Lean Approaches in a Knowledge Worker Environment

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Abstract

Most of us are familiar with the concept of Lean (a way to do more and more with less and less). The principles have been applied by the Japanese as part of the Toyota Production System from as early as the 1950's. Subsequently many have applied this in different environments and in combination with other philosophies. It was thus only a matter of time before the application of Lean principles in enterprise environments became a reality. This paper looks at the origin and definition of Lean and then secondly to its application in the knowledge worker environment.

The application of Lean principles in a knowledge worker environment (using the Council for Scientific and Industrial Research (CSIR) in general and specifically the Defence, Peace, Safety and Security (DPSS) operating unit as reference), is further investigated from both a knowledge economy (the generation of knowledge) and a knowledge-based economy (the application of knowledge in innovation) point of view. The quantity, quality, and accessibility of information as well as the processes that produce such knowledge are of utmost importance and a close look is taken at opportunities to eliminate waste. The well-known and rather infamous seven deadly wastes are addressed in this context.

An approach for optimising capacity to handle complexity and to manage risk in a wider domain, other than expanding the resource base, is motivated. The commercial equivalent of this is profit based on reduction of cost rather than increasing selling price.

The importance of teamwork in a multidisciplinary environment and the required work integration and information flow is also discussed together with the concept of pull of the correct information at the correct abstraction level at the right time.

The requirements for the effective application of Lean within DPSS given the bigger context of the CSIR and Armscor are finally alluded to.

1 Introduction and Background

Two concepts immediately come to mind when talking about a knowledge worker environment and that is the definition by Dr Neville Comins (Comins , 2011) of the difference between a knowledge economy and a knowledge based economy. According to Dr Comins, in a knowledge economy, knowledge is the product and/or a productive asset as opposed to a knowledge-based economy where knowledge is a tool used to create economic benefit. We include both these concepts in our definition of a knowledge worker environment, which is the CSIR (Council for Scientific and Industrial Research) as a research organisation and more specifically DPSS (Defence Peace Safety and Security) as a defence research organisation. Within the CSIR Basic, Applied and Experimental (*Frascati Manual Proposed Standard Practice for Surveys on Research and Experimental Development* , 2002) research is conducted. Within DPSS on the other hand very little if any basic research is conducted but the bulk of the work is in focused research and technology demonstrators with a small portion of low volume niche manufacturing. Both the knowledge economy and the knowledge-based economy views therefore hold true in this environment.

The case study research documented in this paper originated towards the end of the development phase of a long term acquisition project for the SANDF under contract from Armscor in accordance with the Department of Defence Acquisition Policy, DAP 1000. This project had its fair share of unrealistic timescales, process inefficiencies, frustrations with delivery delays, difficulties with coordinating concurrent engineering efforts and sometimes losing sight of the true purpose of activities, namely adding value to the customer. The fact that the book on Lean Thinking by Womack and Jones (Womack et al. , 1996) was on the reading list of one of the authors at the same point in time inevitably led to the question: Why can't we apply these principles in a knowledge worker environment?

The research that followed is documented in the rest of this paper starting with an overview of the history of Lean in paragraph 2, a summary of the five principles of Lean in paragraph 3, the case study in paragraph 4, Recommendation and Lessons Learnt in paragraph 5 and Conclusions in paragraph 6.

2 The History of Lean

When you hear Lean, you immediately think: Toyota, and rightly so. However, the world's legacy in terms of the principles of Lean Thinking goes beyond that. Jim Womack, the president and founder of the Lean Enterprise Institute says: "most of us don't realise that we are heirs to a remarkable long struggle in human history to see beyond isolated points in order to optimize the entire value creating process." (Womack) Who knows when the principles in their most basic form have first been put to the test, but some events as early as the 15th century stand out as pioneering moments in terms of work standardisation and process flow.

In 1913, these applications of standardization and flow principles were taken to the next level – and in doing so changed the world. Ford mastered the art of flow, turning over the inventory of the entire company every few days. Ford however lacked the ability to deal with variety (Lean Enterprise Institute).

From there it went bigger better faster – larger machines, running faster, requiring longer setups and requiring very sophisticated management and planning programmes – all this to continuously lower costs per process step. After World War II, the Japanese were forced to carefully consider whether they would follow the same approach. Japan knew it could not compete with America's mass production.

Kiichiro Toyoda, Taiichi Ohno, and others at Toyota made history by implementing a shift from focussing on lowering cost per process step to speeding up and synchronising the flow of the product through the entire process. This became known as the Toyota Production System (TPS). The intent of the Toyota Production System was to reduce costs, provide high variety and quality and deal with customer volatility. This was achieved by right-sizing machines for the volume needed; self-monitoring machines to ensure quality; organising the machines according to the process sequence; quick setups, pulling just enough production from each process as well as a corporate culture of respect, empowerment and teamwork

The philosophy of Lean was thoroughly described in the book *The Machine That Changed the World* (Womack et al. , 1990). Six years later Womack and Jones refined these principles into five that we will apply in this paper (Womack et al. , 1996). Since then much has been said and written about Lean and the application of Lean has moved beyond the misconception that it only applies to high volume production in the manufacturing industry (Oppenheim et al. , 2008). In Toyota itself, Lean extends over the entire enterprise, from manufacturing to design and engineering, supply chain, and all supportive activities (Morgan&Liker , 2006).

Outside of Toyota, Lean has also been implemented in logistics and distribution, services from financial to healthcare, retail, construction, maintenance and in the office environment. Since 1993 the Lean Advancement Initiative (LAI) (Lean Advanced Initiative) has been active in research regarding Lean in Product Development (PD) and Lean through Enterprise Integration. In 2009, INCOSE's Lean Systems Engineering Working Group (LSEWG) reported on the maturity of Lean in different industries (refer to Table 1) and communicating the task at hand for their workgroup (Lean Systems Engineering Working Group , 2009, February 1).

Table 1 : Lean Maturity in Enterprise Area

ENTERPRISE AREA	MATURITY LEVEL
Lean Manufacturing	Very Mature
Lean Enterprise	Mature
Lean Supply Network	Mature
Lean Office	Mature
Lean (Final) Engineering	Mature
Lean Product Development	Less mature, fast growing
Lean Systems Engineering	Until now- least mature

3 The Principles of Lean

This section introduces five principles of lean. Each principle will be discussed in more detail in the sections that follow. The purpose is to apply every principle within the knowledge worker environment to assess its applicability.

Womack and Jones' five principles (Womack et al. , 1996) are further propagated by the Lean Enterprise Institute (Lean Advanced Initiative):

1. Specify value (defined in more detail in paragraph 3.1) from the standpoint of the end customer by product family.
2. Identify all the steps in the value stream for each product family, eliminating whenever possible those steps that do not create value.
3. Make the value-creating steps occur in tight sequence so the product will flow smoothly toward the customer.
4. As flow is introduced, let customers from the next upstream activity pull value from the preceding activity.
5. As value is specified, value streams are identified, wasted steps are removed, and flow and pull are introduced, repeatedly applying these principles until a state of perfection is reached in which perfect value is created with no waste.

McManus (McManus , 2005) has said the following about Lean in the engineering environment:

> *"The first objection to the application of lean techniques developed in the factory to engineering processes is that "engineering is different." This is true. It is not, however, a reason to reject lean as a method for engineering process improvement."*

McManus summarises the difference in approach of these steps between Manufacturing and Engineering. This is illustrated in Figure 1, with the engineering application given in italics below the manufacturing application.

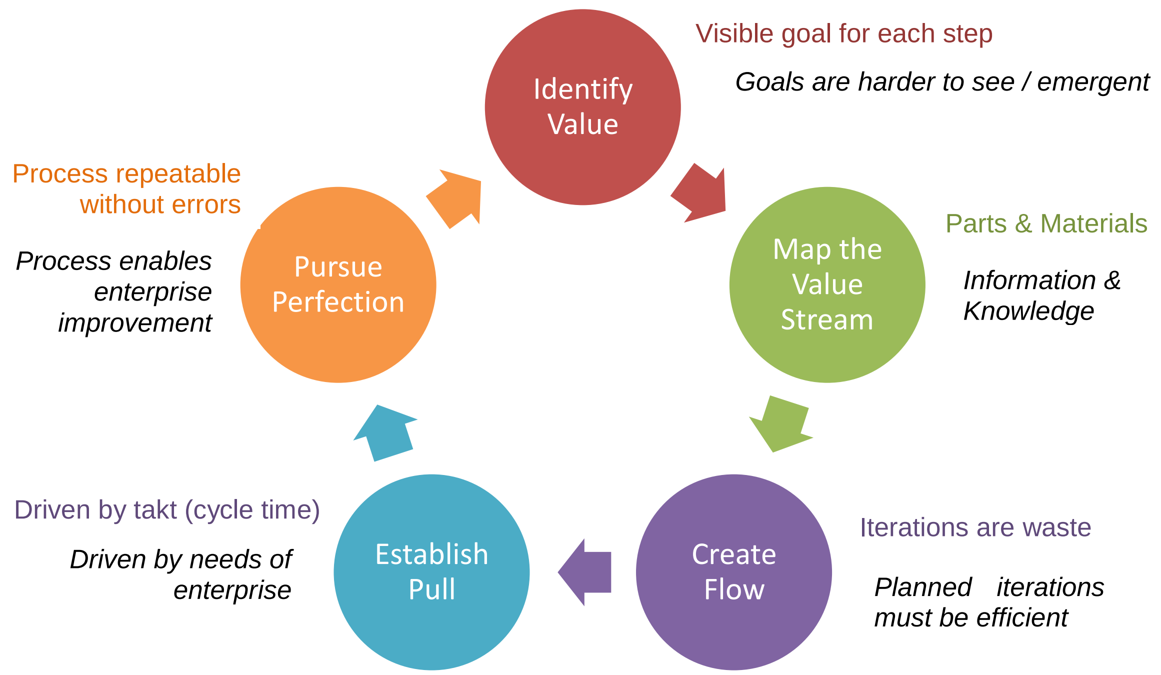

Figure 1 : 5 Principles of Lean (McManus , 2005)

MacManus has developed a Manual for Mapping the Value Stream in a Product Development environment. Figure 2 shows the steps described in the Manual. The steps have been colour coded to show how they interact with the original 5 steps described in Figure 1.

