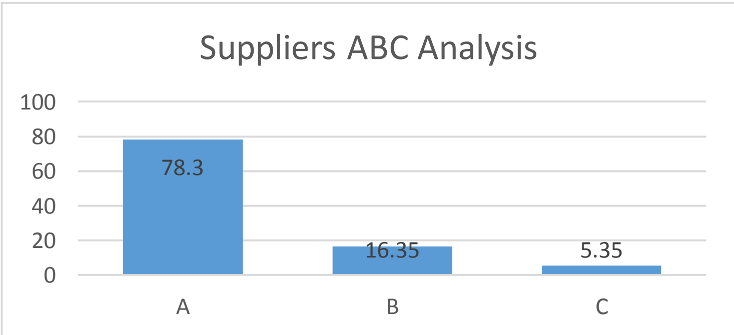

Figure 10 demonstating the supplier ABC analysis

When compared with the location analysis it was observed that 66.67% of the A and B suppliers are located[6] within a 14 min drive from the factory, however these 66.67% contributes 86% of the total RM table 16.

Table 16 Supplier location analysis

Suppliers by numbers	Drive Time	Quantity	Contribution
1	7	779297	30%
2	8	506754	19%
3	4	374776.72	14%
4	9	254040	10%
5	12	131852.97	5%
6	14	91875	4%
7	12	77887	3%
11	13	34398	1%
Total Supply		2250880.69	86%
Total RM		2613823.69	

For confidential reasons the actually supplier names were omitted, or a more detail view of the results in table 16 please refer to annex D table 53

4.4. Productivity Analysis

It was difficult to determine productivity of DOF operation, because most of the equipment use at DOF doesn't have any manufacturing capacity rating on them; as some of them created in house. However to gage an estimated capacity, we've analyzed data from the past three year to identify the maximum production achieved, setting this as a benchmark (assuming that it's possible for production to be maintain that this level.)

Table 17 Comparative analysis of production over a 3 year time period

Granulation Production Analysis			
Year	2010	2011	2012
CorkGRAN total sale (CG+UCG)	1,117,610.00	881,205.00	1,379,058.35
Purchase FG	106,788.00	0.00	341,574.72
Inventory Use			0.00
In house production	1,010,822.00	881,205.00	1,037,483.63
Productivity Benchmark October			1,230,552
Production %	82%	72%	84%

From this historical comparison it can be observed that the greatest *in house production* was recorded in 2012, further investigate into the monthly production of 2012 indicated that the highest production was obtain in October at 45576 kg, therefore making the above mention assumption

[6] Location distance obtained from google maps

the annually productivity can be estimated at 12*October recorded value. Thus the relevant productivity for each year is estimated and indicated as a percentage in table 17, with 2012 having a productivity of 84%.

Table 18 CortiPAN productivity test

	CortiPAN capacity (company estimates)	*Sales 2012*
Year production capacity (m3)	3125.76	1187.46
Production %		37.99%

As for the CortiPAN when matching its sales for 2012 against, yearly capacity it's estimated at 37.99% of capacity, understandable as sales have decrease drastically over the past years.

4.5. Layout

The current layout as depicted in figure 18, annex B shows the location of workstation and the flow of material within the factory. The current layout design results in material being transported long distance between workstation, as workstation are disperse in differ areas of the factory and in some cases WIP are move back and forth along the same line several times e.g. CortiPAN, every board manufactured, is moved from the MC to WH for stabilizing, and then goes back to the MC for package, to return to WH for storage and final move to RM location for shipping. This design results in excess material movement, time and effort spend time accomplishing task which addeds not value.

4.6. Summary

DOF operation have been experiencing variation in annual sales from the year 2010 to 2012, this variation in demand is evident across the entire product range. however greater in products such as Broken, CortiPAN and UCG, these recording a standard deviation of over 50% where as the CG recorded 39% the lowest deviation. Our analysis showed that the majority of time products are with DOF internal supply chain no value is being added, spending most of their time in delays/waiting. Additional all products exhibits excess lead time ranging from 29.14 to 55.63 days. The demand amplification charts showed that for the granulation process production and RM supply exceeded the actual in house sales demand. However the CortiPAN process better matched RM supply with sales demand with both linear trend matching. The ABC anaylsis of products sales showed that DOF A product is the Granulation (CG and UCG), the B product is CortiPAN and C is composed of Broken and Cork roll. Supplier ABC analysis that 66.67% of DOF A and B supplier are located within 14min drive from the factor and these supplier contribute 86% for all RM supply. Final it was esitmated that 2012 production was 84% of the manfacturing capacity.

5. Proposed solution

We'll like to state that the solution presented in this chapter were not actually implemented at the DOF, this is due to the limitation faced during the execution of the study, particularly the time and language limitation. Implementation of any solutions would require effective communication with the workforce, sharing the findings obtained from the analysis and training employees in lean techniques, guiding the implementation process and finally time need to measure changes & stability. Therefore in this chapter we'll give the proposed recommendation to DOF operation, which can be used as the bases for future changes and further investigation into specific areas.

5.1. Area of Improvements

Rother and Shook (2003), in their book "learning to see", stated that some of the waste in the current VSM would be as a result of product design, machinery, and the remote location of some activities and it wouldn't be possible remove all of them immediately; however they advise to take these process features as given, and alternatively focus our efforts on pursuing waste not bring about by these features. We begin with a list of the wasteful activities identify from the PAM for each of the product, then thereafter we'll analyze these waste with the 5W1H approach to match lean tools to areas of interest (waste).

	CG and UCG	CortiPAN
Excessive Inventory	✓	✓
Overproduction	✓	✓
Excessive movement	✓	✓
Long Waiting time	✓	✓
Defects and waste	Equipment waste – poor equipment design, e.g. to facilitate daily operation at the dehumidifier one fork lift needed to lift the pallets to the platform level (approx. 8ft high), to offloading of grains and because platform area is too small to store bags, the forklift is frequently left in this position. Collectively estimating about 3hrs/day for this purpose.	Poor unit conversion between work station, and Waste – estimate 13.19[7]% material is wasted on every CortiPAN board, and defects account for an additional 2%.
Warehouse storage	UCG stock wasn't easily identifiable, as the only label on these bags is a 20 cm^2 paper sewn onto the bag, which can be easily dislodged during the handling.	

To find ways of improvements for the areas identified above we utilize the 5w1H technique to discovery solution to the problems, however we'll not specify when action would be taken, due to

[7] Each board has a baking dimension 1.6*5.4, however only 1.5*5 is sold

the fact that the scope of this thesis doesn’t include the implementation of changes but the recommendation of changes to the management of DOF.

Table 19 5W1H: Areas for improvements and recommendation action

What?	Why?	Where?	Who?	When?	How
Reduce Inventory	Excessive inventory, is waste, it hides problems and is money and WH space tied up that can be put to more productive use.	Warehouse and RM storage	Jorge		Kanban pull system, only producing what the customer demands
Reduce Over production	Overproduction is also a waste resulting in increased inventory and WIP	Granules and CortiPAN	Jorge		
Production Control	To achieve balance production flow	Manufacturing	Jorge		Heijunka & Kanban Visual Management and 5S
Reduce Material Moment	Excessive movement is waste	WH and shop floor	Jorge		Layout change
Improve Material supply	In order to streamline the process RM supply should be controlled by customer demands	Storage Area, and Administration	Jorge		Internal kanban system
Improve Material flow	Streamline material unit flow would help reduce waste, allowing for smooth conversion of work into FG	Manufacturing both CortiPAN and granulation	Jorge		Change unit size to convert directly into FG

5.2. Future VSM

For the future VSM maps were create based on information from the operator balance chart which measured the takt time for all the products, to identify if any activites has a cycle time above the required takt time. We’ll begin with the CG & UCG these two products are represented in one summary (table 20 and figure 11) since they sharing some activites and equipment, on productin line 1, this allows us to obtain clearer image of the demand on each activity hence we present the operator balance chart in this manner.

Table 20 shows the cycle time for each activity, with the underline activities indicating that they are shared between CG & UCG (such as 1st processing and De-humidification for these activities we sum their individual cycle time), then the total demand on the production process is calculated (what is actually produce inhouse) and finally estimates the two takt times which are;

- Unshared process Takt time, this is for activities that are not common to both products
  - CG = 13.71 sec/kg
  - UCG = 21.77 sec/kg
- Shared process takt time, for activities that are commom to both products = 8.41 sec/kg

Table 20 Operator balance table for production line 1, products CG & UCG

	1st Processing	Separation (CG)	Separation (UCG)	De-humidification	Compression	Repackage
Total Cycle time/activity	9.00	15.00	9	17.00	7.00	6
	CG	UCG				
Total Daily Demand on the system	35	49				
Package size (kg)	60	27				
Equivalent kg	2100	1323				
Total Demand (kg)	3423					
Available time (sec.)	28800					
Unshared processes Takt time (sec/ kg.)	13.71	21.77				
Shared process Takt time (sec. kg)	8.41					

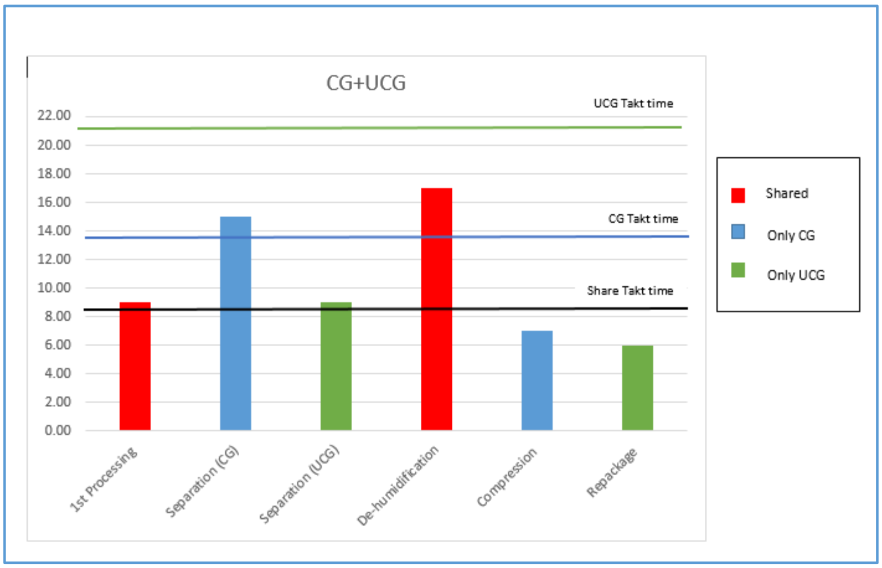

Figure 11 Illustrates the operator balance chart for production line 1, products CG & UCG

The figure above show three color scheme to help distinguish the activities into their respective group, illustrating three items of importance which we'll present below.

- ✓ The red columns represent all shared activities, with the black line indicating the takt time required to meet demand at all share activities. Here we see that both share activities cycle time exceed the takt time, 1st Processing exceeds by 0.59 of a sec/kg, whereas the De-humidification activities exceeds by twice the takt time mesuring 17 sec/kg.
- ✓ The blue columns time indicates the activities conducted only by CG, with the blue showing the required takt time. The separation activity exceeds the takt time by 1.33 sec/kg whereas the compression activity operates safely below the takt time.
- ✓ The green columns shows the activities special to UCG only, and the green takt line showing the required takt time for UCG. Here we see that both activities separation UCG and repackaging are both operation safely below the takt time.

A similar analysis was done for the CortiPAN and Broken, table 21, shows a summary for the data for full analsis please visit annex D table 44, figure 23.

- Unshared process Takt time, this is for activities are not common to both products
  - CortiPAN = 29 sec/kg
  - Broken = 1067 sec/kg (the takt required to meet the demand for broken cork 2012)
- Shared process takt time, for activities that are commom to both products = 28 sec/kg

Table 21 Operator balance table for production line 2, products CortiPAN and Broken

	Processing	*Filling into bag*	*MC*	*Packaging*
Activity cycle time	11	3	28	3
Unshared processes Takt time (kg/sec.)	29		1067	
Shared process Takt time (kg/sec.)	28			

The results for the Production line 2 operator balance chart shows that all shared activities (identifty here with the underline mark) cycle times are far below the required takt time. The same is for the unshared activities also which only the CortiPAN performs (mixing to ploishing and packaging). However the MC (which houses the activities Mixing to polishing) has a cycle time of 28, which gives an effective slack of only 1sec therefore this activity should be monitored when further increases in daily demand occurs.

From the both operator balance chart above we can conclude that the activities which operate above takt time 1st Processing, Separation and De-humidification.

- ✓ 1st Processing output is governed by the rate at which raw material is feed at the beginning of the process, and this rate in turn is dependent on the type of material and humidity of the material.
- ✓ Separation is governed by the rate of flow into the final milling stage before the separation, this activity doesn't have any set up time, or change over time etc. therefore to reduce the process time the operators need to control the feed rate, increasing the feed rate is one option or have 37min (65sec*34) over time each day to meet the demand.
- ✓ De-humidification process illustrates the greatest mismatch between Takt time and cycle and hence it is the bottleneck of the process and should be the pacemaker for the production line 1. We'll revisit the de-humidifier later on.
- ✓ Although all activities in production line 2 currently operates below the require takt time, based on demand for 2012, however the activity with the lowest slack time which is the MC would be designated as the pacemaker for production line 2.
- ✓ All other activities in both production lines operate safely below their respective takt time.

Now that we have analyzed and interpret the results from the operator balance chart, we can redesign a new VSM map with the knowledge and insight gain about the process, where resources are in abundant and where there is scarcity. The VSM map of DOF was redesigned with the goal to reduce inventory throughout, thereby reducing the lead time and also to better control the flow within the system. The insight gain from the operator balance charts verified that most activities cycle time (for 2012 demand) is operating below the required takt time for either production lines and by extension the products, suggesting there isn't a great need for excessive inventory within the system.