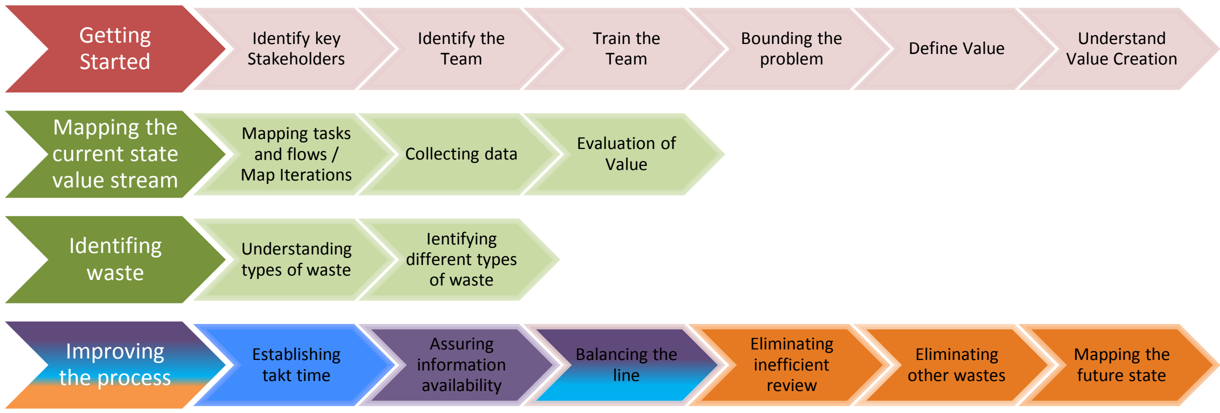

Figure 2 : Product Development Value Stream Mapping (PDVSM) Process
(McManus , 2005)

The five principles are further described below as we see it to be applied in a knowledge worker environment (using the Council for Scientific and Industrial Research (CSIR) in general and specifically the Defence, Peace, Safety and Security (DPSS) operating unit as reference).

3.1 Step 1: Identify Value

Maximising value as perceived by the customers (both end-customers as well as customers from the next upstream activity) is ultimately what Lean is about. Without an understanding of value for the customers, true waste is hard to identify and eliminate, processes cannot flow effectively and perfection cannot be pursued. According to the SE Lean Enablers (Enabler 1.2.1), value is defined as the outcome of an activity/process that satisfies at least one of these conditions:

1. The external customer will pay for that
2. Transforms information / processes to reduce uncertainty
3. Provides specified performance right the first time

To meet the first condition one needs to understand what the customer will pay for. In any organisation different operating units may have different answers to that question (The answer for our Case Study is given in Figure 5). The values of the organisation relating to its core business or mission statement should also be taken into account and should typically be reflected in their business processes.

An observation from lessons learned in the Aerospace industry states that Lean capabilities are not merely firm-specific but rather plant-specific (Crute et al. , 2003). In our case this means, project specific. Therefore understanding Value created in the organisation is only the first step. Understanding value in the specific project should follow as next step. The most basic understanding of value in any Development Project is:

$$Value = f(Peformance, Affordability, Time)$$

This is in essence what we want to accomplish with Systems Engineering – maximising performance in the available time and money. Though the variables are the same, in each Project the equation will differ. Each Project will have a different optimum or sweet spot, where Product Performance, Affordability and Time meet. A way of getting to grips with that spot is to define your Value Precedence for the project.

This should not be in conflict with the values of the business unit (our example given in Figure 5). If there is a contradiction these should be resolved (Enabler 1.2.5). According to this value precedence the rest of the processes should be tailored upfront. More time and effort needs to be assigned to the processes contributing to the top priorities as per the defined value.

Values need to be communicated downwards to establish a customer focussed culture (Enabler 1.2.6). In the Project Team environment we use Systems Engineering techniques to establish this. With the careful mapping out of Value Streams, it is important to be able to analyse the bark on the tree, but not lose sight of the immensity of the forest! As Systems Engineers it is natural to approach value (the flip side being waste) in the same manner as Requirements, using Requirements Traceability principles. Value should be traced down the levels of abstraction of processes / activities. If Step 1 is for example to be a waste free activity, then all its children (activities 1.1 – 1.n) should be waste free activities as well optimising the value of the parent activity. Wasteful activities will be traced up to Step 1, preventing Step 1 from delivering optimal value (just as a non-conformance of a lower level component would cause non-conformance in the entire system).

To make it practical, as we go through our Value Stream Mapping (VSM) steps (McManus , 2005), we can take a single process in that VSM and map it in more detail. On this lower level, we will follow the same steps, but the value against which we evaluate is now the allocated value as determined by the parent process. Although the Business Values and Value Precedence are still valid, they may not mean much at lower levels. Instead, our new refined goal is to enable our parent process to effectively and efficiently add its values as identified. On each level there may be unique constraints or legislative requirements and those must also be evaluated in light of the new defined value for that level.

In a large organisation with several diverse customers (as with our Case Study), there is another challenge to overcome. Not only do values need to be communicated downwards, but also sideways to supporting business units. Support may be required for example from other business units, without them having an understanding for the customer focussed culture in our part of the organisation. This is a difficult challenge that can only be overcome with cross-functional managerial support and the breaking down of the compartmentalised, silo view of the organisation.

A final refreshing idea on value in terms of target cost is the waste-free cost of a product (Womack et al. , 1996). This becomes the target cost for an item and not the classic cost plus models we normally use. In the case of the CSIR as not-for-profit organisation, this relates to an increased capacity to handle complexity and to manage risk in a wider domain, as opposed to expanding the resource base, i.e. doing more with less.

3.2 Step 2: Map the Value Stream

Before one can start mapping the value stream, the context for the process under analysis needs to be defined. Figure 3 below from the Product Development Value Stream Mapping (PDVSM) Manual illustrates this.

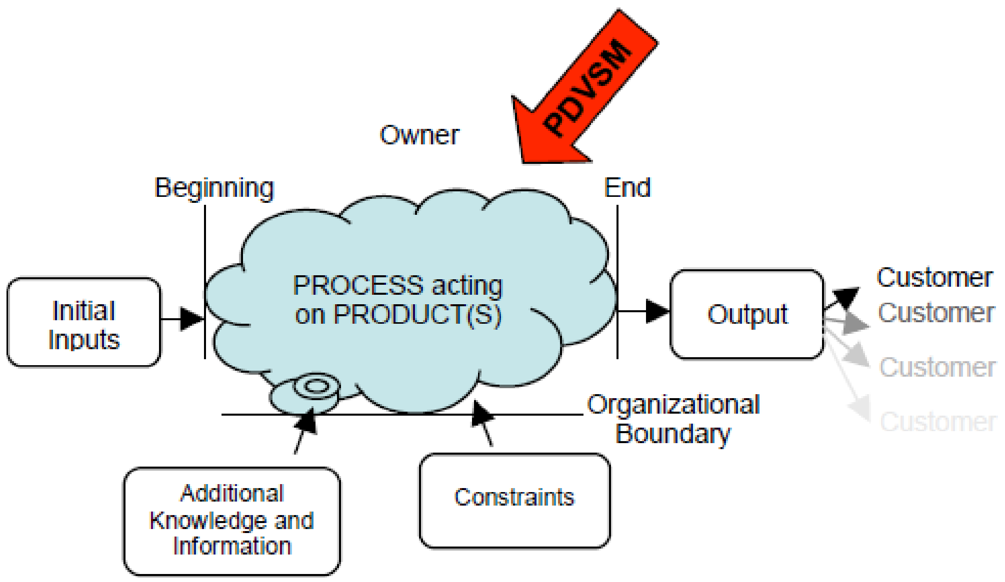

Figure 3 : Bound the problem (McManus , 2005)

Once value is understood and the boundaries are clear, one can start with the mapping process:

1. Arrange process steps and information flow[1]

[1] In this manual it is a recommended that a VSM breakdown consists of between 10 and 30 identified tasks. This way tasks remain tractable and the total process of sufficient depth to provide useful insight.

2. Get performance data on the activities
3. Evaluate how value is created

During the course of the literature review, we identified the following aspects to keep in mind when performing VSM:

1. Value Stream focuses on inputs and outputs (refer to paragraph 3.2.1)
2. Approach the VSM in a healthy way (refer to paragraph 3.2.2)
3. Identify Waste using types of wastes (refer to paragraph 3.2.3)

3.2.1 Focus on inputs and outputs

When defining Value Streams, Womack and Jones (Womack et al. , 1996) recommend strapping yourself to the work as it goes through the entire production line. In our case this means to continuously look from the viewpoint of *information flow*.

It is a common problem receiving inconsistent answers to the questions: “Where does your task output go?” and “Where does your task input come from?” When these answers are in conflict, let yourself be guided by the answer to the latter question (McManus , 2005).

3.2.2 The Healthy Alternative

The typical approach (Womack et al. , 1996) for evaluating the value of an activity / process is to define 3 types of activities:

- *Type 1- Value Adding,*
- *Type 2 - Necessary Non-value Adding*
- *Type 3 - Pure waste*.

Type 3 activities should be removed while Type 2 activities should be made as efficient as possible.

This exercise is more complicated in a Systems Engineering / Product Development (SE/PD) environment than in a typical manufacturing environment (Browning , 2003). In the typical production line context – the types of wastes are more apparent and the effort to remove waste often equates to eliminating a step or a process from the flow. Eliminating processes or steps in a similar way in a SE environment may be bad for your health as explained by Browning (Browning , 2003) with his Two Perspectives on Getting Lean:

Liposuction	**Diet & Exercise**
Focus on reducing waste	Focus on improving value
Effective only with large, easy-to find chunks of fat	Is effective for removing waste throughout
Can compromise overall health	Improves overall strength, agility & flexibility
Does not address the root cause of the fat	Addresses the root cause
Is relatively cheap and quick	Requires on-going investment and commitment
Focus on doing less	Sometimes requires doing more
Measures fat removed	Measuring fat and muscle (realising that muscle good weigh more)

Figure 4 : Two Perspectives on Getting Lean (Browning , 2003)

Liposuction may be tempting at first – providing an initial (false) sense of accomplishment. For example, as the PDVSM Manual (McManus , 2005) suggests one of the ways of improving flow in the systems is to ***Eliminate Unnecessary or Inefficient Reviews and Approvals***, it makes one immediately want to do away with perceived inefficient reviews and proposals. However, as it also rightly states, you need to get behind the real intent of the review and make sure that you are not causing more waste in the system by the removal. In our analysis, our intent will not be on just removing fat, since some of the real non-value adding activities may be hidden within value adding tasks. Other are actually inherently value adding – they are just executed in a non-value adding way (McManus , 2005). In the Product Development Environment the latter is often the case and the emphasis is therefore more on waste in necessary activities executed with incorrect information or not executed thoroughly. Removing waste, or rather maximising value – may even mean adding a process or step to ensure that the necessary activity could be executed. Lean is thus not necessarily equal to Less! (Oppenheim). In our case study we will not focus so much on categorising the activity – but rather describing how and to what extent they add value. Do they add to the product, the process or reduce uncertainty?

3.2.3 Considering types of wastes

In the light of what has been discussed under the healthy way and the challenges with identifying waste, we need to learn from previous experience and refer to the well-established and documented types of waste (Ōno , 1988) and what they typically look like in our application (McManus , 2005), (Oehmen&Rebentisch , 2010), (Oppenheim et al. , 2008) as an aid in our analysis.

The categories of waste as originally defined by Ohno are listed below.

1) Transport – moving material or information from place to place.
2) Unnecessary inventory – all components, work in process and finished product not being processed.
3) Unnecessary motion – movement by people or equipment that is more than required.
4) Waiting – Waiting for materials, information or decisions.
5) Over production – producing too much or ahead of demand.
6) Over processing – performing unnecessary processing on a task or an unnecessary task.
7) Nonconformities – the effort involved in inspecting for and fixing nonconformities.