Figure 12 show the fully redesign VSM map for CG process, the other VSM map for CortiPAN and UCG are shown in annex D figure 24 & 25 respectively.

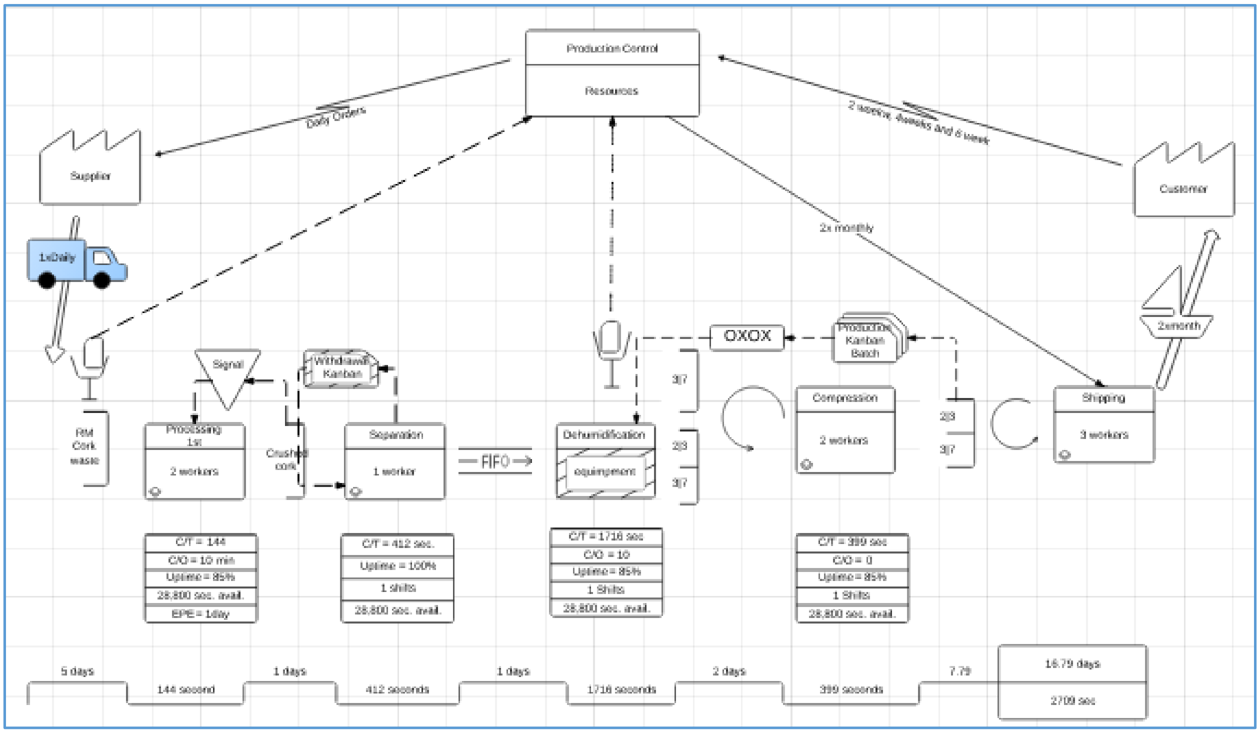

Figure 12 Redesign VSM map for the CG product

The new VSM works on the philosophy of pull production, unlike the current push production system currently used at DOF, where kanbans and supermarkets are used to facilitate the pull of material through the process. As can be observed there are five supermarkets within the process there are;

- FG supermarket from which customer demand are met
- WIP supermarket between De-humidification and compression to hold a safety stock of two days for the compression process for protection against equipment starvation from De-humidifier.
- WIP supermarket between Processing 1st and Separation to protect again production issues at Processing 1st.
- Raw material supermarket to control the flow of raw material into the operation, this aims a having the raw material pull into the operation only when customer orders are made.
- Final purchase WIP supermarket, which would control the flow of purchase 3|7 grains into the process

Addition to the supermarket we see there are three kanban production systems,

- 1st system between the FG supermarket and pacemaker De-humidification, also there is a production leveling process here, to level the demand at the pacemaker.

- 2nd system is located between the Processing 1st and Separation, this system is a signaling kanban, which would indicate to the Processing 1st when the Separation process is active to that production can begin at Processing 1st.
- FIFO (first in first out) system between the Separation and De-humidification process, which is complimented with the kanban square technique to help curb the desire to engage in over production.

Table 22 below shows the compiled results for the new redesign VSM maps, with projected LT reduction of 40.63, 16.14 and 18.14 for the CortiPAN, CG and UCG respectively. These reduction represent in some case as much as 73.03% decrease in the LT of the CortiPAN, 62.25% decrease for UCG and 49.01% decrease for CG. Which is understandable as the current VSM is obese with FG, WIP and RM inventory.

Table 22 Results for the redesign VSM map, with comparison to the current VSM map.

	Lead Time (LT) days)		*Projected Reduction*	
Product	Before	After	Days	%
CortiPAN	55.63	15	40.63	73.03
CG	32.93	16.79	16.14	49.01
UCG	29.14	11	18.14	62.25

Recall that current VSM has production control at several points along the manufacturing, let compare with new VSM.

Table 23 Identifying the new Production Control (PC) points in the new VSM

Product	Current PC Points	Future PC Points	Comments
CortiPAN	Processing Baking (MC) Shipping	Shipping	All future VSM of were design with DOF building their products to a FG supermarket (WH), which ties in line with the FG strategy. Therefore PC points in the new future VSM's occur at Shipping only. When a customer makes an order specifying quantity of FG, this quantity is then removed from the FG supermarket, creating a domino effect, whereby FG supermarket would pull the exact quantities needed for each product to replenish its stock, from the upstream processes/production line. This pull of managed using kanban and Heijunka tools.
CG	Separation Dehumidification Compression Shipping		
UCG	Separation Dehumidification Repackaging Shipping		

In addition we believe it suitable to have a separate finish good inventory strategy at DOF, which is,

- Make to Stock (MTS) – for the high runners products which are the A and B products
  - A – CG and UCG
  - B – CortiPAN
- Make to Order (MTO) – for the low runners product C
  - CortROLL

- Broken

5.3. Production Control via Kanban Pull System, Heijunka and Visual Management

The next step in fulfilling the design for the new VSM activity is outlining the production pull system which aim to ensure that inventory, production and waste remaining within low limits, the number of kanban was determine using the following formula,

$$Kanban = \frac{Expected\ demand\ during\ lead\ time\ x\ safety\ stock}{size\ of\ the\ container}$$

$$k = \frac{DL(1+S)}{C}$$

K = Number of Kanban card sets
D = Average number of units demanded over some time period
L = Lead time to replenish an order (expressed in the same unit as demand)
S = Safety stock expressed as a percentage of demand during the lead time
C = Container size.

As much before in the description of the new VSM design there are three kanban controls on the production line for CG and four for UCG. Whereas two kanban controls for the CortiPAN production line. Table 24 below show for each product, the location and number of kanban required to control the production flow. To calculate the number of Kanbans needed, in most cases we utilized the current container size used by DOF, to estimate a value for the safety stock was however more difficulty, because DOF experiences high variation in sales of all its products (higher the 39% standard deviation, i.e. standard deviation/mean for each product) therefore to estimate the value of safety stock we used the following equation:

$$Safety\ Stock = z * \sigma$$

Where:

$z =\ service\ level\ deserved\ by\ DOF$

$\sigma = standard\ deviation$

DOF desire a high service to reduce to the possibility of stock out resulting in their inability to meet customer demand, therefore a safety level (z) of 1.96 was selected, which would result in only a 2.5% chance of stock out. However to accomplish we had made the assumption, which is:

- That the demand for each product follows a normal distribution curve.

Table 24 Kanban Calculation for product

Product	*Kanban location*	*Kanban Count*
CG	Separation – Dehumidification	2
	De-humidification – Compression	4
	Compression – Warehouse	52

UCG	Separation – Dehumidification	2
	Dehumidification – Repackaging	4
	Repackaging – Warehouse	10
CortiPAN	Processing – MC	8
	MC – Warehouse	81

For full details of the calculation please check annex D, table 44.

5.4. Heijunka

To accompany the kanban control, Heijunka was used to level production at the pacemaker of both production lines. Recall that the pacemaker for the production lines are;

- Production line 1 (CG & UCG) – Dehumidifier
- Production line 2 (CortiPAN and Broken) – Manufacturing Cell

Current there is no leveling occurring at either of these points; rather production is executed in large batches of;

- ➢ Dehumidifier – large batch size work equivalent of 2/3 days
- ➢ MC – large batch size work equivalent of 3/4days
- ➢ Compression – large batch side 0.5/2.5days
- ➢ Processing activity CortiPAN – 1week

Therefore we utilize Heijunka to levelling the activities at these two points in either production lines, the level schedule for each product at the pacemakers are indicated in the table 25 below, this schedule is for an EPEI (every product every day) of one day for the CG and one weeks for the CortiPAN. The schedule for the CG and UCG was choose to push the production system one step further than what it is currently. Whereas for the CortiPAN, because if wide product variety and large setup times averaging between 30 min. for every changeover a level period greater than one day is more effective.

Table 25 Heijunka levelling table for the pacemaker process in production line 1&2

Production Line 1		*Production Line 2*	
No. of Products	*3*	*No. of Products*	*6*
No. of change over	*120*	*No. of Change overs*	*12*
	0.045		*11*
Day	*1*	*Days*	*11*
Product	*Daily quantity*	*Product CortiPAN*	*One week quantity*
(2|3) bales	*9*	*10 mm*	*12.00*
(3|7) bales	*27*	*20 mm*	*27.00*
(2|5) bags	*49*	*30 mm*	*14.00*

	40 mm	*9.00*
	50 mm	*26.00*
	60 mm	*3.00*

5.5. Visual Management

To aid in production control, clear and easy communication of information about jobs, we have decided to utilize visual management dash boards, these board must have a simple design and are focus on driving business processes from the boardroom to the shop floor (Parry and Turner 2007). We' suggest two visual boards;

- 1st to illustrate jobs and their priorities
- 2nd visual metric board to measure and match production to the target demand from customers.

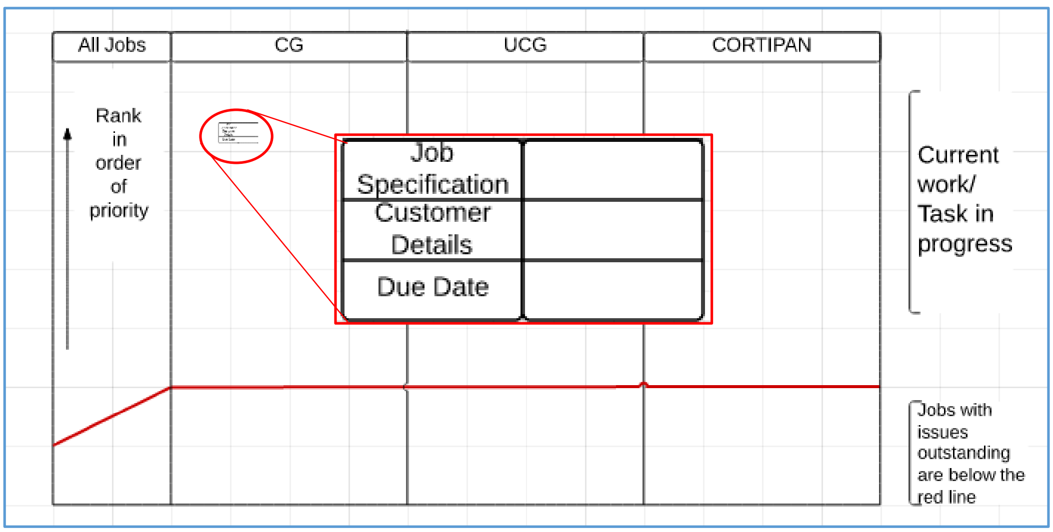

Figure 13 Visual board for jobs management

The figure 13 shows the proposed design for the 1st dash board for DOF (design adapted from the *Application of lean visual process management tools by Parry and Turner 2007*). This board shows the three main product of DOF (CG, UCG and CortiPAN), under these division each Job can be represented and for clarify different colors can be used to represent the different products (e.g. red-CG, blue-UCG and green-CortiPAN). In the column on the furthest left we see an area where all jobs can be arranged according to their priority of completion, this is also the same for each job within each division and any job which is facing difficulties that are preventing its completion should be place below the red line with a comment on the issue preventing said job completion, for quick notification to management. Figure 13, also shows a simple design of a job card that can be used to track record and track jobs.

The second visual metric figure 14 measure production at frequent intervals to ensure production

Areas	Activities	Units	Monday Production	Target	Tuesday Production	Target	Wednesday Production	Target	Thursday Production	Target	Friday Production	Target
	Processing 1st											
	Separation CG											
	Separation UCG											
Granulation	Dehumidification CG											
	Dehumidification UCG											
	Compression											
	Repackaging											
	Processing											
CortiPAN	MC											
	Packaging											

Figure 14 Visual metrics for production control

occurs at the level desired based on the actual demand being pulled by the customers. The metric list all activities within both production lines, the purpose is to match the actual demand to the actual work being accomplish at each activity in the production lines so that, it would be easy to pinpoint areas where production is lagging or leading actual demand, thereby keeping a check on all activity areas.

These visual tool are very simple in design, allowing ease of reading, understand, for reporting the progress in a division on the shop floor giving a snapshot of jobs progress, where resources might have slack (man power) and where doesn't etc. The use of the prioritization would also provide managers schedule solution for jobs and also inform customer of the estimate rate of progress and the expected of the Job completion. It should be noted that these boards should be place in a central location which is visible to all workers. We recommend two types of scheduling technique, which can assist executing jobs, if several jobs are placed at the same time.

- Simple - First in First out
- Dynamic - Critical ratio or earliest due date

5.6. 5S and Layout Alteration

5S system is suggested for use in the WH and WIP inventory area, aiming at improving the current operation of storage area, ensuring items are neatly stock and clearly visible at all time so workers can obtain information quickly about inventory levels. The motto of 5S is "a place of everything and everything in its place" this is to help ensure order, reducing chaos which is usually present in all manufacturing operations.

Present view of DOF storage areas:

DOF WH is dynamic with material location in the WH occasionally changing, and WH executing multiple functions such as: storage of FG, occasional WIP granules existing the separation, CortiPAN during stabilization, and occasionally a separation device for manual abstraction of stoppers from grains was also operated in the WH. Below are some observation made about the WH:

- Product duplication with UCG being stored at different location in the WH,

- FG's, CortiPAN and Granulation WIP is store in the WH,
- Separation device for manual abstraction of stoppers from grains was also operated in the WH.
- Material loading is accomplished at random location in WH
- Occasionally vehicles such as trucks and forklifts are left in the WH.
- General observation – WH is generally clean and free from trash at most times, however it's not unusual to find items that are not FG's such as: WIP, equipment/vehicle place at random places in the WH.

Present view of DOF WIP inventory area:

WIP inventory area – like the WH this area is very dynamic, with material flowing in and out, some observation about what's present in this area:

- WIP inventory – of CG and UCG
- Other material – dust use as fuel for the boiler,
- Equipment – Compressor, Cylinder dryer, Broken cleaning equipment, De-humidifier
- Other equipment's – bags for grains, pallets (large and small) for stocking bales and BB of grains
- General observation – within this area there seems to be some order in where items are place, however pallets and bags are stock without order, waste grain that isn't being used is left in the area for extend periods and the area is very dusty.

Indicated in table 26 below is a proposal for the implementation of 5S at DOF, (please refer to annex D figure 26 for complimenting diagrams and FOM estimation)

Table 26 5S program

	WH	WIP inventory area
Seiri (sort) – we sort in the above areas into:	➢ Valuable to WH operation – all FG's ready for shipment. ➢ Valuable, but not critical to WH operation- WIP CortiPAN, granules and manual separation device. ➢ Waste – currently limited waste (trash) was identified in the WH	➢ Valuable to operation – everything mention above, excluding waste. Sorting here is about bring order to the area. NB: All WIP grains should be placed in this area (not the WH)
	Keep valuable items and remove all others.	
Seiton (set in place) – using simple logic we've suggested a few changes to the layout of both WH and WIP incorporate only what is needed and valuable to either operations.	➢ FG's ➢ Forklift for picking ➢ Cleaning equipment/area (broom etc.) ➢ Etc. FG stocks was arrange based on FOM to the dispatch area to reduce the movements of people, stocks and the handling equipment.	➢ WIP, Cork Dust ➢ Forklift for transporting FG's to the WH ➢ Cleaning equipment/area (broom etc.) ➢ Etc. WIP should be stock according to proximity to equipment used.
	Wall fixtures and floor striping or painting should be use denote the exact location for each item to be stored in either areas, also to map out the path for vehicular traffic to ensure this area would always remain free to allow the free flow traffic.	

<table>
<tr><td rowspan="3">Seiso (shine) – routine cleaning of the areas should be incorporated into the daily activities, this an important to the implementation of 5S. This clean can involve:</td><td colspan="2">Seiso Checklist</td></tr>
<tr><td>➢ Provide WH good lighting
➢ Sweeping the WH floor area,
➢ Relocating the pallets which becomes free after shipping to the respective place,
➢ Keep clean over time.</td><td>➢ Provide WH good lighting
➢ Neatly pack bags and pallets
➢ Keep individual workstation clean
➢ Daily remove all cork waste from the work area.
➢ Keep clean over time.</td></tr>
<tr><td colspan="2">There should daily cleaning program for the area e.g. 10 minutes at the end of day.</td></tr>
<tr><td>Seiketsu (standardize)</td><td colspan="2">Concentrate on the best practices for the WH, set achievement (above) as standard which must be maintained daily. Use visual charts where possible to display the standard GOOD vs. BAD practices to be a reminder to employees of the desired work practices, create cleaning program, showing area ownership and a checklist so that each employee would be aware of their cleaning duties.</td></tr>
<tr><td>Shitsuke (sustain)</td><td colspan="2">This is the difficult part and requires commitment from both workers/manager to ensure acceptance and adherence to the above standards of work, for successful in the long term. Difficult arises due to the nature of the operation at DOF, especially in the WIP inventory area due to the loading of cork dust pit for the boiler. Therefore sustaining the cleaning program would require a great effort to ensure the working area remains tidy.</td></tr>
</table>

NB: the 1st 3S's Seiri, Seiton and Seiso items mention above should be agreed on by all stakeholders (employees and management), to ensure employees involvement and acceptance of change, thus ensuring they know what part they play in the overall success for implementing 5S.

To build on the 5S changes in the WH and WIP storage area (C) the material flow of factory was altered a bit to reduce material movement. This changes are made possible with the new VSM design, calling for induction in all forms of inventory, thereby making space available which was previously occupied by inventory. The reduction in RM inventory is one such location where space would now be free for utilization, this free space can now be utilized for the stabilization process of CortiPAN, as depicted in the new layout diagram figure26 annex D.

5.7. Streamline Production Flow with better unit conversion between workstation

To better streamline to process we examine the material flow to identify areas of disorder which could be the source instability, due to the fact that the transfer unit between workstation doesn't convert smoothly into units of FG's. This is briefly presented in tables 27 below, the table shows the FG unit at 60kg and 27kg for CG and UCG respectively, also shows the transfer size unit for the three stages. When we compare the equivalent FG (end product) at each stage by dividing by 60kg (27kg) it can be observed that for the CG production, the current output units utilize at both separation and dehumidification isn't directly convertible into FG, which can resulting in a situations where either there is too much work at the workstation to not enough, further making a bit difficulty to match production with demand in a seamless manner.

Table 27 Units conversion between workstation analysis

All values in kg.		*Unit conversion between workstation*			
Activity		*Separation*	*De-humidifier*	*Compression*	*Repackage*
Transfer unit		*27*	*162*	*60*	*27*
CG FG	*60*				
Equivalent FG		*0.45*	*2.7*	*1*	
UCG FG	*27*				
Equivalent FG		*1*	*6*		*1*

The opposite is the case for UCG, one observation made about the separation packaging process is: there no specifically control over the amount of grains placed into a bag, it is more less a rough average therefore we can accept that there would be some disparity in the 27kg weight quoted by manager and this inconsistence/variation can create some internal turmoil.

Thus to ensure the amount of grains process matches the daily demand for the CG we proposes a new transfer unit and means of transport:

- A container (metal or plastic) with the following characteristics,
  - Wheels to enable easy movement between workstations
  - Having a volumetric size of 2m^3 or 3m^3 (for the 3m^3 total surface area (TSA)[8] H= 1, W 1.22 and L= 2.45) to be able transport 120kg and 180kg respectively. (1m^3 quoted by the PM for 3 bags)

Table 28 New proposed transfer size between workstation and its respective unit conversion

		Unit conversion between workstation			
Activity	*Unit*	*Separation*	*De-humidifier*	*Compression*	*Repackage*
	Kg	*120/180*	*120/180*	*60*	*27*
FG CG	*60*				
Equivalent FG		*2/3*	*2/3*	*2/3*	

These transfer size would be ideal because they converts directly into FG, also having several other benefits such as,

- Help better control production by direct conversion into FG
- Streamline material flow – ensuring what is produce matches what's needed
- Reduce changeover time – with the proposed EPEI of 1 day there would be one change over at the downstream workstation (compression), by controlling the work load before the workstation to match demand, there wouldn't be blockage due to the fact that machine is loaded pass the demand, resulting in longer offloading/cleaning machine time in preparation for next product.
- Reduce material travel distance between workstations
- Free up equipment for more important task.

A similar inspection of the unit conversion for the CortiPAN was conducted with the objective of optimizing two parameters:

[8] TSA value obtain using excel solver, the objective function minimize TSA using excel solver estimated the dimension needed.

1. Conversion of CortiPAN board into packages
2. Space utilization on each pallet for shipping

The current packaging configuration used at DOF is show on the left hand side of table 29, the products that catches our attention is the 20 and 40 mm, presently the packaging size for the 20 and 40 mm is 8 & 4 pieces respectively, because every CortiPAN plate manufactured is divided into 15 pieces effectively this package gives 1.88 and 3.75 package per board for the 20 and 40 mm dimensions as illustrated in table 29. The reasoning from our analysis is that to improved conversion of CortiPAN boards into packages all packaging such be done in factors of 15, such as 3, 5 or 15 pieces.

Table 29 CortiPAN current packaging practice analysis and future proposal

		Current packaging		*Future packaging*	
mm	Piece/ board	Pieces/Pac kage	packages/ board	Pieces /Package	packages/ board
10	15	15	1	15	1
20	15	8	1.88	5	3
30	15	5	3	5	3
40	15	4	3.75	5	3
50	15	3	5	3	5
60	15	3	5	3	5

Why is this mismatch between number of pieces in each board and the pieces in each package important? The importance resides in the fact that the FG's unit of sale (i.e. the minimum a customer can order), isn't a pallet although the pallet is used for shipping, the actual FG's unit of sale is the package. Therefore any customer order for e.g. the 20 and 40 mm would require production to exceed customer demand in order to fulfill customer order. This over production however would be less than the required amount for a package (thus it can't be package and placed in FG's) therefore, it would remain as WIP pending a new customer order or additional production before being utilized, however this would be an ongoing cycle.

The second objective is to optimize the space utilization on each pallet, the available space/dimension on each pallet is: height 2.6, width 0.5, and length 1m. Figure 15 below shows an example of the packaging configuration used, for the 20mm CortiPAN product, in this exam the dimension for the current package (8 pieces) are used. The figure shows that by using this packaging size there is unused space equivalent to 0.4m (1.2m – (2*0.5 + 0.16) = 0.4m) on each pallet ship, table 30 below show two things:

- The current space utilization for each respective packaging configuration currently be used.

➢ Our analysis and propose solution to increase optimization of the available space on the pallet.

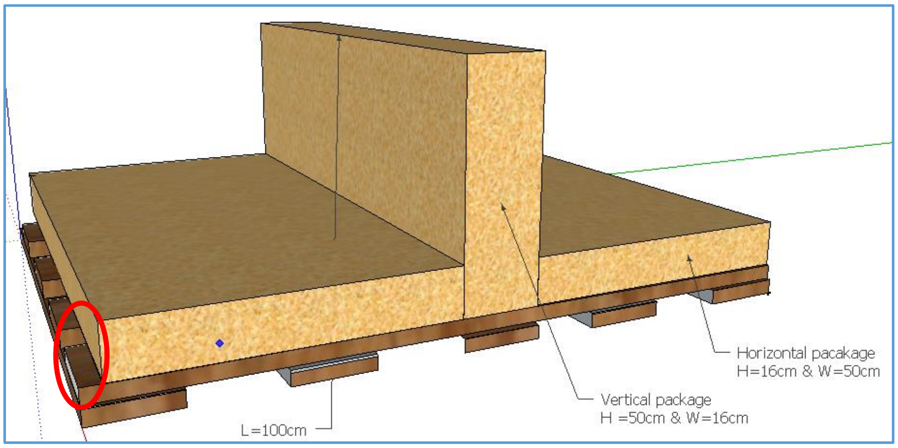

Figure 15 showing package configuration for the pallet

The increase optimization, was obtain by manipulating the package size to better maximize the space constrain of the pallet; which is height (2.6m) and width (1.2m) constrains, the length dimension of the CortiPAN is exactly equal to the pallet lenght. As can observed there are two horizontal packages, with width dimensions of 0.5 m each, effectively leaving 0.2m available to optimization, where as for the height, the entire 2.6m as free for maniplution to exploit the most of height. Our optimization results seen in table 30, shows that it is possible for 4 out of the 6 product can optimization their pallet space utilization.

Table 30 Showing results obtain from optimizating the pallet space utilization

Available space 3.12m³										
				Present	Proposed optimization					
mm	Package size	No. of pieces	Space used (m^3)	% Used	Packag e	No. of pieces	Space used	% utilized	Increase in Space Used	Increase in pieces
10	15	555	2.775	89%	5 or 10	620	3.1	99	10%	11.71%
20	8	296	2.96	95%	5	310	3.1	99	4%	4.72%
30	5	195	2.925	94%	5	195	2.925	94	0%	
40	4	148	2.96	95%	5	155	3.1	99	4%	4.72%
50	3	117	2.925	94%	2	124	3.1	99	6%	5.98%
60	3	99	2.97	95%	3	99	2.97	95	0%	

Can be noted by optimizing the pallet space, making the suggested changes in to the packaging configuration it is possible to increase the carrying capacity of each pallet for the four dimension; 11.71% (10mm), 4.72% (20 & 40mm) and 25.25% (50mm). However there is one conflict however between the two objective mention at the beginning of this section, i.e. for the conversion optimization it requires packages to contain number of pieces that are factors of 15, however for the space optimization for the 50mm requires package size of 2 pieces

5.8. Quantifying potential benefit to be gain from recommendations

Thus far we have explore DOF operation, conducted an analysis of their activities, from which we have made some recommendations for improvement; in this section we'll quantify the potential benefits to be gain from these improvements, again we noted that the results below were not actually obtained, but it's what we anticipated, these would be explored in the following order:

- New VSM design,
- Increase pallet optimization
- New equipment for material transfer between workstation
- Layout alteration

The new VSM map design, recommendation for drastic reductions in all forms of inventory and the transformation from the current push production system being utilized, to a more efficient pull production system where work is only accomplish on real demand. The analysis of DOF current VSM show large inventory spread across all its products and production line, in table 31 we've quantify the benefits that can be gained by reducing RM, WIP and FG inventory and also adapting the pull production flow. The table shows a summary of the cost analysis for each product, this cost analysis was conducted on a monthly average of RM, WIP and FG inventory calculated in the current VSM map.