Sometimes an eighth waste category is added to the original seven. For example, an addition by Liker (Liker , 2004) is unused employee creativity referring to losing time, ideas, skills, improvements and learning opportunities by not engaging or listening to employees. Front line workers are in fact the most knowledgeable resource for improvement initiatives.

Table 2 shows the seven categories of waste as they apply in a production environment. Along with that, typical applications for the SE/PD environment as described in (Malotaux , 2011) and (Oehmen&Rebentisch , 2010) p8). Malotaux also gives possible remedies in the 3rd column.

Table 2 : Examples of Waste in the Product Development / SE Environment

Manufacturing	Product Development / SE	***Possible* Remedies** (Malotaux's suggestions)
Over-production (Creating too much material or information)	Extra features, Unused documents; Two people working on the same information; Delivering information too early.	Prioritizing real requirements, Deciding what not to do
Inventory (Having more material or information than you need)	Partially done work; Stockpiling information	Synchronization, Just In Time
Transportation (Moving material or information)	Handoffs; Miscommunication of information; Inefficient transmittal of information; Large and long meetings; Long email distribution lists inefficient transmittal	Keeping in mind: - Responsibility (what to do) - Knowledge (how to do it) - Action (doing it) - Feedback (learning from result)

Manufacturing	Product Development / SE	*Possible* Remedies (Malotaux's suggestions)
Unnecessary Movement (Moving people to access or process material or information)	Task Switching; Needing to move to gain access to information	Maximum of two tasks in parallel
Waiting (Waiting for material or information, or material or information waiting to be processed)	Delays People waiting for information Information waiting for people Unsynchronized concurrent processes Long lead time activities Unrealistic schedules	Process/organization redesign
Defective Outputs (Errors or mistakes causing the effort to be redone to correct the problem)	Defects Information requiring rework Correcting information Errors in component or architecture design Incorrect or obsolete information to next task	Prevention
Over-processing (Processing more than necessary to produce the desired output)	Design inefficiency, Wishful thinking Re-invention; different IT systems - converting data back and forth; Over-engineering	Knowledge, experience, reviews Preflection (Malotaux)
Ignoring ingenuity of people	Ignoring ingenuity of people	Effective management, empowerment, Bottom-up responsibility

*The Definitions in brackets are from the Lean Enablers for Systems Engineering (Oppenheim et al. , 2008)

3.3 Step 3: Flow and Pull

Flow is established when all the waiting and unnecessary motion is removed from the Value Stream. A great way to enable that is to follow the Lean principle of work cells and have an integrated multidisciplinary team with the same understanding of the customer culture sit under one roof (with preferably no inner walls!). This was proven by (Allen , 1988) - there is an exponential drop of frequency of communication between engineers as the distance between them increases.

Other activities to assure availability of information is to practice the 6S (Sort, Stabilise, Shine, Standardize, Sustain) principles in information; make information visual (Enabler 3.7) and to pull not push information (Enabler 4.2.1).

In a Development Environment information is typically pulled. Downstream activities, for example the writing of Technical Manuals or support documentation, will collect information from the Design Authority. Though information is pulled, it does not automatically mean that it is flowing. Sometimes information can be pulled too early. This could happen, especially in a Concurrent Engineering environment, by having pressure on the schedule resulting in pulling some tasks forward causing them to be out of sync, or upstream activities being delayed due to external reasons. The effect is normally inaccurate information resulting in re-work or it could result in long waiting times. The solution lies in scheduling and management and continually trying to balance the line (the value stream), synchronising flow and pull. Identifying bottle necks and allocating resources or work accordingly can be tricky given the resources or expertise available or potential resistance in the organisation due to perceptions, or any form of barriers. Scheduling must be actively managed (re-allocating resources) and preferably requires a buffer (having reserve resources available). Reasons for externally caused delays should be investigated and eliminated or minimised. The "five whys" can aid in this process to get to the root cause of delays. Working to a takt time (derived from the German word **Taktzeit** which means *cycle time*) could also help to balance the line. For example, the team can decide on a 2 week takt time, where the team comes together to schedule and prioritise work for that time. For the next session, one has more information on how long activities take and one can balance the line better without complex scheduling methods.

Another important aspect to improve flow is to break down monuments. A monument is a machine or process which is too large to be moved and accommodate reconfiguration (Womack et al. , 1996). In *Lean Enterprise Value* (Murman , 2002), assets, processes or mindsets that were originally created for a good reason but which have not adapted to changing circumstances are included as examples.

An aspect of flow in PD that is different in manufacturing is that iterative flow[2] may actually be beneficial (McManus , 2005). This is however a difficult balance to strike, the designer is never finished designing, while the project manager is running out of time and money. How much of that design detour taken was actually a value adding step to get to the 'right' answer. How much of that can be addressed upfront or as the project progresses and how much is actually only visible through the 20/20 vision glasses of hindsight?

The bottom line is that while iterative flow will inevitably take place, it is important to ensure that the flow again is optimised. For example: an iterative process with a silo (compartmentalised) view becomes a mammoth of a monument causing long waiting times that means multiple times the waste. Also, in a pull environment it may happen that changes are not fed back to all other users of the information due to a lack of understanding by the information provider as to what the impact of these changes are in the output of other users. An example is specification updates of supposedly minor characteristics that may have a major impact on another system.

3.4 Step 4: Pursue Perfection

Before continuing to analyse processes and proposing the elimination or addition of some, we must emphasise that we are by no means trying to perfect the single process to follow for all Knowledge Worker Environments or Development Projects. The idea is to demonstrate how to critically consider each process in the value stream for each project or type of operation to add value to the client. This is also not a once off process, but a culture of continuous improvement, where the front-line worker is enabled to improve his environment and processes continuously (Enabler 5.3.2 and Enablers 5.7).

Some important aspect of Perfection to be highlighted is the role of communication, coordination, collaboration (Enablers 5.4) and standardisation (Enablers 5.6) in achieving this state. Perfection also speaks of excellence in the normal activities of each discipline instead of heroic moments in crisis times (Enabler 5.2.2).

Thinking that with Lean we have finally arrived would not even be true to Lean itself. Lean focuses on continuously moving towards Perfection. Lean, although a very mature approach is by no means a stationary approach. Without re-inventing the basic principles tried and tested at Toyota, this will not be an on-going process of learning and growing.

3.5 Step 5: Respect for People

This principle is best captured in the following Lean enabler: Treat People as Most Valued Assets, not as Commodities. (U 0.70) (Lean Systems Engineering Working Group , 2009, February 1). All of the above principles are only possible when mutual respect between employees, empowerment of employees, a customer orientated culture and a will for continued improvement and excellence exists. One can achieve a lot with a team where there is a shared vision and understanding that everyone contributes to. For the pursuit of perfection, this must not only be true for a certain group or team working closely together, but for the entire organisation (for example between a business unit and the support services) and even organisations working closely together. A lot of energy is otherwise spent on managing the Us-Them attitude. People are not merely a resource to be allocated to a task, but the company's most valuable asset. Without their commitment and their buy-in, value cannot be optimised.

[2] (McManus , 2005) suggests a tool for mapping these kinds of iterative processes and information flow. It is called the DSM mapping.

4 Case study - Applying Lean in a Knowledge Worker Environment

In this initial study we focus on only some of the steps described in Figure 2 (Product Development Value Stream Mapping Manual (PDVSM)) (McManus , 2005) to demonstrate the feasibility of and the value added by applying Lean principles in a Knowledge Worker Environment. We also draw on the work done by the Lean Enablers for Systems Engineering Working Group of INCOSE (Oppenheim et al. , 2008) throughout this Case Study. The Enablers from the Quick Reference Guide to Lean Enablers for Systems Engineering (SE) (INCOSE Lean Systems Working Group , 2009) are referenced throughout the paper as “Enabler x.x.x”.

4.1.1 Background to the Case Study Project

The case study project is a long term acquisition project for the SANDF under contract from Armscor in accordance with the Department of Defence Acquisition Policy, DAP 1000. The project in question is highly challenging and many of the Design Engineer (DE) as wells as Systems Engineer (SE) and Logistic Engineering (LE) personnel had little experience. The culture of the organization up to the start of this project was smaller, mainly DE-focused activities. Not surprisingly, there were many unknowns and disagreements in perspective and approach, some of which remains and needs to be resolved by acting on the recommendations made in this study.

4.1.2 Defining Value for the Case Study Project

DPSS provides the following value propositions to its customers (not intended to be an exhaustive list):

1. Contracted Research (typically applied research) where a specific problem is investigated for the South African National Defence Force (SANDF) and the final deliverable is a report containing the findings and recommendations. Contracted research can also be undertaken as part of maintaining a ready technology base (the knowledge and the capacity) for the use of the SANDF and possibly in support of projects, either from Defence technology funding or from CSIR Parliamentary Grant (PG) funding.
2. Technology demonstration where mostly existing knowledge (not necessarily just DPSS developed knowledge) is used to demonstrate a new solution to a problem in the client domain. It is the front end of the innovation chain required before technology solutions can be commercialised and taken to the market.
3. Product/System Development for the SANDF where products or systems are developed under contract from Armscor in accordance with the Department of Defence Acquisition Policy, DAP 1000.
4. Product/System Development for other research or defence organisations. This is limited to low volume niche products related to equipment developed in support of the Defence Evaluation and Research Institute (DERI) role for the SANDF.
5. SANDF operational support in the form of Quick Reaction Tasks (QRTs) during the preparation for and execution of operational missions.

In this case study we will be looking at the specific value added by TSO (Technology for Special Operations), a competency area of DPSS. More specifically we will look into the function to provide the client with a required or requested capability on a long term or strategic level (part of item 3 above). TSO has a very close client relationship, partly due to the type of work conducted which requires very close interaction. TSO creates value for the client by taking charge of their capability needs and enabling them to perform certain activities or have a certain capability. Before looking into further processes it is important to understand **how** this aspect of the organisation creates value for their client. The following high level value stream articulates just that.