As can be observed the current VSM map has huge sums of money tied up in inventory, when comparing the average inventory value and avg. sales value of a month the comparison shows some compelling results, that for the CortiPAN its inventory value is 807% the average monthly sales value. Whereas for CG and UCG the estimate inventory value is 81% and 85 % respectively of the average sales for UCG and CG.

Table 31 Quantitfing benefits of the New VSM

Product	*Estimate current value (€)*	*Average monthly sales (€)*	*Compariso n to sales*	*Projected future vale (€)*	*Potential Saving (€)*	*%*
CortiPAN	120,380.03	14,925.23	807%	21,187.95	99,192.08	82%
CG	63,415.05	74,556.81	85%	34,196.12	29,218.93	46%
UCG	34,753.02	43,037.31	81%	11,202.96	23,550.06	68%
Total	218,548.09			66,587.03	151,961.07	70%

The future design VSM however show dramatic reduction in the all forms of inventory across all products, reducing inventory value CortiPAN, CG and UCG by 82%, 42% and 68% respectively resulting an total reduction of 70% with an estimated potential savings of € 151,961.07. Please refer to table 44, 45 & figure 25 annex D for more details.

The new VSM calls for better control of the flow of material into and out of the company, i.e. try to stabilize the material flow, proposing a raw material pull not push. An initial study of DOF supplier's shows that 80% of DOF A and B suppliers are location within a 20 min driving distance for DOF operation, therefore because of their close proximity to supplier DOF can change its raw material delivery pattern, to daily delivery table 54 annex D.

Benefit of the new pallet optimization

Here we'll illustrate the cost benefits to be gain by the results of the pallet optimization for the four dimension 10, 20, 30 and 40 mm. For a detail view of the calculation please refer to annex D.

Table 32 Estimating the tansportation cost saving, due to pallet optimization.

Transportation Cost fixed at €*2000/truck*						
Truck capacity/pallet	Carrying Current capacity		Future Carrying Capacity		Reduction in Transport cost	
	Avg. m^3/pallet	TC/m^3	m^3/pallet	TC/m^3		
26	2.93	26.25	3.1	24.81	1.44	5.48%

The most immediate benefit to be gain from our proposed pallet optimization is a decrease in transportation cost of 5.48% for every truck of pallet shipped. Additional to this benefit there is of increase in revenue in the long term, which we estimated below.

Table 33 accounting the potential value changes for pallet

CortiPAN sizes	*Avg. value/pallet (€)*	*Value Increase (€)*	*Amt. Increase (€)*	*VC increase for new package /pallet (€)*	*Actual-VC increase (€)*	*Pallet sale record 2012*	
10	799.62	893.26	93.65	1.28	92.37	17.03	1573.0611
20	436.23	456.86	20.63	0.55	20.08	71.77	1441.1416
40	421.32	441.24	19.93	0.55	19.38	44.81	868.4178
50	414.13	518.71	104.58	2.45	102.13	171.1	17474.443
Total							21357.06
Revenue2012	*179102.70*						

Table 33 above show a summary of the estimated revenue increase per pallet due to the changes suggested. Additional a cost increase was evaluate to determine actual value to be obtain, accounting for factors such as increase variable cost (VC) of each pallet.

The only estimated increase in cost that would be incur as a result of the changes, was attribute to an increase in wrapping material used for packages. Using the year 2012 sales records a potential revenue increase of value € 21377.43 could be achieved using the optimization packaging, representing an 11.92% increase in revenue for the year 2012, refer to annex D table 46 to 49, for more detail. However it should be noted an assumption was made to obtain the above estimated value this is;

- Defects from the CortiPAN production is 0, (the actual defect rate is estimated at 2%) which is equivalent to 0.3 of every CortiPAN board produced, therefore for every 50 pieces of CortiPAN plate 1 is defective because this value is quite small we made the assumption of 0% defects.

New Material transfer

The new method for material transfer between workstations aims at streamline the flow into the production processes, the focus here is to adjust the mismatch between the CG transfer batch and FG size, as shown in table 27 and 28 above. Recall that either transfer batch were either too small or too big to smoothly convert into FG, result in overproduction at the pacemaker, processing more than what is needed to meet the daily demand as illustrated in the table 34 below.

Table 34 Benefits from new transter batch at the pacamaker

	CG FG	Equivalent (kg)	work at de-humidifier (big bags)	Actual work (roundup big bags)	Equivalent (kg)	Excessive production (kg)	Excessive production time (sec)
Units/ quantity	60		162				1716
CG Daily Demand	36	2160	13.33	14	2268	108	1144.00

To meet the daily demand of 36 bales the process suffers an overproduction of 108kg or an equivalent 1144 sec. (19mins 04sec). The significant, is that the time at the bottleneck is very scarce and most critical to the efficient function of any process, overproduction here would negatively affect the productivity of the process. The new proposed transfer batch system provides one solution which results in a saving of *19 min* at the bottleneck. Some addition benefit of the proposed solution is given in table 35, here we show how the changes affect the PAM of CG.

Table 35 Results of how changes in transfer bactch affects PAM of CG

	Transport distance (m)	Transfer time (min)	Total activity time (min)	Operation activity time	VA time
Before	266.5	2.5	5425.16	1.06%	31.82
After	141.5	0.5	5301.86	0.96%	34.02
% difference	46.9%	80%	2%	9%	6.91%

Here we see positive result such as an overall 46.9% reduction in material transit distance, 80% reducing in the transfer time from between workstation, 9% reduction in operator operation activity time, indicating that the operator would do less manually work in facilitating VA activities. However the VA time, has increase, due to the increase time at the de-humidifier from 20 min to 22.2 min

Benefit from New Layout

In the new layout proposed, the greatest benefits comes to the CortiPAN product other products such as the CG benefit has be highlight above table 35 with an estimated decrease in material movement of 46.9% therefore we'll just show the benefit to gain by the CortiPAN with the new layout alteration.

Table 36 Shows the reduction is material travel which can be obtain with the new layout proposed

	Distance Current (m)	New Layout (m)
Dist. moved internally/pallet shipped	285	30
Conversion of small pallets into shipping pallet	2.2	2.2
	627	66
Dist. to loading	95	10
Total internal dist. moved/pallet shipped	722	76

6. Conclusion

In this chapter we present the main conclusions from this thesis. We divide this chapter into three parts; conclusions concerning literature review and its implication on DOF, conclusions drawn from the analysis, and finally we discuss interesting directions for future research.

The main objective of the presented work was to apply a lean analysis to DOF process flow, identifying areas of waste and lean tools that can utilized to reduce the waste within DOF process, thereby helping to improve DOF operations. There were several limitation faced while executing this study, such as; *lack of available data, limited access to information, limited time allocated for study (longitudinal effects) and language barrier.* Thus it wasn't possible to implement the proposed solution and quantify the actual results obtained. However despite these limitation we did quantify the potential benefits that can be obtained by DOF from the solution proposed.

6.1. Conclusion from literature review and its implication on DOF

This was included because SME faces greater barriers for the successful implementation of lean. Therefore some critical factors that would need to overcome barriers are:

- Leadership responsibility, committed management support, resource and finance,
- Behavior change within the organization; to improve workers motivation, participation and communication (information sharing)
- Knowledge and knowhow for implement lean to prevent backsliding into pre lean operation state.
- To develop greater influence over supplier and customer behavior, to reduce variability.

6.2. General Conclusion concerning Work

From the analysis conducted, its was concluded that DOF operation has the follow characteristics according to lean; overproduction, waiting (long LT), unncessary inventory (RM, WIP and FG) and excess transportation in the case of CortiPAN. The underling effects that are cause for these waste are; high variability both in Sales and Supply of raw material to the factory, the adoption of a push production system with limited production control and factory layout.

The solutions proposed aims at attacking these waste throughout each product value stream, by converting the process to a pull production based on customer demands, implementing production control mechanism such as Kanban system, Visual management techniques (dash boards and 5S) and Heijunka at the pacemakers activites. Addtionally the solution calls for better unit conversion for CG and CortiPAN products, and a small alteration to the current layout to reduce material movement.

These proposed solution bears potential benefit to DOF, such as;

- ✓ Reduction in Lead time for each product,
- ✓ Reduction in all forms of inventory – resulting in less cash tied up in inventory and available for utilization.
- ✓ Reduction in material movement – during manufacturing and shipping
- ✓ Reduction in overproduction – due to multiple production control tools and pulled production system which would control the flow of material through the process.

- ✓ Reduction in waiting – as less inventory exist
- ✓ Reduction in space required –allow for layout changes
- ✓ Increases in optimzation of both package and pallet space for shipping.
- ✓ Streamline flow within manufacturing process – CG and CortiPAN.

6.3. Future work

This study has provided a framework for a new way of thinking at DOF; however we are not presumptuous to believe these are all the problems facing DOF and only one solution to correct them, rather we accept this as just the first step or iteration for the implementation of Lean and the continuous improvements which is at the heart of lean manufacturing. Therefore it only prepares the soil for the lean foundation with which the company can grow. Future work would include;

- ✓ Implementation of VSM – table 54 annex E shows the Value Stream Plan for achieving the future state VSM.
- ✓ Implementation of lean tools
- ✓ Further analysis to identify additional techiques that can be used at DOF e.g. SMED
- ✓ Adopting Kaizen approach

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Annex A

Table 37 showing the results from the Shah and Ward (2003) Lean Bundles

Tools	Bundles	Unionization			Age of Plant			Size of Plant		
		Natural	+	-	Natural	+	-	Natural	+	-
Lot size reductions	JIT								1	
JIT/continuous flow production	JIT						1		1	
Pull system	JIT								1	
Cellular manufacturing	JIT			1					1	
Cycle time reductions	JIT			1			1		1	
Focused factory production systems	JIT								1	
Agile manufacturing strategies	JIT								1	
Quick changeover techniques	JIT								1	
Bottleneck/constraint removal	JIT								1	
Reengineered production processes	JIT						1		1	
Predictive or preventive maintenance	TPM								1	
Maintenance optimization	TPM			1					1	
Safety improvement programs	TPM					1			1	
Planning and scheduling strategies	TPM					1			1	
New process equipment or technologies	TPM								1	
Competitive benchmarking	TQM								1	
Quality management programs	TQM							1		
Total quality management	TQM					1			1	
Process capability measurements	TQM			1					1	
Formal continuous improvement program	TQM								1	
Self-directed work teams	HRM			1			1		1	
Flexible, cross-functional workforce	HRM			1			1	1		

Legend	
-	Negative association suggests that plants are less likely to implement these practices.
+	Positive association factor, implies that plants are more likely to implement these practices
Natural	No statistically significant relationship was found with these practices.

Annex B:

Table 38 shows a list of all the raw material used in manufacturing DOF products

Granulation	Quantities	CortiPAN/Broken	Quantities
APARA BARRIGAS	###	APARA DESP. AGLOMERADO	###
APARA BROCA C/ COSTA	###	APARA FALCA	###
APARA ESPECIAL	###	APARA QUEIMADA	###
APARA GROSSA	###	CORTIÇA QUEIMADA	###
SERRIM DE CORTIÇA	###		
BOCADOS DE CORTIÇA	###		
CORTIÇA AMARELA	###		
CORTIÇA DE CALÇOS	###		
GRANULADO	###		
REFUGO	###		
CORTIÇA VIRGEM	###		
APARA GROSSA TRITURADA	###		

For confidential reason the exact quantities were omitted.

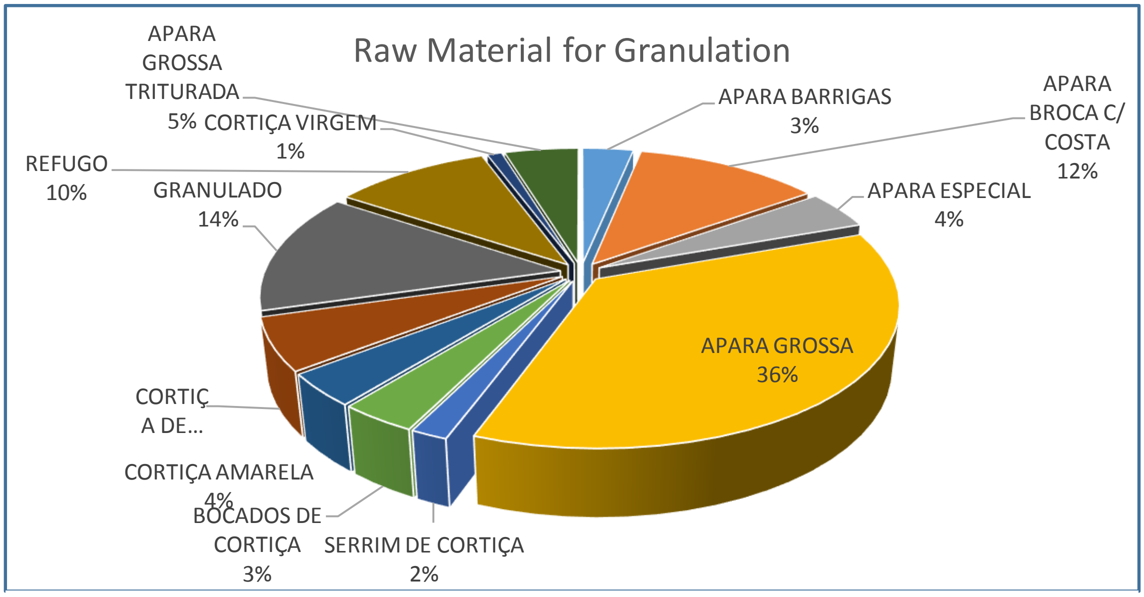

Figure 16 Showing the raw material distribution for Granulation

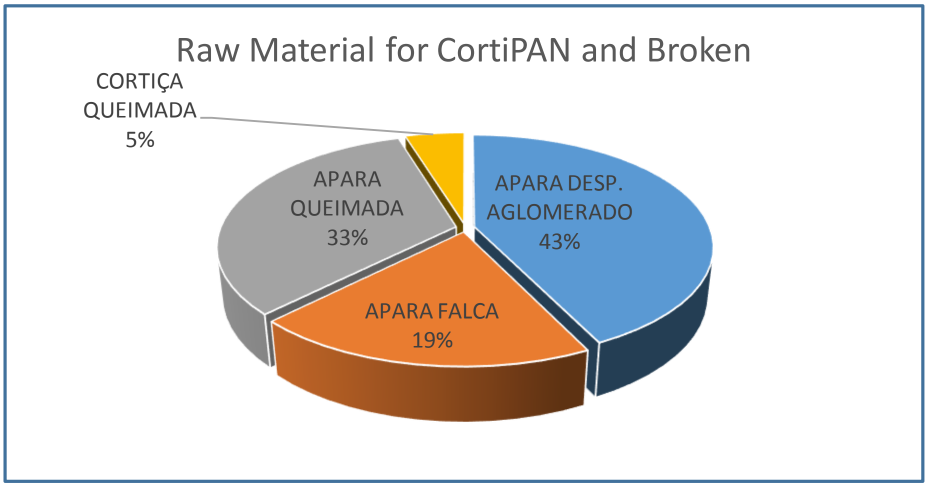

Figure 17 Showing the raw material distribution for CortiPAN

The Figure 18 below show a schematic view and the flow of material through manufacturing section of DOF facilitates. The area within the facility is distinguished by use of labels A, B C, D and E, and different colors to highlight the perimeter of the specific area.

The black line outlines the main manufacturing are, which contains section A, B and C:

- A - 1st processing has the feeder which controls the rate of flow into the process, sifter for the separation of dust and removal of large pieces cork pieces and the 1st grinder.
- B – separation area houses equipment for sorting grains into their perspective size range, these equipment's are
  - Wire maze for size sorting and
  - Density tables for weight sorting
- E is the CortiPAN manufacturing cell which houses all the equipment for the CortiPAN, mixer, oven cooling duct, saw, polishing machine and packaging equipment.
- C – Area houses the dehumidification and the Compression equipment, this area also is used for the WIP storage of gains for compression (CG) and (UCG).

The blue lines outlines the area allotted for the warehouse identify by letter F,

- F is warehouse area used for storage of FG for shipment and also currently the storage of CortiPAN boards during stabilization activity.

Final the area outline by green lines designate the area for storage of raw material and WIP (broken and CortiPAN grains)

- D1 is the storage area for the broken and CortiPAN material.
- D2 is the storage area for raw material entering the company.

There are two main flow within the manufacturing area:

- Production line 1 – identify by the red dash lines, for both CG and UCG
- Production line 2 – identify by the purple dash line for CortiPAN and broke

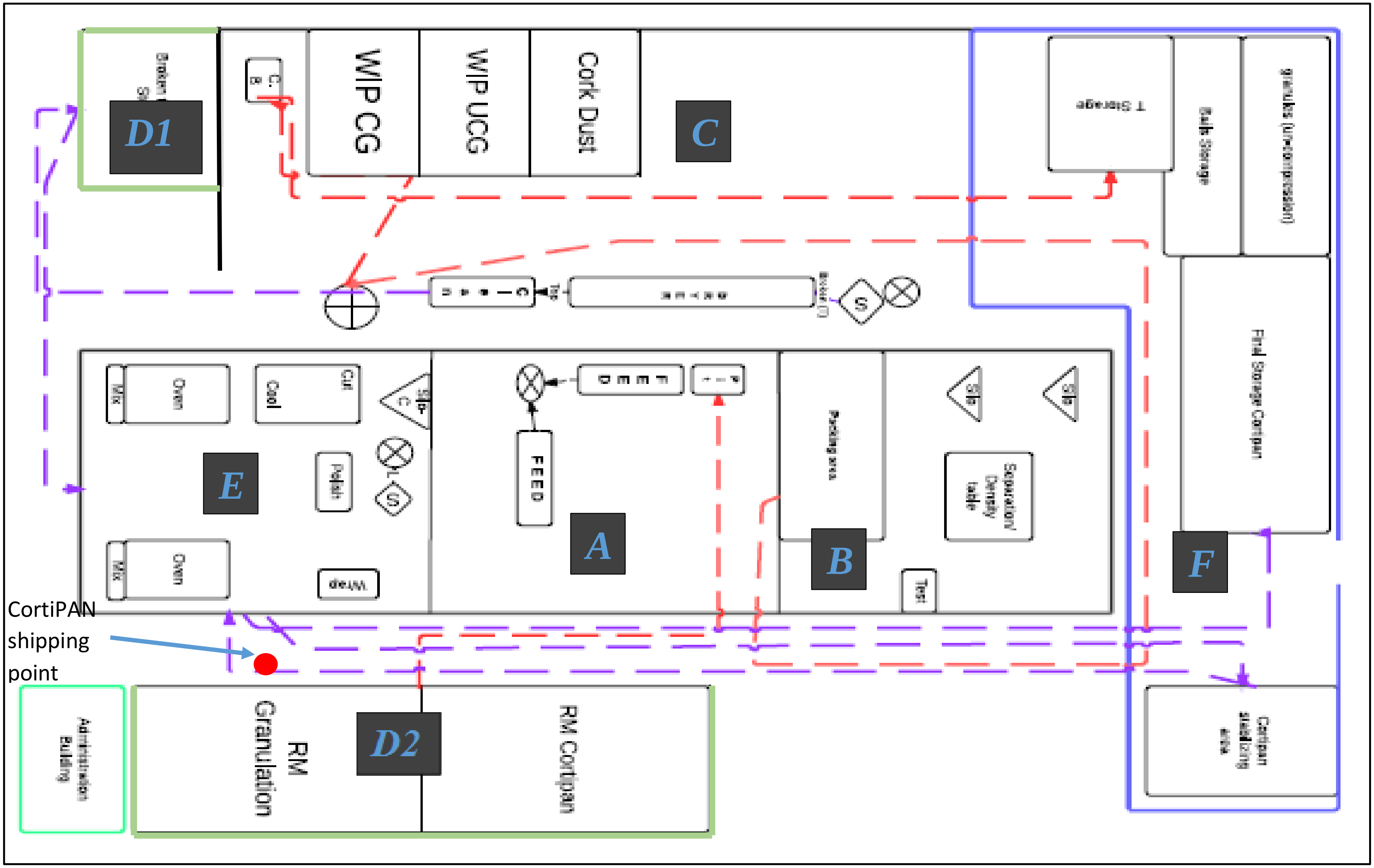

Figure 18 Current layout of DOF factory

Table 39 Human Resources Analysis

#	Gender	Date or birth	Age	Work area	Profession		Unskilled	office	Broken	CortiPAN	Granulation	Other
1	F	7/3/1979	34	office	Clerk	Clerk		1				
2	M	6/21/1966	46	Metal shop	Mechanic	locksmith mechanic					1	
3	M	7/2/1974	38	Compression	worker treatment of cork	Helper	1				1	
4	M	6/13/1960	53	Everywhere	Production Manager				1	1	1	
5	M	5/14/1969	44	Separation	worker treatment of cork	tracer of cork	1				1	
6	M	3/10/1971	42	Office	Accountant	Director of Services		1				
7	M	1/30/1966	47	Granulation	worker treatment of cork	Helper	1				1	
8	M	8/10/1965	47	Granulation	worker treatment of cork	Helper	1				1	
9	M	8/17/1959	53	Dryer	worker treatment of cork	tracer of cork	1				1	
10	M	1/22/1958	55	office	General Director and Executive manager			1				
11	M	6/2/1973	40	Granulation	worker treatment of cork	Helper	1				1	
12	F	5/6/1965	48	Compression	worker treatment of cork	Helper	1				1	
13	F	9/3/1953	59	Broken	worker treatment of cork	Helper	1		1			
14	F	2/24/1955	58	Broken	worker treatment of cork	Helper	1		1			
15	M	2/7/1967	46	Driver	Driver of heavy goods vehicles	heavy truck driver			1	1	1	
16	F	2/6/1959	54	office	General Director and Executive manager			1				
17	F	7/6/1964	48	Compression	worker treatment of cork	Helper	1				1	
18	F	6/11/1964	49	CortiPAN	worker treatment of cork	Helper	1			1		

19	M	6/18/1982	31	CortiPAN	worker treatment of cork	Helper	1			1		
20	M	5/1/1984	29	Security	Security		1					1
21	M	9/29/1983	29	office	Export director			1				
							13	5	4	4	11	1
	21		45	total				25				
				Percentage			62%	20%	16%	16%	44%	4%

Table 40 Showing the baking time according to CortiPAN thickness

CortiPAN Thickness	Baking Time (min)
10mm	7.5
20mm	10
30mm	12.5
40mm	15
50mm	17.5
60mm	20

Annex C

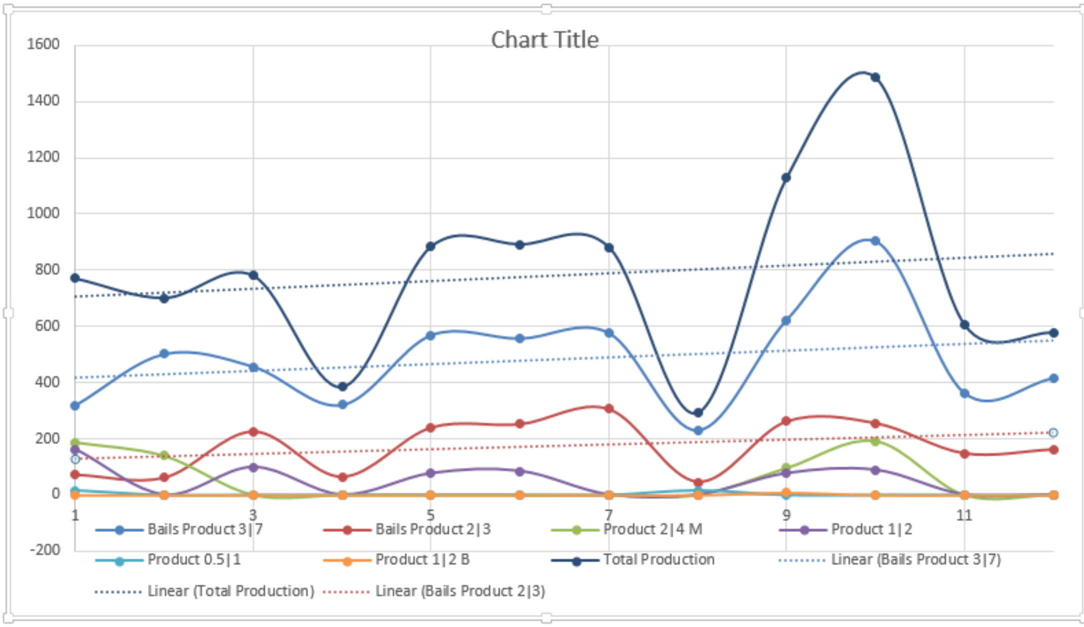

Figure 19 demonstrating the internal granulation production as a result of the variability in sales demand for 2012