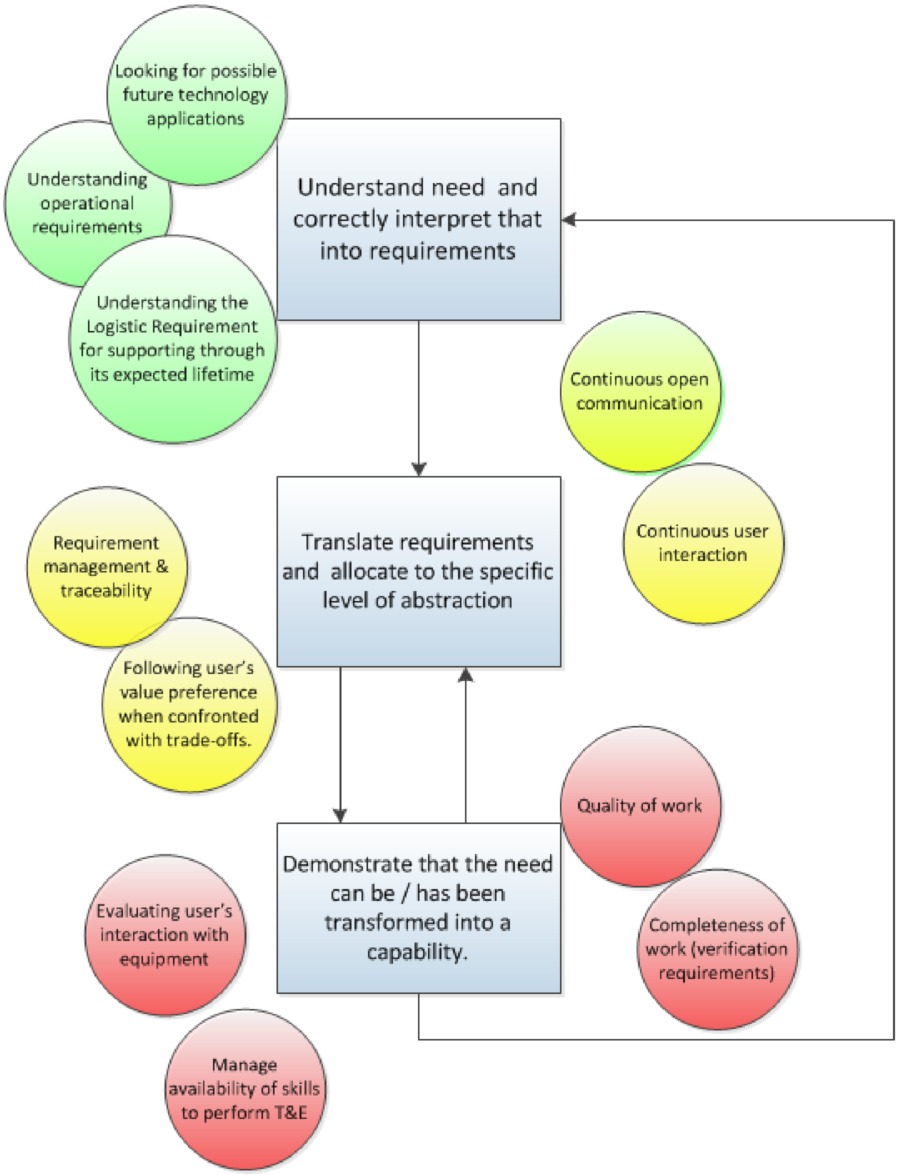

Figure 5 : TSO Value Creating Process

For the specific project used in the case study, there is a specific Value Precedence defined as follows:

Table 3 : Value Precedence for Case Study Project

1.	Safety of operating personnel
2.	Safety of cooperating equipment
3.	Mission success
4.	Safety of main equipment
5.	Reduced complexity of use
6.	Life Cycle Cost

The Value streams defined in the next section are therefore evaluated against the context of Figure 5 and Table 3.

4.1.3 Mapping the Value Stream

For this paper, we have mapped 3 Value Streams as examples. These Value Streams include one high level process (Example 1) and two more detailed lower level processes (Example 2 and 3).

Example 1, includes all the main project team activities for a specific Development Item to go from the Functional Baseline (FBL), through the Allocated Baseline (ABL) to the Production Baseline (PBL) as guided by the acquisition of armaments in accordance with DAP 1000 (Department of Defence Instruction: ACQ NO 00005/2003 , 2010). Due to the amount of high level processes, the information flow was mapped out with a Design Structure Matrix (DSM Mapping) as suggested by (McManus , 2005) as a tool for mapping these kind of iterative processes and information flow. The Matrix is included in Appendix A. The processes mapped out include activities of the Design Engineers (DE), Logistic Engineers (LE) and Systems Engineers (SE) as well as Operational Experts (OE) on the team. During system development, this set of processes is executed concurrently for all the different subsystems that are in development and makes for quite complicated information flow, scheduling and resource management.
Configuration Management (CM), Support from CSIR procurement and Shared Services, Internal Quality Control as well as all external inputs from the client were considered as external inputs and outputs for the purpose of this example. These external inputs and outputs were however also evaluated and were the source of one of the detailed examples (refer to 4.1.4.2).
The value streams for each of the identified value activities can be mapped out in detail down to possibly several levels of abstraction. This will be done as part of future work.
From the analysis of Example 1, only two lower level processes were considered for the case study and they are discussed in more detail in paragraphs 4.1.4.2 and 4.1.4.3 below.

4.1.4 Value Stream Evaluation

Due mainly to time limitations but also to the intent to briefly illustrate the use of Lean in a Knowledge Worker Environment, we do not have quantitative performance data of processes as mentioned in the Literature review in point 2 of section 3.2. In the following examples our analysis on the flow of input and outputs is qualitative in the form of opinions of the Project Team members, as captured in the survey conducted as part of this study. In Example 2 we have determined the times associated with the processes in the Value Stream. All examples were further evaluated and analysed in terms of the literature and best practises for Lean in the SE (INCOSE Lean Systems Working Group , 2009).

4.1.4.1 Example 1 - High Level Team Activities from the ABL to the MBL

These processes were mapped as they are currently being applied in the case study project. The Project Team's perception of how well information flows between these activities were captured. Team members were asked to rate how well the information flows to their task and from their task on a scale of 1 to 4, see Table 4. The data is incorporated in Appendix A.

Due to the qualitative nature of our study, we have followed the same philosophy as in section 3.2.1 when we determine the quality of information output / input. The rule of thumb is that the user of the information will determine whether the information is of acceptable quality - not the creator! Feedback from the team was therefore weighted such that the opinion of team members that received data as input was assigned double the weight compared to the opinion of team members who generated the data as output. This initial survey was completed to get a general idea of the perception of the team and also to identify problem areas to start the more detailed mapping process. In future work, more detailed performance data can be captured for the identified processes. It is important to note the caveat that for some processes a common basis of understanding exists vs. whilst for others there is an effort in progress to establish / train that insight which can in future affect the ratings shown on the form.

From the results of the initial survey of the 287 data handover activities, the perception of the quality of data flow is as follows:

Table 4 : Result of DSM Initial Survey

Definition of Rating Scale	Scale	Percentage of data handover activities
Information flows, there are only minor errors or waiting	1	47.7%
There is an understanding of flow, but it is not always realising / Information is not flowing effectively.	2	47.0%
Poor to no information flow / missing process / resulting in waiting for information or information defects	3	5.3%
Processes missing / No information flow or an understanding thereof	4	0%

These results show that almost half the time (1^{st} row), team members are happy with the information they need to work with and need to provide. In almost the same number of responses (2^{nd} row) it is clear there is some room for improvement to the integrated approach to really enable the effective flow of information. At this point it is important to emphasize these results do not report on the Project success (the Project has been very successful), but that the percentage does report on the collective opinion of the Project Team on scope for process improvement. The positive aspects contributing to these percentages are as follows:

1. Co-location - one open office for the Project Team. (SE enabler 3.5.5, 4.2.7)
2. Project Team has common vision, vision well communicated
3. Technical experts in each discipline group of team (e.g. SE/LE/DE) (SE Enabler 6.4.3)
4. User experts on the team (SE enabler 1.3.2)
5. Integrated approach (SE enabler 2.2.3)
6. Requirements management and RAM management software tools

For the rest of the Case Study, the main focus will be on the 5.3% of activities where information flow is really poor. These activities were deduced from the results in Appendix A and include:

1. Inputs to most of the Logistic Support definition and planning-related activities (Support means Maintenance, Spares, Support Equipment etc). The inputs to the Technical Manuals also did not score well.
2. Feedback / iterative activities (lack of understanding about the effect information changes has on other outputs)
3. Definition of product and material characteristics for the MBL (focus mostly just on functional) – this will become even more apparent by the time the Physical Configuration Audit (PCA) is conducted.
4. Procurement Support from the CSIR. (SE Enabler 3.6.4) - Engineers spend many hours on procurement administration activities such as phoning suppliers to get them back onto the CSIR Procurement System after they have been automatically removed by the procurement office upon expiry of qualifying documentation (e.g. tax certificates).

All of these points should be further analysed, but we have focussed on one process from point 1 and one external process for the purposes of this paper. The following two lower level processes were identified for further analysis.

The first, Example 2 - The Configuration and Approval Process, is something that was considered to be problematic not so much on the basis of the information that flows, but on the basis of the time taken for the information to flow through the process. The time that it takes to follow the approval process for a classified document is a great problem. This process is illustrated in Appendix B and further discussed as example 2 below.

The second, Example 3, focuses on point 1 above. The further analysis was the generation of the Support Documentation and other relating Logistic and Systems Engineering Documentation after the finalisation of the Design. This process is illustrated in Appendix C and further discussed as example 3 below.

One last note on this level is that one should not only focus on the flow of information, but also question whether each process adds value and how it can be streamlined.

4.1.4.2 Example 2 - Eliminate Unnecessary or Inefficient Reviews and Approvals

McManus (McManus , 2005) states: "Reviews and approvals are the tasks most frequently deleted outright during Lean Advancement Initiative (LAI) member improvement efforts. Again, the issue is what value is created. Reviews can be used to reduce risk. If all they are doing is catching mistakes, they are at best necessary non-value-added quality assurance tasks. If they are used to control iterations and assure convergence on the best solution, they can be key value adding steps. In all cases, they should be arranged so that maximum value is created at minimum cost to the project.

The costs take two major forms: waiting for approvals that are ultimately given, and rework loops when reviews find problems or value-adding opportunities. The former is pure waste of waiting, and should be eliminated; the latter may be value adding, but must be managed."

It is our experience that it is important to distinguish between reviews that have creative and user-input generation components (e.g. Preliminary Design Review (PDR) - highly valuable) and reviews of a more administrative nature. Reviews that often have such an administrative nature are the approval of documentation, especially outside the immediate technical inputs of the first peer review within the project team. This Configuration and Approval Process for the case study project is documented in Appendix B. The process consists of the main documentation approval process in Figure 6, with further details on the Internal Acceptance, Internal Approval and External Approval sub-processes in Figure 7, Figure 8 and Figure 9 respectively.

The Internal Acceptance process deals with internal release of the document for external review, while the Internal and External Approval Process deals with formal approval (obtaining signatures) after external review have been conducted.

An evaluation of the timeline revealed that for the absolute best case where no signatories have additional comments after the initial peer review (and assuming only one client signatory), the total time to generate and approve a document can be almost 2 months. The worst case where all signatories have additional comments after the initial peer review (and still assuming only one client signatory), the total time to generate and approve a document can increase to almost 4 months. For every additional client signatory that time increases by eight days.

The following focus areas for waste elimination have been identified (Refer to paragraph 5.2.1 for a more detailed discussion of the focus areas):

- Focus Area 1: Waste due to Over-production – relating to the creation of unnecessary information.
- Focus Area 2: Waste due to keeping Inventory – relating to generating documentation prematurely before the source information is stable resulting in rework when it is eventually required.
- Focus Area 3: Waste due to Transportation – relating to the handling and delivery of documentation in a classified environment.
- Focus Area 4: Waste due to Unnecessary Movement – relating to unnecessary sequential review loops aggravating the effect of waste due to transportation
- Focus Area 5: Waste due to Waiting – relating to delays in the approval chain due to stakeholders not available or not promptly approving documents received.
- Focus Area 6: Waste due to Defective Outputs – relating to superficial or fragmented (the correct stakeholders not all present at the same time) reviews leaving undetected errors or oversights in documents.
- Focus Area 7: Waste due to Over-processing – relating to spending more than the required effort to produce a document.

4.1.4.3 Example 3 – Generation of Support Inputs after Design Finalisation

The VSM for this process is given in Appendix C[3]. The following focus areas for waste elimination have been identified:

4.1.4.3.1 Focus Area 1 – Waste Due To Information Storage and Accessibility (INVENTORY):

Information is one of the primary products in our environment. Information storage and handling has great room for improvement on this project. Currently the project makes use of the following data repositories:

Table 5 : Data Repositories

Database / Server	Detailed items	Contributing to	Opportunities for reducing duplication
SE Database (CORE) For the SE Model	Product Breakdown Structure (up to Major components) Sections for documents to be generated All requirements All verification requirements All test events	Specs Test Plans Safety Management ICD Behaviour Diagrams / Context Diagrams / Structure Diagrams	PBS only serving the needs of SE documentation
Logistic Database (Ramlog) for simulation capturing of technical data and generating technical documentation	RMS data and support tasks and elements requirements data. Logistic PBS and item data.	Operators Manual WRM IPB LSADB deliverable	PBS only serving the needs of Log deliverables
CAD package (Inventor) for the Mechanical Design Model	PBS for all manufactured items Manufacturing drawings Data for mechanical analysis	Manufacturing Drawings Configuration for production Models	PBS only serving the needs for Family Tree
E-plan for the Electrical Models	No BoM currently used Layout of items with items descriptions	Manufacturing Drawings Configuration for production Models	Very little PBS data – information to be required ad hoc by requesting from designer
Project Server	All database generated docs MRI (master PBS) All manually generated docs: - ATP (the how) - Setting to Work: - Technical Manuals: - Procedures Photos and Pictures made from model	All project activities Pic used in Technical Manuals, IPB, Product Specs	MRI and SE model – updated separately. Everyone have access to MRI (spreadsheet) – only SE has access to CORE. Every individual generates pictures for themselves, stored in separate folder. All documents stored in easily accessibly way.
Configured Information	MRI, All documentation, Diagrams	Configuration Management	Consider Local Configuration and then final when Documentation is mature.

As can be seen in Table 5; similar data is stored at 5 different places. One example of this duplication is that each discipline in the team has its own Product Breakdown Structure (PBS), or architecture, in which the detail work takes place. Although all of the PBS data is necessary in the different applications – it is still one system described from different views. This duplication is waste (INVENTORY) and also results in other forms of waste:

- DEFECTS. Duplication of information causes updates being made and not followed through in all the databases, causing incorrect information resulting in re-work.

[3] The boundary conditions and constraints are indicated on the diagram. This diagram has evolved over time and is strictly speaking already a first order future VSM. Information flow between LE and SE has been improved e.g. providing info for Technical Manuals. There is still room for improvement.

- OVERPROCESSING. Data need to be consolidated which requires changing it from one format or structure to another.
- TRANSPORTATION. Information need to be moved from one place to another – this requires time and effort and when the information becomes out-dated, this process is repeated. It also means printing out all the documentation and getting the right signatures (the topic of Example 2) - a time consuming process and one you would not want to do repeatedly.

A lot of time is spent on finding documentation in a very deep folder structure leading to team members creating private workspaces as intermediated work areas. As the project documentation grows, documentation is not in the suggested folder structure and difficult to find. This causes a lot of waste due to WAITING and OVERPROCESSING as well as frustration for team members.

The current rigid and formal CM structure (a monument from days before advanced computer models) is not optimised to exploit the benefits of modern design tools. Entering into the formal CM too early could result in a lot of OVERPROCESSING and MOTION. Other long term options to investigate are version control and other technologies to aid in designer controlled Configuration Management (CM) before going through a formal Configuration process for Production.

4.1.4.3.2 Focus Area 2 – Waste Due To the Means of Information Flow (OVER-PROCESSING / WAITING)

This area of waste focuses a lot on the red areas identified in Appendix A. A large component of this is data for input to logistic support definition and planning -related activities. The data is mainly pulled from the DE by the LE. The two main forms of waste identified in this process is the availability of information (WAITING) and also the way in which information is transferred (results in OVER-PROCESSING). There are several possible reasons for these wastes:

1. *Misalignment between LE and DE*

   On this project the SE/LE/DE disciplines have been integrated and work concurrently. There is definitely still room for improvement and a specific area that came out of the DSM was the post-design inputs to the LE. Keep in mind, the DE's natural focus is on delivering the technology demonstrators. With this specific project (refer to the Value Precedence in Table 3) mission success and consequently Reliability, Availability and Maintainability plays a very important role. Processes and workflow should therefore enforce an ever increasing progress towards total integration of the SE and LE disciplines with the design. This was of key importance on this project.

   A catalyst for misalignment between disciplines would be the pressure that concurrent engineering places on the design process. To succeed in the integrated approach and really have LE make an impact on the design (not only implementing changes afterward to accommodate maintenance for example), the Log issues must be considered during the design and implementation phase. Total Systems design for operational suitability (vs. just a functional product) is more complex, more time-consuming and requires wider design skill and harder work.

   The problem on the case study project has been compounded due to the fact that the DEs design progress fell seriously behind spending progress, causing high pressure on DEs to complete design, causing DEs to basically disregard all non-direct DE efforts (such as SE and LE) and crisis design a basic functional outcome. This was compounded by the transfer of budget from LE to sustain DE. The shorter schedules were forced by the limited funds remaining to sustain the development team, calling for an earlier end-date to development. To end the Development Phase earlier, the LE also has to end earlier. LE was thus put in a position to generate earlier outputs based on even later design results information - high risk. LE development thus ends later than Prime Mission Equipment (PME) design and involves significant LE processes to apply design information to generate the Development Phase LE outputs. Further delays of development trials and design data packs etc makes this more marginal to achieve.

   The organisation is not structured around design implementation, so when the design implementation period comes, the DE also became the one doing the physical implementation. One can imagine that with the DE out of office for several periods and with limited time available, the concurrent working with other disciplines became quite difficult or almost impossible. This resulted in a backlog of Log designer input/time requirements. The sudden increase in time and effort required by Log from DE, while the DE is under pressure for implementation, caused the DEs therefore to shy away from it, focusing on the immediate hardware delivery at hand and the Log backlog piles up even more. The problem therefore spirals into ineffective information flow, creating a lot of tension between DE and LE.

When developing new technologies or applying technologies in a novel way, prototypes are often produced for risk reduction (SE Enabler 3.2.5). This is not an exemption to address RAM issues during the design process. Obtaining Log data prematurely also results in Over-processing. There is clearly a balance to be achieved in the concurrent engineering.

2. *Lack of understanding of upstream activities with the information*

   A second problem is that the DE often does not understand what happens to the information that he passes on to the LE. This results in LE often receiving incorrect information to re-process or waiting a long time for new information. For example, obtaining input data for the Support Requirements Lists from designers starts too late. The designer feels it is premature to start focussing on support of the design while the item is not yet completed (not understanding that only high level data is required and not final design information). In the meantime the LE needs to start with PBS and functionality for the FMECA which is used to drive the analysis for what needs to be supported. When the DE finally has time to provide input to the LE, the design has progressed to the extent that little design influence can be done. The DE then also has set ideas on the support of the item based on his intimate knowledge of the design and feels that the LE, who has subsequently had to continue logistic support analyses (e.g. Level of Repair Analysis (LORA) and Cost of Repair Analysis (CORA)) with deficient information, has not added value to the process.

   The truth is that the FMECA is primarily a design tool - DEs however generally do not have the experience, insight or inclination to apply this. The FMECA is secondarily a support requirements analysis tool. - This is a key area for gaining process improvement benefits.

   Designers were also provided with quite thorough RMS design concepts (at the PDRs) and associated requirements in B-specs. Sadly, when designers do not have a good understanding of the LE discipline and the importance of the tight integration of SE/LE/DE, it comes as no surprise that LE requirements tend to be disregarded when milestones are being missed.

   It may be that the DE is not interested in Log related activities, it may be that the LE does not communicate the requirements in the correct way to the DE, or it may be that the higher level process has never really been explained to junior engineers joining the Project and that they are figuring it out as they go along. It is most likely a combination of all of the above. The solution for challenging these silos is seen to lie in better training and communication and is discussed in section 5.2.2.

3. *The Designer as Bottleneck*

   The SE also requires inputs from the DE for completion. This puts a lot of strain on the DE availability, especially when he is still trying to prepare the hardware for a deadline. Any implementation delays ripple into the deliverables of LE and SE as well. The bottom line is the DE is a major bottleneck at this point of the project.

   Something that could relieve the bottleneck to some extent, as well as help with point 1 and 2 above, is shorter and more regular interaction between LE and DE (same applies to SE) as opposed to just the “forced” interaction in preparation for formal events like a CDR, release of a Technical manual, etc. The fact is that the week or so of intense SE/LE/DE interaction before the PDRs and CDRs resulted in the most significant integration of these disciplines and arguably the most Total Systems Design value added. Part of the reason was that the review agenda forces the DE out of the single (functional) dimension comfort zone and to co-opt assistance from SE and LE- to the absolute benefit of the design solution. The process needs more of that discipline. This is also a key area for gaining process improvement benefits. Recommendations on continuous interaction between DE and LE and further exploiting this bottleneck are made in section 5.2.2.

5 Recommendations and Lessons Learnt

5.1 General Recommendations

1. Lean should be pursued in a knowledge worker environment to ensure that value to the customer is optimised while at the same time enabling the organisation to do more with less.
2. Lean initiatives must start with the understanding and participation of management to ensure that the ultimate goal of a project is not just successful outcomes (contractual deliverables), but also the generation of these outcomes in the most cost effective manner (no waste).
3. Contracting processes of especially complex, high risk projects should allow for a stage gated approach where uncertainty and risk is reduced as the work progresses. Executing such projects within prematurely fixed timeframes will inevitably lead to concurrent engineering being applied outside its limits leading to inefficiencies (waste) in Flow of information.
4. The use of Integrated Product Teams (IPTs) on complex or high risk projects shall be encouraged as well as all measures that can improve common understanding and information flow (e.g. sitting close together in an open plan office).
5. Lean approaches should not be limited only to the processes within the sphere of influence of the IPT. Significant greater benefits can be gained from addressing the whole value chain, including client interaction processes like contracting and approval/acceptance processes.
6. Lean should be pursued as a culture of continuous improvement – singular initiatives on isolated projects will not deliver lasting benefits.

5.2 Lessons Learnt from Case Study Examples

5.2.1 Example 2

Being confronted by the monument from the past in the document approval process in Appendix B, it is clear that this monument, in conjunction with the external parties should be challenged and broken down. One must however keep in mind that monuments were erected for a reason and sometimes the reason is still valid while the method may be outdated. The elements of the monument addressing that reason should not be abandoned (the healthy alternative).

5.2.1.1 Focus Area 1: Waste due to Over-production

In product development, the waste of over-production addresses the creation of unnecessary information or the delivery of information out of sync (before it is required or too late).