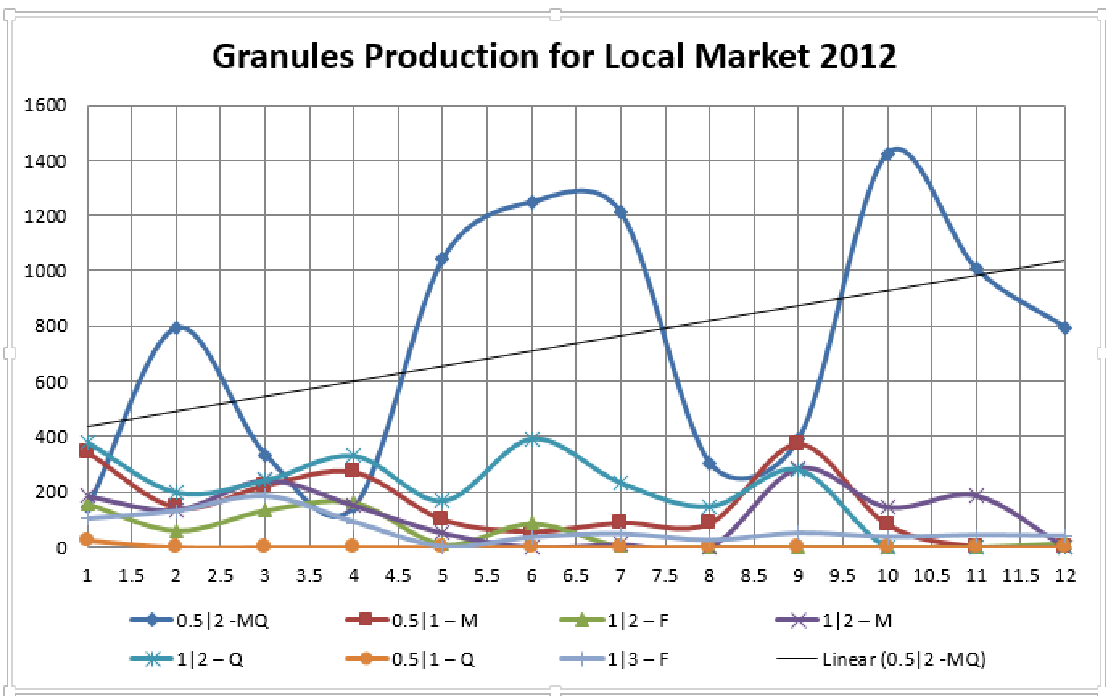

Figure 20 UCG production 2012

Table 41Process Activity Mapping for CortiPAN

CortiPAN												
#	STEP	FLOW	AREA	DIST (M)	TIME (MIN)	People	OPERATION	TRANSPORT	INSPECT	STORE	DELAY	COMMENTS
1	Deliver to Pit	T	A	41	3	1		T				
2	Sifting (removal of large pieces of cork and also dust)	O			4.59	1	O					
3	Grind 1	O			0.12		O					
4	Separator	O	C		0.05		O					
5	Grind 2	O			0.05		O					
6	Dryer	O			3		O					
7	Cleaner	O			0.1		O					
8	Silo	S	E		84					S		Storage capacity of 15tons, which is equal to 25 BB, it take 3.5 min to process a BB so therefore I assume 84mins if the production is continues. (5000kg)
9	Package into Big Bag	O			3.06	1	O					2 from 1.5
10	Delivery to CortiPAN Area/Storage Area	T	D1	37	2	1		T				
11	Place in Mix	T	E		2	1		T				
12	Mixing	O			4		O					5 to 8
13	Pour into Baker	O			0.4	1	O					
14	Bake	O			14	1	O					
15	Cooling Oven	O			2	1	O					
16	Wait for cutting	D			20						D	
17	Cut/clear/sack	O			3	1	O					
18	Waiting to Polish	D			16						D	
19	Polish/stack	O			10	2	O					1 Feeds the machine with cut boards, another receives and stacks
20	Waiting for Forklift	D			0.3						D	
21	Deliver to warehouse for stabilizing	T	F	95	2.5	1		T				
22	Waiting for Stabilizing	D			4320						D	Operation Delay
23	Deliver for unitization/ packaging	T		95	2.4	1		T				
24	Unitization/Package	O	E		25	1	O					
25	Transfer to Warehouse	T	F	95	3	1		T				
26	Await shipment	D			52800						D	A period of 5months was used because we observed stock in the WH data Nov. 2012
27	Pick/move by forklift/fill lorry	T	D2	95		3		T				1 forklift driver 2 inside truck packing
28	Wait to fill Load	D			60	3					D	1 Hauler 2 Operator
	Total			458	57384.57	21						
	Operators				4389.37	1.61						
	Percentage Operation				8%							

Table 42 Process Activity Mapping for CG

UCG												
#	**STEP**	**FLOW**	**AREA**	**DIST (M)**	**TIME (MIN)**	**PEOPLE**	**OPERATION**	**TRANSPORT**	**INSEPECT**	**STORE**	**DELAY**	**COMMENTS**
1	Deliver to Bucket	T	A		3	1		T				
2	Feed to Grinder	O			4.59	1	O					
3	Grind 1	O			0.12		O					
4	Separator	O			0.05		O					
5	Grind 2	O	C		0.05		O					
6	Dryer	O			3		O					
7	Silo	D	B		240					S		
8	Milling	O			0.2		O					
9	Separation (Net/Density table)	O			2		O					
10	Fill into buckets	O			1.5	2	O					
11	Inspected (weight)	I			0.15	2			I			
12	Fill into bags	O			0.05	2	O					
13	Delay to Fill bag	D			8						D	19
14	Close/label	O			0.45	2	O					
15	Stack	O		12.5	0.1	2	O					
16	Delay to fill Pellet	D			176						D	
17	Transfer by forklift Cyclone for dehumidifying	T	C	95	2.5	1		T				
	Unload/open	O			10							
18	Delay to empty	D			10	1	O					
19	Dehumidifying	O			20		O					
20	Fill Big Bags	O			8.6	1	O					
21	Transfer to Store	T		22	0.2	1		T				
22	Wait Bag Size transfer	D			960						D	
23	Transfer/Open/Empty to Pit near (dust pit)	T		28	0.4	1		T				
24	Transfer into Small Bags	O			1.5	2	O					
25	Closing bags and charging to pallets	O			0.45		O					18bags/pallet
26	Waiting to fill pallet	D			17							
27	Transfer to Warehouse	T	F		1	1		T				
28	Await Shipment	D			1440						D	5days (90bags/charge)
29	Pick/move by forklift	T			30	1		T				3men and machine
	Total			207.5	2940.91	21						
	Operators				52.66	0.38						
	% Value Adding				1.79%							

Table 43 Process Activity Mapping for UCG

CG												
#	**STEP**	**FLOW**	**AREA**	**DIST (M)**	**TIME (MIN)**	**PEOPLE**	**OPERATION**	**TRANSPORT**	**INSPECT**	**STORE**	**DELAY**	**COMMENTS**
1	Deliver to Bucket	T	A	50	3	1		T				
2	Feed to Grinder	O			4.59	1	O					
3	Grind 1	O			0.12		O					
4	Separator	O			0.05		O					
5	Grind 2	O	C		0.05		O					
6	Dryer	O			3		O					
7	Silo	S	B		180					S		3hrs of storage
8	Milling	O			0.1		O					
9	Separation (Net/Density table)	O			2		O					
10	Fill into buckets	O			1.5	2	O					
11	Inspected (weight)	I			0.2	2			I			
12	Pour into bags	O			0.1	2	O					
13	Delay to Fill bag	D			7						D	
14	Close/label	O			0.45	2	O					
15	Stack	O		12.5	0.2	2	O					
16	Delay to fill Pellet	D			154						D	
17	Transfer by forklift to Cyclone for dehumidifying	T	C	95	2.5	1		T				
18	Exit forklift and climb 10ft stair case to de-humidifier pit				0.5			T				
19	offloading/loading dehumidification pit	O			10		O	T				
22	Wait for pit to empty	D			10						D	
23	Dehumidification	O			20		O					
24	Filling in a bag				8.6							
25	Transfer to Press Store	T		15	0.2	1		T				
26	Wait press	D			1920						D	6 days to meet demand of 2 containers, assuming on average material wait 4days
27	Transfer/Open/Empty to Press Pit	T		15	1	1		T				
28	Prepare/Compress Granules	O			5	2	O					
29	Package	O			1.5	2	O					
30	Stack/label Bails	O			0.15	2	O					
31	Delay to Fill Pallet	D			113.35						D	1 pallet is fill every 2hrs (16 bales)

32	Transfer to Warehouse	T	F	59	5	1		T				
33	Await Shipment	D			2880						D	Every 11days 2 containers 192bales/each are shipped, I assuming bales would wait on avg. 6days for shipment (60kgs/bale)
34	Pick/move by forklift	T		20	1	1		T				
35	Wait to fill Load	D			90	3					D	4 in container 1 in machine (cleaning the bales before charging 30mins 1 man)
36	Await shipment	D			0	1					D	
	Total			266.5	5425.16	27						
	Operators				57.51	0.29						
	% Value Adding				1.06%							

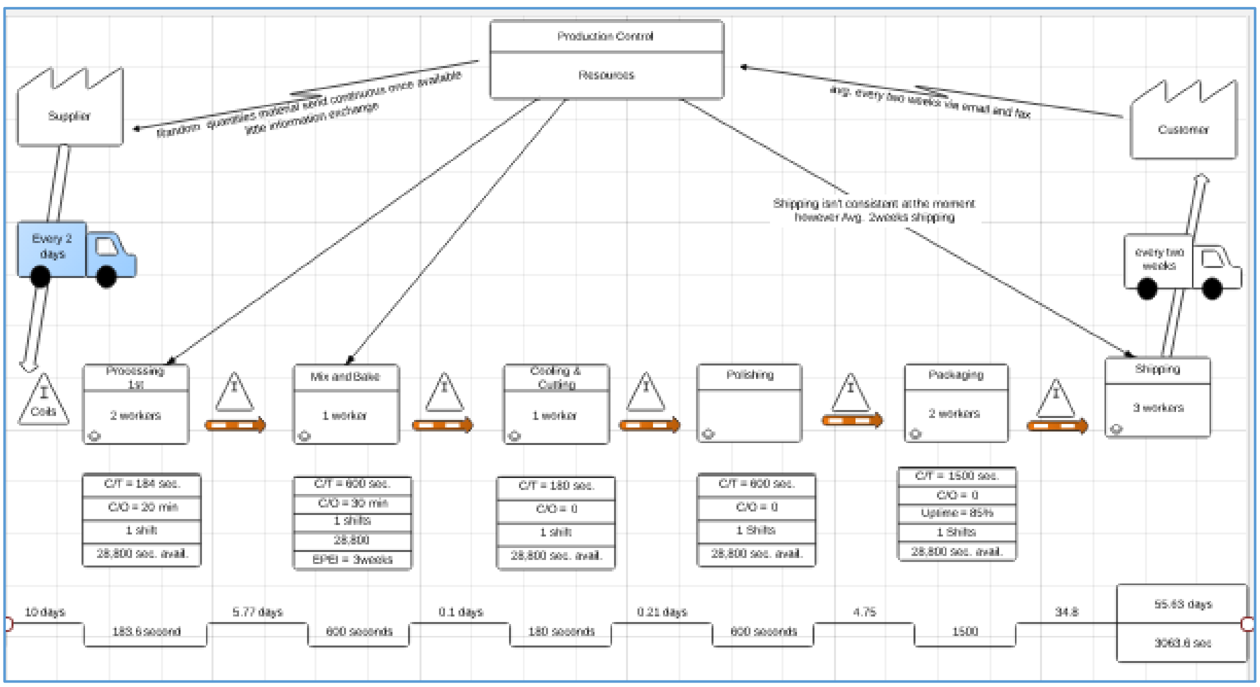

Figure 21 VSM current state CortiPAN

Figure 21, shows the current state map for the CortiPAN process, as can be observed that this process abides to a push production system with work pushed to the warehouse. The same is observed for the

UCG current state VSM figure 22.

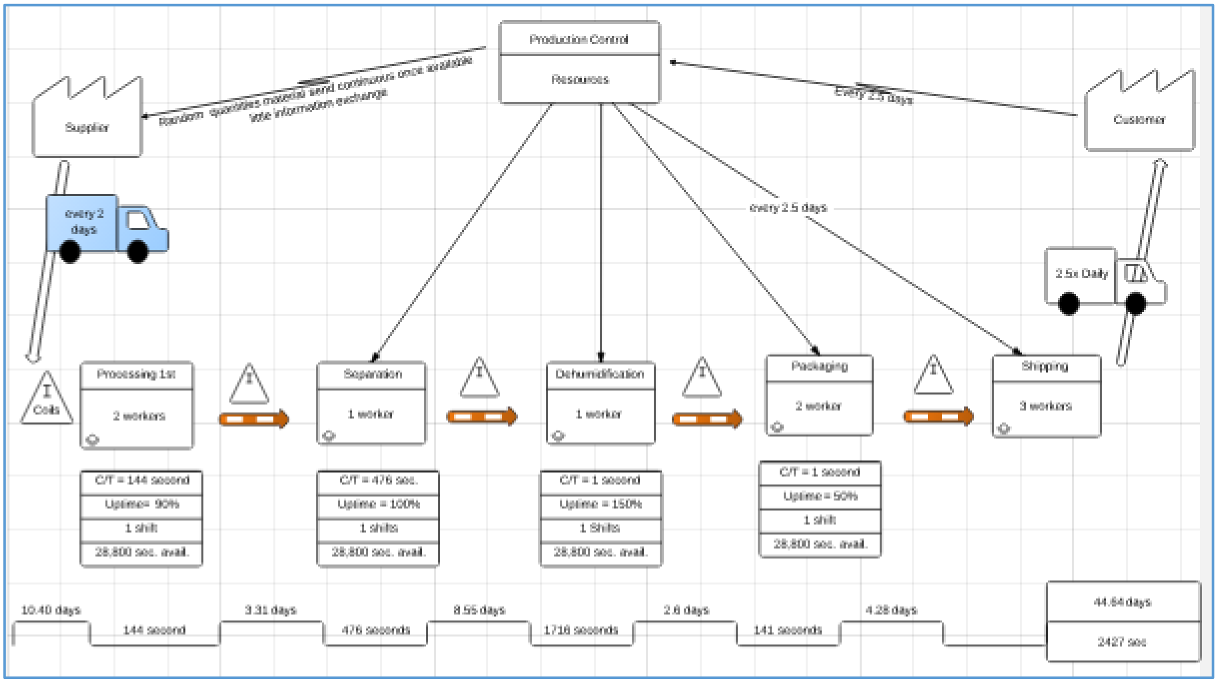

Figure 22 VSM current state map for UCG

As can be seen both current VSM operates on push production, and there exist large quantities of inventory within the VSM resulting in a long LT

Annex D

Table 44 Operator balance chart table for production line 2 CortiPAN and Broken

	Processing	*Filling into bag*	*Mixing to Polishing*	*Packaging*
Total Time for shared processes	11	3	28	3
	CortiPAN		Broken	
Daily Demand on the system (m^2)	145	Bag (27kg)	3	
m2	7.5			
Average kg/CortiPAN board	52.85			
Equivalent kg	1022		27	
Total Demand (kg)	1049			
Available time (sec.)	28800			
Unshared processes Takt time (kg/sec.)	29		1067	
Shared process Takt time (kg/sec.)	28			