The source of the problem here is the document itself. If the author does not understand the need for the document or the level of abstraction, he can quite easily generate a document that contains far more information than is actually required. The problem is also often that documents are generated because it is asked for in a process standard, while there is little understanding of the true value that the document is intended to add and therefore no ability to make a judgement call if this document is at all required within the context of the specific project and the level of abstraction that is required to sufficiently address the need.

In the elimination of this form of waste, there is no replacement for experience. Process standards should be used as guidelines and applied with discretion given the context with the sole aim to add value to the development process and thus ultimately to the client.

5.2.1.2 Focus Area 2: Waste due to keeping Inventory

Generating documentation prematurely before the source information is stable will lead to documents filling up the filing cabinet but it is not really used as the next step in the process cannot make use of it yet (e.g. compiling a test procedure while the specification has not yet been fixed or starting to produce design documentation when the requirements have not been fixed). This information becomes analogous to unnecessary amounts of material or components that are accumulated between production steps. It takes up space to store it and represents huge amounts of human resource effort that is largely wasted as it will require re-work. When different bits of information required for a process step arrive out of sync, it is often an indication of a poorly coordinated schedule, incomplete inputs from a prior phase, planning not accommodating processes required as input or cultural (a predominantly DE vs. a total systems engineering culture) that can lead to total systems engineering processes to be disregarded by DEs.

5.2.1.3 Focus Area 3: Waste due to Transportation

The physical transportation of information in the case of the documentation approval process is a huge time consumer. In a classified document environment there are strict rules for the preparation and packaging of such documentation which very often has to be hand delivered. This problem is exaggerated if there are a large number of approvals to be obtained for a document over a geographically distributed area. The use of paper copies for approval requires that it all happens in series and if there are any updates required to a document halfway through this process, it all starts from scratch. For the case study project this was a particular issue as members of the project team were distributed as far apart as Stellenbosch, Pretoria and Langebaan. This often led to approval of documents taking as long as three months. Refer to the estimated times for process steps in Appendix B that accumulate to these long delays.

The use of modern technology can however allow for secure electronic transmission and even electronic approval of the majority of documentation. Transportation time is thus drastically reduced and documentation can progress through the approval process much quicker and actually be available in time when they are required. Who has not done a test based on a test procedure that was ready in time but still somewhere in this black hole of approvals?

5.2.1.4 Focus Area 4: Waste due to Unnecessary Movement

Looking at the document approval process as documented, it is clear that there is a huge amount of movement of documentation between different parties. Is all of this really necessary? In a production environment the unnecessary movement of material from one batch of machines to the next is eliminated by moving the machines closer to each other and grouping them to optimise the flow of the material from one step in the production process to the next. The equivalent of that in the documentation approval process is to get all the relevant people together in one place on the same time to review or approve a document. Most projects have regular stakeholder meetings where such activities can take place. The problem is often that one or more of the stakeholders are not present. The alternative is to focus on the quality of the document while it is still under your control by means of a thorough formal review meeting with all stakeholders to eliminate some of the sequential commenting and correction loops. Combined with the use of electronic distribution and approval, the number of movements can be restricted and the total time spent on the movement can also be minimised.

5.2.1.5 Focus Area 5: Waste due to Waiting

Waiting can be caused in one of two ways. Information is either delivered too early and waits to be processed by the next process, or information could be delivered too late in which case the next process is being held up by waiting for the information to arrive. The former has been discussed under focus area 2 above and leads to information not being used because the next process is not yet ready for it. By the time the process is ready; the information is most likely outdated and needs re-work. The latter case is one of the more significant causes of project delays. In the case of documentation approvals, the largest portion of the waiting time is documents lying on someone’s table, waiting to be read or approved. When humans are involved in the reading and approval of documents, not much can be done to speed up the process if the humans involved do not share your priorities or do not manage their time effectively. The best way to limit this form of waste is by limiting the required number of stakeholder approvals by formally agreeing which level of documentation needs to be approved by whom. Surely everybody does not have to sign everything.

5.2.1.6 Focus Area 6: Waste due to Defective Outputs

Defective outputs in the case of documentation approval are quite simply remaining errors or omissions in documents. The only solution here is to have formal reviews with all the relevant stakeholders where they have the opportunity to prepare for the review (actually read the document) before the review. Comments on reviewed documents can be discussed in the group to ensure everybody agrees with the resolution of the issue. The option of sending a document to stakeholders for commenting in a sequential fashion may very well lead to further comebacks during the approval process when disagreements between stakeholders on specific comments will lead to multiple reworks.

5.2.1.7 Focus Area 7: Waste due to Over-processing

Over-processing can be equated to spending more than the required effort to produce a document. Examples of this are lengthy and elaborate narratives where the use of a diagram or picture could have illustrated it more effectively. Another form of over-processing is repetitive changes in formatting and presentation where the upfront agreement of a standard template could have eliminated such uncertainties. Knowing your application area and understanding the audience is also very important in pitching the information at the right level. Over processing differs from over-production in that over-processing leads to taking too long to produce a document versus producing too many (unnecessary) documents.

5.2.2 Example 3

5.2.2.1 Focus Area 1: Better Flow of Information in Shared Environment

There could have been much more waste in our Case Study due to processes not clearly defined or work not completely standardised. Almost coincidently a lot of these issues were resolved, simply by being in one small office, people overhearing discussion influencing their work. The on the job training and transference of tacit knowledge that takes place in such an environment is also remarkable. Work cells are definitely a top priority for enabling flow in a Development Environment**.**

Along with close proximity in terms of knowledge and information from team members, the "close proximity" of data available is also paramount for information flow. Being able to work in a shared folder and knowing that the most up to date information on that subject matter is in the folder reduces a lot of waste.

In earlier discussion of the case study we mentioned private workspaces forming due to the structured workspace being too deep and how that causes waste and frustrations among team members. This can be countered with technologies available to structure each user's workspace according to their needs, while allowing information to be displayed correctly and easily to all other users. Such packages also typically include good version control (SE Enabler 5.4.7).

5.2.2.2 Focus Area 1: Pick the Low Hanging Fruit

Waste that can clearly and easily be removed (the low hanging fruit), should be done immediately. In Example 3 Focus Area 1, this could simply be done by improving interactions between team members through a structured process for sharing work. One such example is having a shared and structured image repository for the Project. Several SE and LE technical documentation requires good quality images (see dotted lines in Appendix C). Only the DE and Draughtsmen however have access to the 3D models. Being in the same office and having good working relationships makes it very easy to quickly ask a DE to generate a picture, but when working against deadlines, this causes a lot of interruptions for the DE or the LE / SE to be delayed. It also requires rework for the DE when two months later, for another application, the DE is prompted by someone else for a similar picture. By merely building up and using a common picture repository, a lot of waste can already be eliminated. Easy access to pictures will result in less engineering time spent on searching for or generating pictures and by continually replacing pictures with updated ones in only one place, will ensure that less pictures of out-dated models are in use.

5.2.2.3 Focus Area 1: Find Software Solutions to Support A Full Integrated Data Approach (Golden Rule – Store Data Only Once)

A software solution is required to integrate the different Product Breakdown Structures. Ways of interfacing between the SE database (CORE) and the LE database (RAMlog) are currently being investigated. The same should be done for other Software packages (E-plan - Electronic; Inventor - Mechanical). The high level architecture should still be a SE responsibility, although the PBS would then be further developed by the DE and ultimately pulled into RAMlog. The high level PBS (MRI) should be easily accessible by designers – so that they could build their family trees in accordance to the agreed names and numbers. Changes to the High Level PBS during the detail design should be communicated back to SE and automatically sync with LE info.

With a more integrated SE/LE database, it should also be investigated whether the Technical Manuals content could not also be generated from the LE database / SE database, preventing the duplication of data and potential use of outdated data when working concurrently.

When doing such custom integration between software tools, the flexibility of the tools and their interoperability through, for example, a common scripting language is essential. (SE Enabler 3.8.4).

5.2.2.4 Focus Area 2: Break Down Silos between Engineering Disciplines

Silos can also be between business units or even engineering groups or teams within a business unit. In the case of LE / DE interaction these silos stems from different mind-sets due to different disciplines. They therefore need to be challenged. The following is proposed:

1. Proper training/induction in the complete ARMSCOR acquisition process, requirements from MIL Standards for LE and SE documentation (SE Enabler 4.2.4).
2. Improved communication with DE:
    a. improved translation of Log Requirement for Dev Item (here the SE should aid in improving the refinement of that in the Specification);
    b. When starting with a process e.g. Logistic Support Analysis – the LE need to explain to DE the context and end goal including what is needed from them. Therefore, whenever the LE approaches the DE for information, there is a greater understanding and cooperation (SE Enabler 3.6.6).
    c. Explain in more detail the format in which the LE requires data. Investigate opportunities to minimise the level of effort on both sides (SE Enabler 3.6.6, 4.2.6).
    d. Keep communication to the DE short and to the point (SE Enabler 3.5.6).
    e. DE must take responsibility for Log requirements on their systems just as they do with the functional requirements.

Although processes and input requirements have been explained before, it takes more time and continuous communication to establish a new culture. It is more complex and challenging to design for more than just the functional dimension. People tend to make things easier for themselves if allowed to, especially under time pressure. For the CDRs the team were able to connect back to the PDR concepts, measure the delta and this time the designers presented their own design RMS status. That shows commendable growth in insight and bodes well for future projects.

Continuous interaction (SE Enabler 3.5.4 and 3.5.5), by means of 10 minute meetings daily or 30 min meetings once a week could aid in the LE being up to date with the design progress as well as having an opportunity to influence the design from a RAM perspective or influence the format of data flow. This would also enable the LE to be more involved in assisting DE with Log aspects of their design (SE Enabler 4.2.5). This would only suffice if all DEs have the same shared understanding of the value of LE and the LE processes. As long as this is not the case a better way would be to use these “forced” events where the DEs could be coached in the information to be provided, but have smaller intermediate internal review events, to enable the continuous flow of information as a build up to the formal events.

For example, designers could be busy deciding between components for their designs. The LE’s input at that point could result in choosing the better component, not only from a functional point of view, but also from a life-cycle, maintainability and reliability point of view. (Note that this has happened in many of the designs - depending on the DE involved. The DE is in charge of his design, he makes the decisions. i.e. if the DE accommodated it, it happened. If the DE disregards the non-functional paragraphs of his B-spec that is what you get.)

The LE could also be more involved with supplier interaction, since the LE knows exactly what kind of information to request from the supplier. The LE would then also have the component data at hand for the Logistic Analysis and Codification processes, without having to request it from the DE first. The design compliance to the RAM requirements remains the designer’s responsibility, but more continuous LE involvement throughout the design would result in much better flow of information. In terms of supportability, the LE could for example better support the designer in researching support information e.g. replacement periods for O-rings/filters or investigating the support environment to aid in the process of establishing support requirements and equipment (SE Enabler 6.2.11).