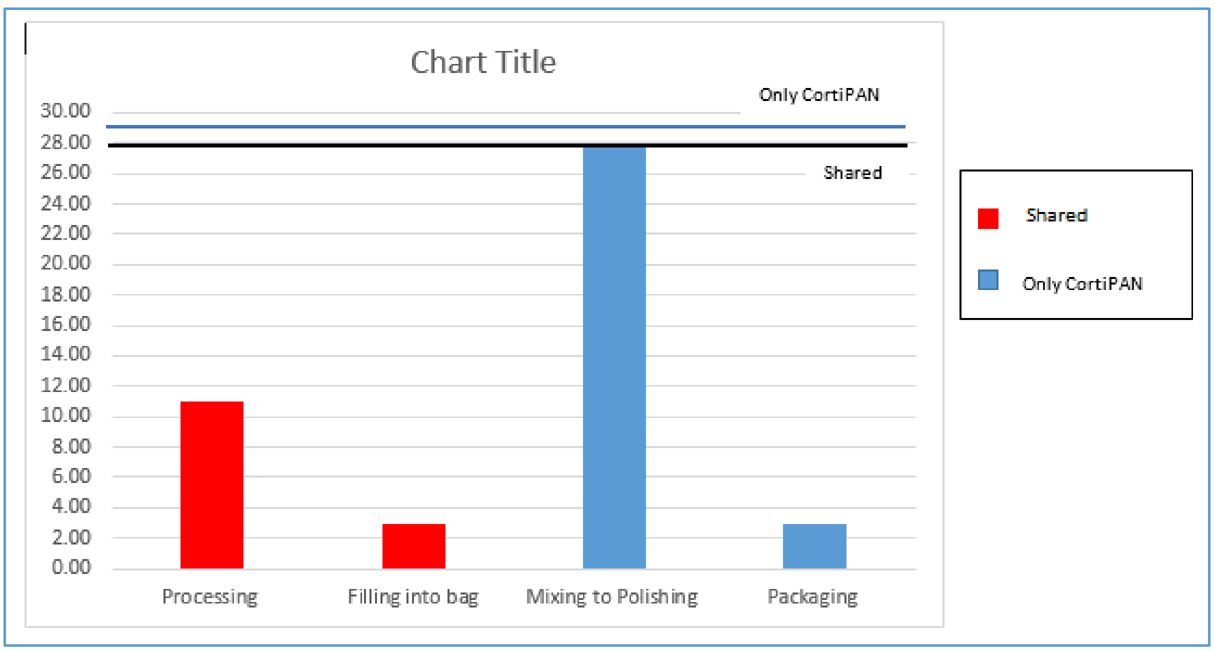

Figure 23 Operator balance chart CortiPAN and Broken

The Operator balance chart figure 23 above show two color scheme to help distinguish the activities into their respective group, similar to figure 8 above.

- ✓ The red columns represent all shared activities, with the black line indicating the takt time required to meet demand at these activities. Here we see that both share activities cycle time are far below the required takt time.

- ✓ The blue columns indicates the activities conducted only by CortiPAN with the blue line showing the required takt time. Again we see that these activities cycle time are lower the takt time, however the MC (which houses the activities Mixing to polishing) shows a slack of only 1sec therefore this activity should be monitored when further increases in daily demand occurs.

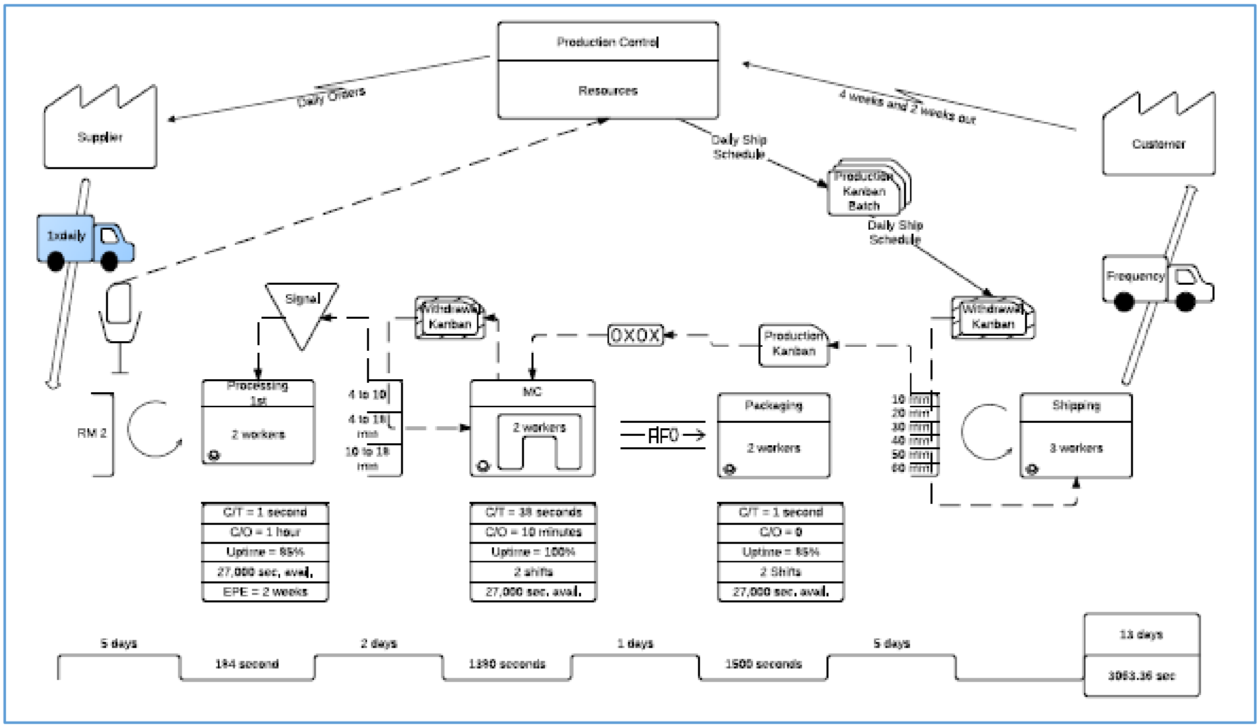

Figure 24 Future design of VSM CortiPAN

The new VSM works on the philosophy of pull production, unlike the current push production system currently used at DOF, where kanbans and supermarkets are used to facilitate the pull of material through the process. As can be observed there are five supermarkets within the process there are;

- FG supermarket from which customer demand are met
- WIP supermarket between processing and MC with a safety stock of 2 days before MC
- Raw material supermarket to control the flow of raw material into the operation, this aims a having the raw material pull into the operation only when customer orders are made.

Addition to the supermarket we see there are three kanban production systems,
The future VSM CortiPAN operators on pull production, employing kanban control and suppermaket to control the flow of material through the production process. CortiPAN future VSM has two kanban control points and three supermakets; kanban control

- 1st kanban control is between the FG suppermaket and the MC, also there is a production levelling process here, to level the demand at the pacemaker. This kanban commission work replenish the supermaket everytime products are shipped from the FG supermarket.

- ➢ 2nd kanban control is between processing and MC to pull broken cork need for the production of the CortiPAN boards.
- 3rd kanban is to control raw material delivery

Finally the new redesign VSM call for greater communication between suppliers and customers; with suppliers it utilizes daily communication with the daily delivery pulling what is needed for each day's production. Whereas for the customer it recommends forecast planning for up to 4weeks (in increments of 2weeks) be communicated with DOF, that way DOF can adjust their production ahead of time to changes in demand.

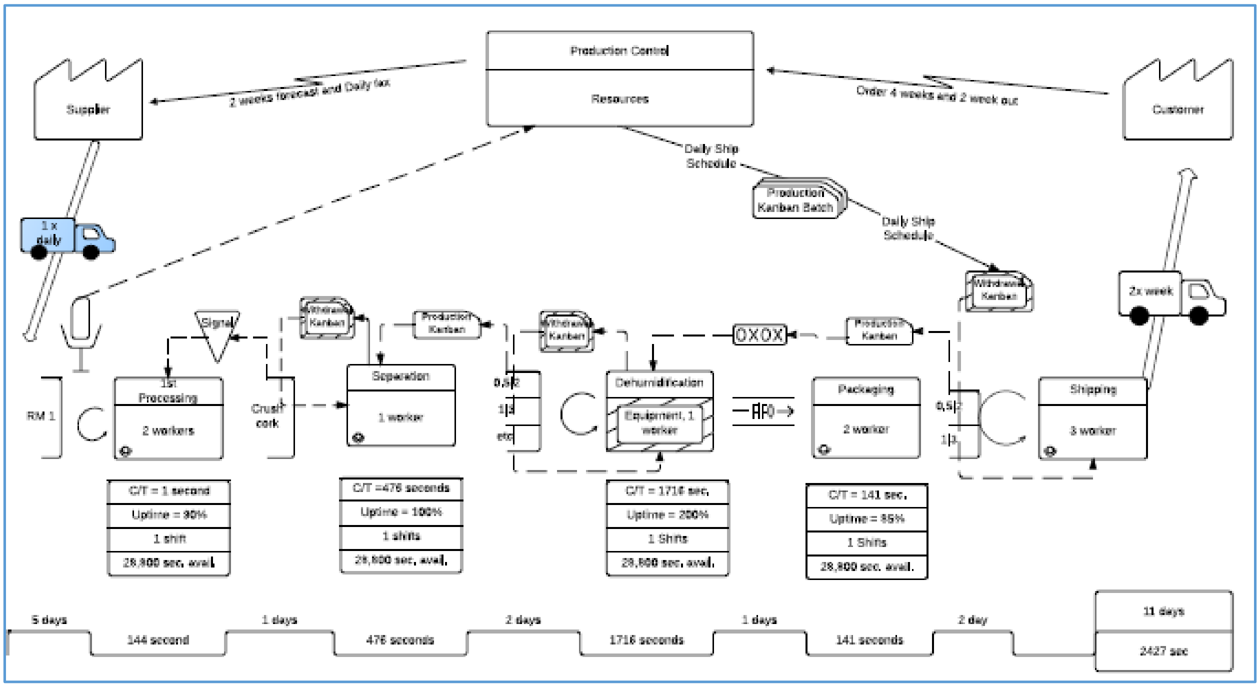

Figure 25 Future VSM UCG

Likewise the UCG is built on several supermarkets and kanban control; with a call for greater communication.

Table 45 Kanban calcualtion

Comment	Units				
		CG New			
With the new transfer batch the Dehumidifier requires 180kg, the separation process would require 0.76hr to respond to this demand using a container size 180 kg		Separation	Dehumidification	Safe Stock = Stdev.	Kanban
	Kg	180	180	76%	2
	hr.	0.76			
Compression demands 300kg/hr. to produce 5 bales. the de-humidifier produce the requires 1hr4min to response to this demand with a container size of 180kg		Dehumidification	Compression	Safe Stock = Stdev.	Kanban
	Kg	180	300	76%	4
	hr.	1.06			
Shipping is carried out every 11 days with a daily production demand of 36 bales/day to meet the required 396 bales, the compression process take 1.17 hr. to response to an order with container size is 16 bales		Compression	Shipping	Safe Stock = Stdev.	Kanban
	Pallet	16.00	396	76%	52
	hr.	1.17			
		UCG New			
De-humidifier requires 6bags, separation is able to response to an order in 3.13 (time to fill pallet), size of container is 24		Separation	Dehumidification	Safe Stock = Stdev.	Kanban
	bags	24	6	100%	2
	hr.	3.13			
Repackaging require 24 bags, dehumidification can response to an order in 0.48 and the container size is 6		Dehumidification	Repackaging	Safe Stock = Stdev.	Kanban
	bags	6	24	100%	4
	hr.	0.48			
Shipping requires 123 bags (shipping is done every2.5days) repackaging response to order in 0.94hr and container size is 24		Repackaging	Shipping	Safe Stock = Stdev.	Kanban
		24	123	100%	10
		0.94			
		CortiPAN			
MC require 21 bag/week and Processing is able to response to an order in 10min container size(1 bag)		Processing	MC (bbig kg)	Safe Stock = Stdev.	Kanban
	BB	1	21	102%	8
	hr.	0.176			

		MC	Shipping	Safe Stock = Stdev.	Kanban
Currently shipping is occurs very random, however this calculation was conducted assuming Shipping of 1 week. Shipping is accomplished once a week requiring 23m3, MC can respond to an order in 2.79 hr., with a container size of 1/2 pallet containing an avg. for 1.6m3	m3	1.6	23	102%	81
	hr.	2.79			

The new layout design shown in figure 26 offers a few changes which I'll high here;

- Standard shipping location to the end of the WH
- Transfer of Stabilization area to RM section
- Red dotted line, floor mappings area prespecifically for traffic flow, not storage of material should be placed withing this area.
- Arranaging of the WH based on Frequency of Movement (FOM), table 45 annex D shows the FOM calculation.