5.2.2.5 Focus Area 2: Balancing the Line / Getting Rid Of That Bottleneck

Another point to discuss is to from an organizational point of view, free some of the designer’s time by removing some of the Support Tasks e.g. procurement administration (SE Enabler 3.6.4). The DE remains the final responsibility on several things peripheral to the design, since most DEs also act as Project Managers on the specific line item. Administrative tasks such as the procurement, interacting with suppliers, receiving and storing procured items etc. could easily be reduced by structuring the organisation or team in such a way. In some cases, the structure already exists, but is not used to its full potential due to a lack of understanding of the bigger organisational context, or due to inadequate support or support processes available.

6 Conclusions

1. Lean is most definitely applicable to a knowledge worker environment, specifically in a product development environment.
2. Lean is not equal to less – in fact, Lean may even be more if you have to add additional process steps to improve the flow of information.
3. Even in an Integrated Design Environment where people have been working together for years in a close cooperation on a project, the Lean approach to maximising value provides a refreshingly new perspective on value.
4. In a commercial environment the basis for product cost from a Lean perspective is the waste-free cost of the product, not the current wasteful cost plus margin. In the case of the CSIR as not-for-profit organisation, this relates to an increased capacity to handle complexity and to manage risk in a wider domain, other than expanding the resource base – i.e. doing more with less.
5. The importance of Flow of information from one process to the next lends itself to grouping these processes together to minimise unnecessary movement. This is a great motivator for an open office environment and has been proven to be effective on the case study project. Grouping options are enhanced by training to enable an Integrated Systems Engineering approach by all active on the IPT – alignment of perspectives and insight vs. conflict and reduced outcomes. Workers inevitably follow the insights and priorities imposed by their next level management, who in turn are project contract performance driven. In lieu of a conscious strategy towards total system solutions this can result in development management for successful projects vs. managing for successful system outcomes. It requires a strategic objective driven from the top and supportive policies (e.g. policies such as demanding proper documentation of designs.)
6. The importance of timing and scheduling to avoid unnecessary compression of timescales resulting in premature pulling of data from one process to the next in order to meet deadlines cannot be overstressed for reasons of quality and efficiency (waste/rework).
7. A common understanding of the whole task at hand by all team members is essential to ensure the smooth flow of information with minimum rework and resultant waste. Training to enable holistic (Total Systems Engineering) thinking as alluded to in 5 above is therefore also essential.
8. The application of Lean principles in a localised fashion will deliver results. However, the whole value chain should be considered if full advantage is to be gained. That means not only optimising at project level, but also at corporate and client level where possible. Much will however be gained (including management support) by initially focussing on those processes that can illustrate immediate benefit at least effort/investment. Looking at the table in Appendix A in its current state, the first major benefit will come from common understanding and agreement on the input/output requirements and phasing of the listed processes.
9. Lean is not a once off process, but a culture of continuous improvement (first need to establish insight and conviction of the same "big picture" by all), where the front-line worker is enabled to improve his environment and processes continuously (Enabler 5.3.2 and Enablers 5.7). Toyota credits Kaizen and the bottom-up employee suggestion system, for half of its success. [Oppenheim, 2006].
10. The case study not only revealed the many unknowns and disagreements in perspective and approach of a predominantly young and inexperienced engineering team. At the same time it also highlighted the positives in the many innovative PM, SE and LE approaches followed and the confidence it has established with the Client that this team can be trusted with a Total Systems solution. What remains is to do that more effectively and Leaner the next time round.
11. Many of the reported disconnects between SE/LE/DE on the case study project are rooted in a shortage of Total Systems Thinking. LE is part of SE in the Total Systems Engineering context. LE drives its outcomes via SE's mechanisms (SEMP, Item Development specifications, Design reviews etc). Implementation discrepancies are deficiencies in DE capability or attitude for compliance with those mechanisms. The basic design information required by LE from DE is the same as that required by SE, as LE has to ensure it works concurrently with the same design configuration status that gets documented in the Product Specs. If one needs to speak separately of SE and LE, one can

say that the design information misalignment is in the first place to be addressed as a DE/SE transfer challenge.

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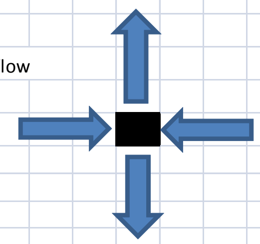
Appendix A – High Level Team Activities from the ABL to the MBL

		User	Industry	Config & Approval	QA	Procurement (CSIR)	Other CSIR / Team	I	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	
Initial Inputs (all docs for ABL according to Mil STD 3)	I																																																	
Concept Design																																																		
Dev Item Identified	1	1.0						2.0			1.0	1.0								1.0	1.0																												1.2
Dev Item ConOps	2	3.0						2.0	1.3																				2.3																				2.1
Dev Item Context (External Interfaces)	3	1.0								1.0						2.2		1.8											2.3																				1.6
Preparatory Design Concept	4	1.0	1.0						1.0	1.8	2.0																																						1.4
Dev Item Functions	5							2.0	1.0	1.0	2.0	1.0																																					1.4
Dev Spec	6	1.0		1.0				2.0			2.0	1.6	1.5																			2.0											1.3							1.6
Design Concept	7	1.0	1.0								2.0	1.7		1.9								1.0																					1.3							1.4
Design Architecture (Components)	8		1.0									1.0			1.0				2.0																								1.7							1.3
Design Characteristics (Performance)	9											1.2	2.0		1.2	1.0																											1.7							1.4
Interface Design (MMI)	10	1.0									1.8	1.2		1.9	1.2	1.0	1.0												2.1														1.7							1.4
Dev Item Availability Case	11		1.0					1.0	1.0	1.0	2.0	2.0	2.0	1.0	2.0	1.8	2.0								2.5																		1.7							1.6
Support Element Concept for Project Phase	12	1.0						1.0	1.0	1.0	2.0				2.2	2.2	2.0	2.4																																1.6
Dev Item Support Concept	13	1.0						1.0	1.0	1.0	2.0			1.5	2.2	2.2		1.8																																1.5
Procedures	14	2.0		1.0						1.0			1.5	2.0	1.5	1.2	1.6	1.5					1.0		1.8	3.0	3.0												1.5				1.5							1.7
Dev Item Safety Case (PDR)	15	1.0		1.0											1.5	1.5	1.8	2.0				1.5			1.7																		1.0							1.4
PDR	16	3.0										1.5			1.3	1.3	1.3	1.3	1.3				1.5																											1.5
Detail Design																																																		
Detail Design	17	1.0	1.0											1.0	1.0	1.0	1.0	1.7	2.0	2.0	2.0	2.0	2.0	1.9						1.9																				1.5
Data Pack (Drawings + Diagrams)	18			2.5																					1.4					2.0																				2.0
Detail for Bought out items	19		1.0																						1.4					1.9																				1.4
Client EC Information	20	3.0																							1.7	1.4	1.4			2.3																				2.0
Detail for interfacing with other Dev Items	21						2.3																		1.3	1.3	1.3			2.3																				1.7
Aquire the Components / Subsystems	22		1.0			3.0																				1.2	1.3																							1.6
Acceptance Test Procedures (how)	23			2.0												2.0									1.8	1.9	1.6	1.5	1.5																					1.8
Test Procedure (what)	24			2.0										1.7											1.7				1.5		2.0																			1.8
Component / Subsystem Received	25					2.0	2.0																			1.9	1.0																							1.7
Component Manufactured inhouse	26						1.0																			1.4																								1.2
Components assembled (Prototype)	27						1.0																			1.4							1.0	1.0																1.1
Subsystem Verification	28				1.5		1.5																		2.0	1.5	1.7		1.3		1.3	1.5			1.0															1.5
Setting to Work	29	2.0																							2.0	1.5	1.7	1.5										3.0												
Support Requirements List	30			1.0				1.0	1.0	1.0				1.0							1.0				2.1	3.0	2.1																							1.5
Training for Trials	31	1.0																			1.5	1.5			1.4	1.0	1.0		1.0		1.0	1.3			1.0	1.0	2.0													1.2
1st Draft Technical Manuals	32			1.0				1.0		1.5	2.0			1.0				2.0				2.3			2.2	2.3	2.3										1.5													1.7
Material Characteristics (for MBL)	33																								3.0	3.0	3.0																							
Product Spec + FAT	34			1.0										1.5											1.9	1.6	1.6		1.7		1.5	2.0						3.0												1.7
System Verification Trials	35	1.0			1.0																							1.8	1.3			1.0			1.0	2.0			1.0											1.3
FCA	36			1.0	1.0									1.0																	1.0	1.0				1.0							1.0							1.0
Statement of Compliance	37			1.0										1.0											1.2		1.6		1.2							1.0							1.0							1.1
Support Acquisition Specification	38			1.0				1.0														1.0			2.5		1.5											1.0												1.3
Support Plan for Production Phase	39			1.0						1.0	2.0	2.0									1.0				1.9		2.0																							1.6
Codification Starts	40																									1.9	2.0	2.0																						2.0
CDR	41	2.0																	1.0				1.0		1.6	1.6	1.5	2.0	1.3							1.0						1.0		1.0	1.0					1.3
Output: PCA, PRR and then start of Production Phase																																																		
		1.5	1.0	1.3	1.2	2.5	1.6	1.4	1.0	1.1	1.9	1.4	1.8	1.4	1.5	1.6	1.5	1.8	1.6	1.5	1.3	1.6	1.4	1.9	1.8	1.8	1.8	1.8	1.6	2.1	1.4	1.5	1.0	1.0	1.0	1.2		2.3	1.3			1.0	1.4	1.0	1.0					

Systems Engineering Activity	
Design Engineering Activity	
Logistic Engineering Activity	
Operation Experts Team Activity	
Info flow, minor errors/waiting	1
Understanding of flow / not always realising	2
Poor info / missing process / info waiting / inf	3

Development Phase for System in Project X
Boundary Conditions: Allocated Baseline to Product Baseline
Constraints: Schedule of Project Contract; Constraints by Support Environment of CSIR
Owner: Project Team