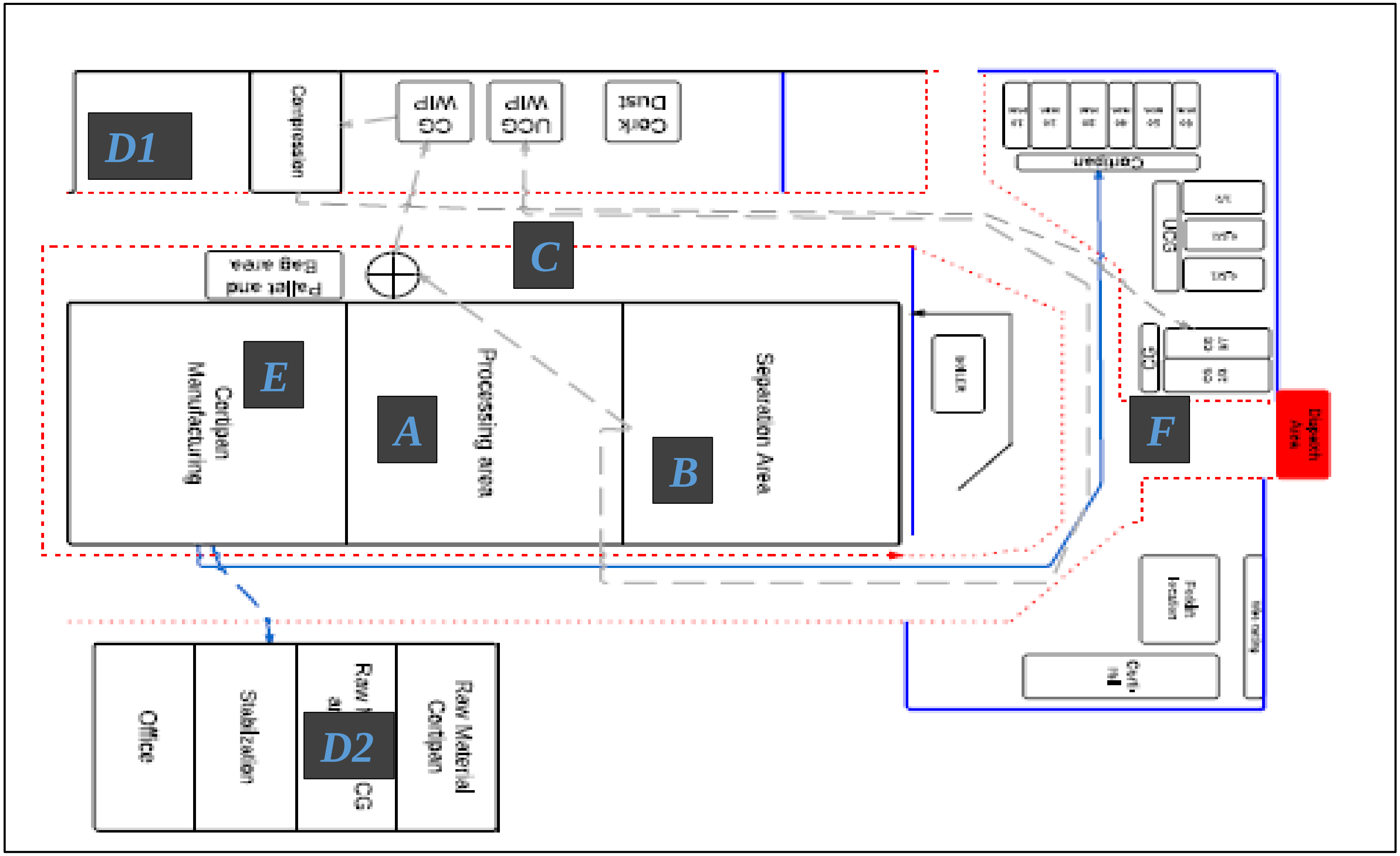

Figure 26 New layout design

Table 46 Showing the Frequency of moment of FG in the WH

	Total quantity	Movement Unit	No. of units moved during 2012	Comment
CortiPAN (m3)	1,187.42	2.92	406.65	the pallet size is used for FG
NCG	355,978.47	648.00	549.35	Quantity of grains stored a one pallet is used as the unit
CG	682,500.35	960.00	710.94	Quantity of grains stored a one pallet is used as the unit

Table 47 Calculating the potential savings with new VSM design

Cost Analysis for Products							
							CortiPAN
Location of Inventory	Average value of material	Current quantity	Inventory in days	Value	Future inventory days	Future Quantity	value
							Euro €
Raw Material	0.20	15,397.99	10.00	3,079.60	5	8378.66	1,675.73
CortiPAN storage area	0.79	3964.28	5.77	3,131.78	2	1374.1	1,085.54
MC	2.24	212.99	0.31	476.03	0	0	-
Stabilization	2.24	3263.49	4.75	7,293.90	2	1374.1	3,071.11
Warehouse	4.47	23909.34	34.80	106,874.75	5	3435.25	15,355.57
Total				120,856.06			21,187.95
							CG
Raw Material	0.36	77493.01	19.24	27,897.48	5	20134.62	7,248.46
Silo	0.43	2227.6	1.06	962.32	1	2094.6	904.87
After separation	1.27	4608.12	2.20	5,852.31	1	2094.6	2,660.14
After dehumidification	1.27	6283.8	3.00	7,980.43	1	2094.6	2,660.14
Ware House	1.27	16316.93	7.79	20,722.50	7.79	16316.93	20,722.51
Total				63,415.05			34,196.12
							UCG
Raw Material	0.36	26129.55	10.40	9,406.64	5	12564.33	4,523.16
Silo	0.43	4047.8	3.10	1,748.65	1	1306.69	564.49
After separation	1.17	11178	8.55	13,078.26	1	1306.69	1,528.83
After dehumidification	1.17	3402	2.60	3,980.34	1	1306.69	1,528.83
Ware House	1.17	5589	4.28	6,539.13	2	2613.38	3,057.65
Total				34,753.02			11,202.96
			Total	219,024.13			66,587.03
			Savings	152,437.10	70%		

The table show the full cost analysis for all RM, WIP and FG for each of the three main products of DOF, the unit prices used in the calculation was obtain directly from sales records for 2012 in most cases and in a few exceptional cases estimated prices were used based on discussion and agreed upon with the production manager.

Table 48 Value of stored inventory for each product

	CortiPAN	*CG*	*UCG*
RM	€ 3,079.60	€ 27,897.48	€ 9,406.64
WIP	€ 10,901.71	€ 14,795.06	€ 18,807.25
FG	€ 106,874.75	€ 20,722.50	€ 6,539.13

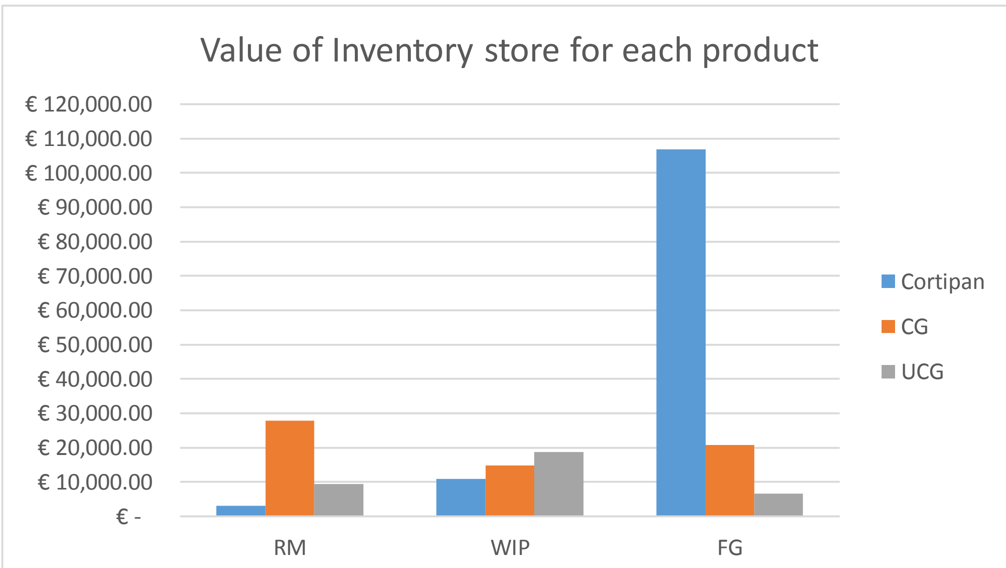

Figure 27 Shows the value associated with the current quantity of inventory stored for each porduct

Table 49 Calculation for the estimated revenue increase due to changes in CortiPAN packaging

CortiPAN sizes	*pallets sold 2012*	*Value of sale 2012*	*Avg. value/pallet*	*Value Increase*	*Amt. Increase*	*%*	*Total value increase 2012*
10	17.03	13616.51	799.62	893.26	93.65	11.7%	1594.7
20	71.77	31306.81	436.23	456.86	20.63	4.7%	1480.7
40	44.81	18879.49	421.32	441.24	19.93	4.7%	892.95
50	171.10	70858.37	414.13	518.71	104.58	25.3%	17894
Total							21862.35

Table 50 Showing the cost break down VC and FC

Variable Cost/m3		Fixed Cost	
cost	7.2	Fixed monthly direct costs	€ 3,780.00
150 g plastic packaging (Wrap 1)	€ 3.61	Electricity direct monthly	1000
500g plastic pallet wrapping (wrap 2)	€ 0.32		
Pallet cost	€ 1.02		
Cost/m3 MP CortiPAN	58.5		
Wear equipment	€ 2.63		

Table 51 Calculating the increase in VC for the new package configuration

	Before	After	Before	After	Before	After	Before	After
	20	20	40	40	10	10	50	50
length	1		1		1		1	
Width	0.5		0.5		0.5		0.5	
Height	0.02		0.04		0.01		0.05	
Pieces/package	8	5	4	5	15	5	3	2
m3/package size	0.08	0.05	0.08	0.1	0.075	0.025	0.075	0.05
No. of packages	37	62	37	31	37	124	33	62
Cost of Wrap 1/package	€ 0.29	€ 0.18	€ 0.29	€ 0.36	€ 0.27	€ 0.09	€ 0.27	€ 0.18
Cost of Wrap 2/package	€ 0.03	€ 0.02	€ 0.03	€ 0.03	€ 0.02	€ 0.01	€ 0.02	€ 0.02
total Cost	€ 11.61	€ 12.16	€ 11.61	€ 12.16	€ 10.89	€ 12.16	€ 9.71	€ 12.16
Increase Cost	€ 0.55		€ 0.55		€ 1.28		€ 2.45	
% increase	4.7%		4.7%		11.71%		25.25%	

Table 52 Accounting the increase in VC

	Increase in value/pallet	VC increase for new package/pallet	Actual	Pallet sale record 2012	
10 mm	93.65	1.28	92.37	17.03	1573.0611
20 mm	20.63	0.55	20.08	71.77	1441.1416
40 mm	19.93	0.55	19.38	44.81	868.4178
50 mm	104.58	2.45	102.13	171.1	17474.443
Total					21357.06
Revenue2012	179102.70				

Table 53 Showing a list of DOF suppliers and the distance from the company

Suppliers by Numbers	Km from DOF	Travel time (min)	Less than 20mins from DOF
1	3.8	7	
2	4.2	8	1
3	2.13	4	1
4	6.3	9	1
5	13.7	12	1
6	8.2	14	1
7	7.5	12	1
8	82.1	52	1
9	67.2	47	1
10			1
11	8.8	13	
12			1
13	7.4	12	
14	10.4	14	1
15			1
16	299	2 h 56	
17			
18	2.6	5	
19	4.6	7	1
20	5.8	9	1
21	10	15	1
22			
23	2.5	5	
24	3.8	7	1
25	6.2	9	1
26	2.8	6	1
27	4.3	7	1
28	9.7	15	1
29		11	1
30			
31	5.1	9	
32	2.4	4	1
33	15.8	16	1
34	9.4	14	1
35	3	6	1
Total			26
			74.286%

Annex E:

Table 54 Value Stream Plan for achieving the future state VSM

DATE:																			
FACILITY MANAGER:																			
V.S. MANAGER:																			
	CORTIPAN																		
Product Family Business Objective	V.S. Loop	Value-Stream Objective	GOAL (measurable)	Monthly Schedule												Person In Charge	Related Individuals & Departments	Review Schedule	
				1	2	3	4	5	6	7	8	9	10	11	12			Reviewer	Date
	1 pace-maker (MC)	*Continuous flow from mixing to polishing. *Finish goods pull system. *Customer negotiation and relationship building *Reduce material waste on the oven	*1 week finish goods inventory. * Frequent small orders	→	→														
	2 processing loop	* Establish a pull system with in process supermarket (broken)	*Pull *Reduce batch size from 1 week to 2 days inventory	→	→														

		*Reduce WIP inventory																	
	3 raw material	*Pull raw material daily	*Supplier negotiation and relationship building *daily raw material shipping *5 days inventory																
	Compressed Granules																		
	V.S. Loop	Value-Stream Objective	GOAL (measurable)	Monthly Schedule												Person In Charge	Related Individuals & Departments	Review Schedule	
				1	2	3	4	5	6	7	8	9	10	11	12			Reviewer	Date
	1 pace-maker	*Develop pull system with finish goods inventory. *Change shipping to 1xweek *Reduce change over time	Try to negotiate with customer to have shipment 1xweek *level production at pacemaker to daily demand (not more)																
	2 separation & dehumidification	*Develop pull FIFO																	

		system *Reduce inventory to daily	1day inventory and 2 days for 3|7 grains	→															
	3 Processing 1st	*Develop pull system , *Reduce inventory after processing	1 day inventory	→															
	4 Raw Material	*Develop raw material pull system with supplier, *Reduce inventory, *Daily deliver	*Supplier negotiation and relationship building *daily raw material shipping *5 days inventory	→		→													
	Uncompressed Granules																		
	V.S. Loop	Value-Stream Objective	GOAL (measurable)	Monthly Schedule												Person In Charge	Related Individuals & Departments	Review Schedule	
				1	2	3	4	5	6	7	8	9	10	11	12			Reviewer	Date

	1 pace-maker	*Develop pull system with finish goods inventory. *Change shipping to 1xweek *Reduce change over time	*2days finish goods inventory *level production at pacemaker to daily demand (not more)	→															
	2 separation & de-humidification	* Develop supermarket to pull products from separation * Reduce inventory WIP to 1day	*Pull signal system *1 day inventory	→ →															
	3 Processing 1st	*Develop pull system (signal kanban) *Reduce inventory after processing	1 day inventory	→															
	4 raw material loop	Same as above	Same as the above raw material																