Direction of dataflow



Appendix B Configuration and Approval Process

B.1 Process Diagrams

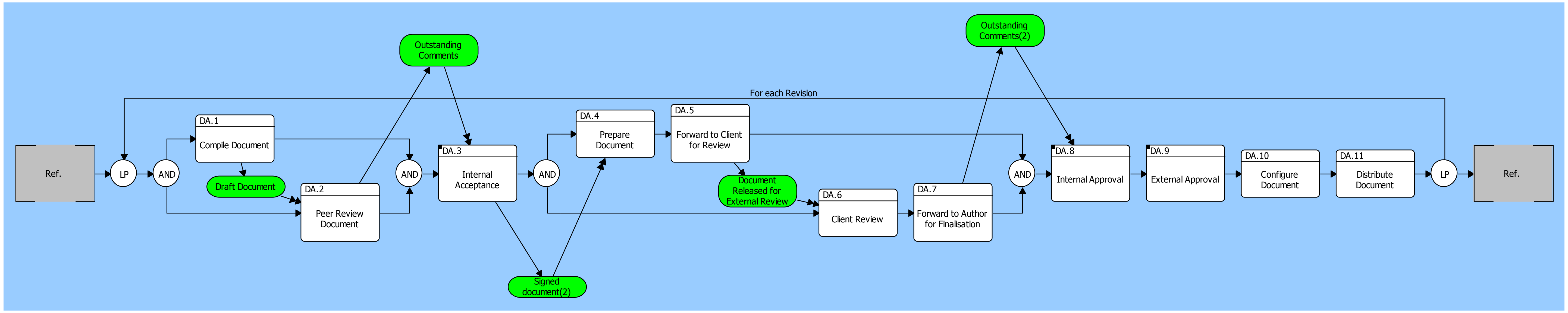


Figure 6: Documentation Approval Process

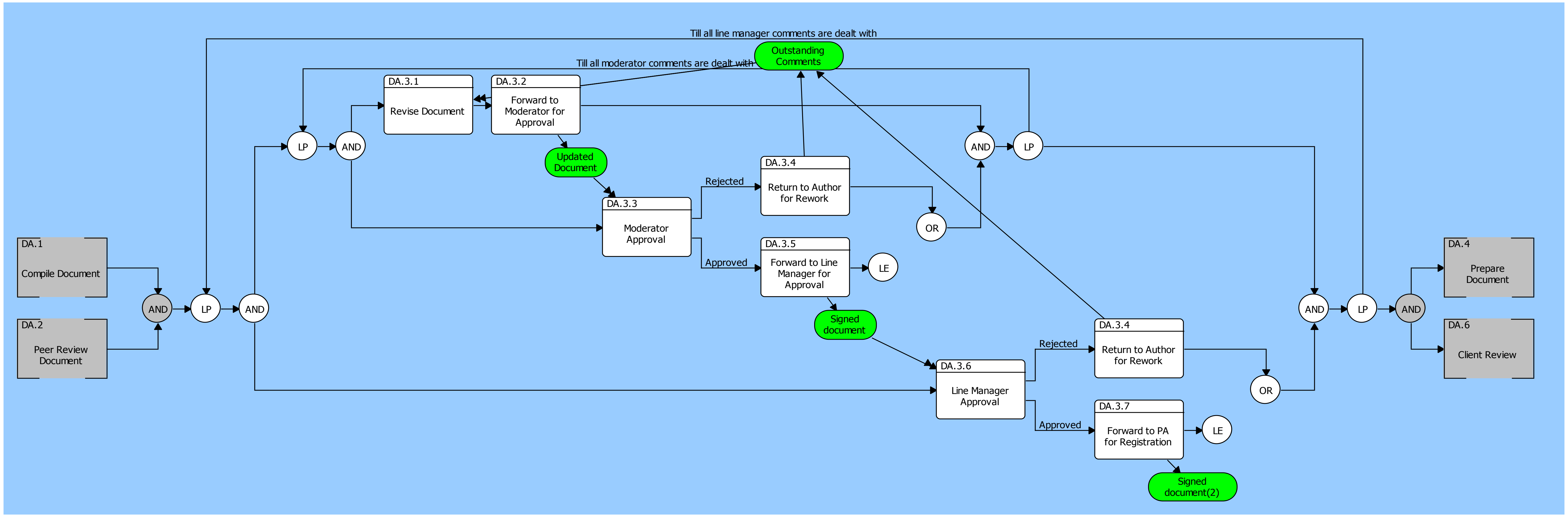


Figure 7: Internal Acceptance Sub-Process

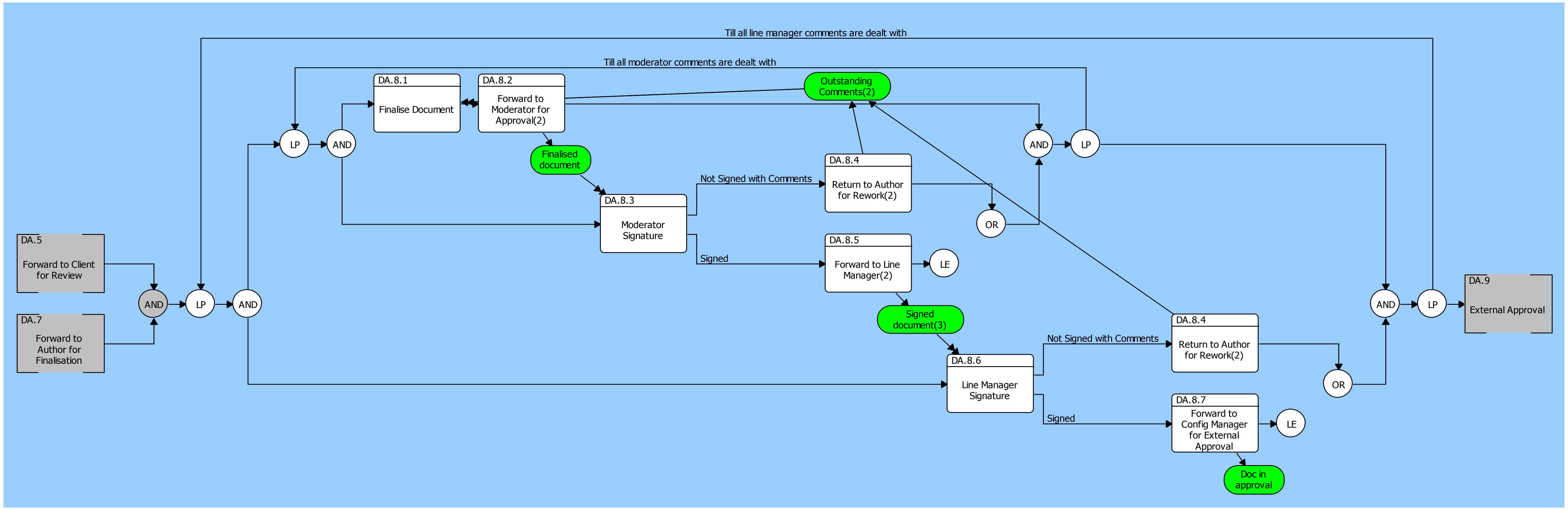


Figure 8: Internal Approval Sub-Process

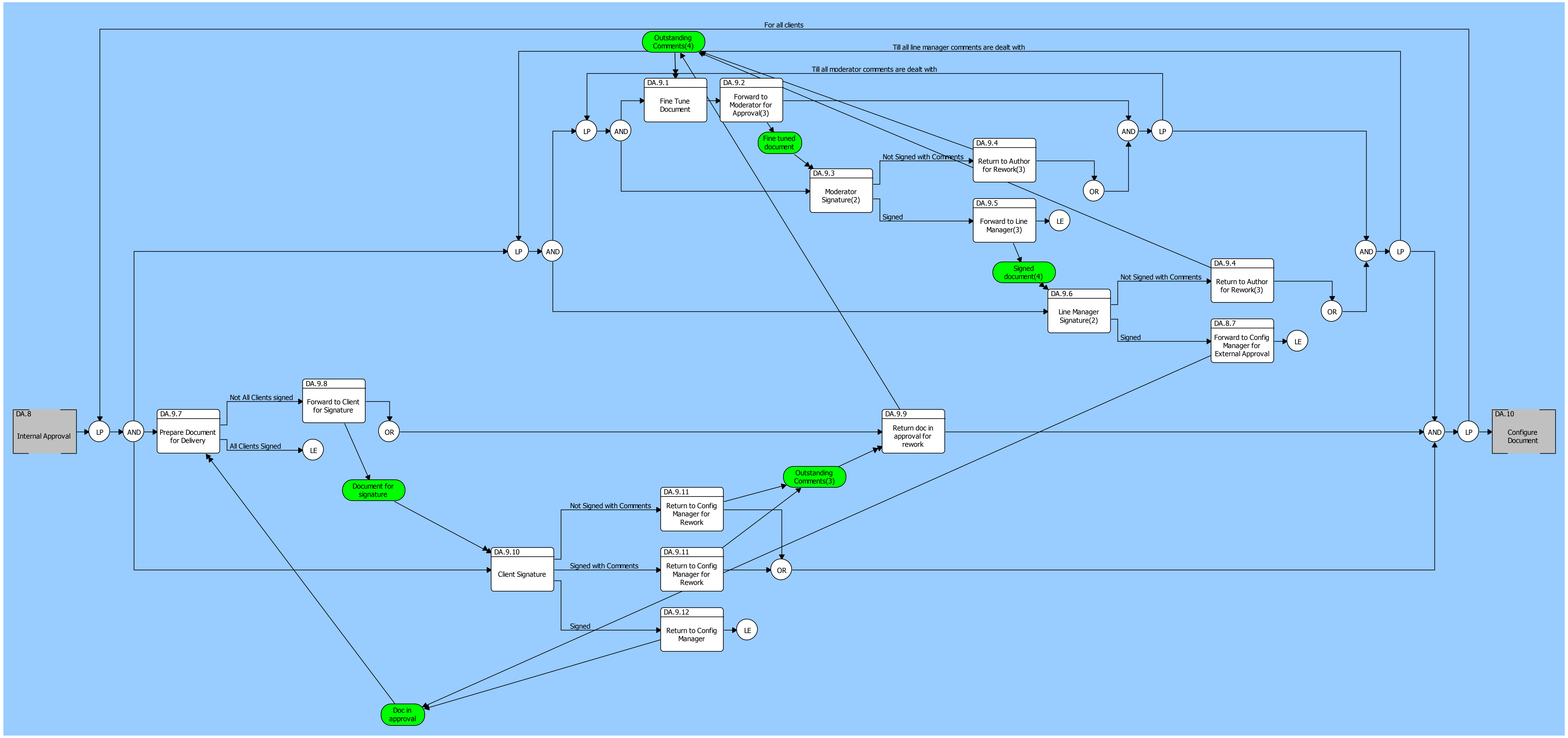


Figure 9: External Approval Sub-Process

B.2 Summary of Task Times

	Duration(h)
DA Documentation Approval	
DA.1 Compile Document	40
DA.2 Peer Review Document	16
DA.3 Internal Acceptance	
DA.3.1 Revise Document	16
DA.3.2 Forward to Moderator for Approval	1
DA.3.3 Moderator Approval	8
DA.3.4 Return to Author for Rework	1
DA.3.5 Forward to Line Manager for Approval	1
DA.3.6 Line Manager Approval	8
DA.3.7 Forward to PA for Registration	1
DA.4 Prepare Document	8
DA.5 Forward to Client for Review	24
DA.6 Client Review	40
DA.7 Forward to Author for Finalisation	24
DA.8 Internal Approval	
DA.8.1 Finalise Document	16
DA.8.2 Forward to Moderator for Approval(2)	1
DA.8.3 Moderator Signature	8
DA.8.4 Return to Author for Rework(2)	1
DA.8.5 Forward to Line Manager(2)	1
DA.8.6 Line Manager Signature	8
DA.8.7 Forward to Config Manager for External Approval	1
DA.9 External Approval	
DA.8.7 Forward to Config Manager for External Approval	1
DA.9.1 Fine Tune Document	16
DA.9.2 Forward to Moderator for Approval(3)	
DA.9.3 Moderator Signature(2)	8
DA.9.4 Return to Author for Rework(3)	1
DA.9.5 Forward to Line Manager(3)	1
DA.9.6 Line Manager Signature(2)	8
DA.9.7 Prepare Document for Delivery	8
DA.9.8 Forward to Client for Signature	24
DA.9.9 Return doc in approval for rework	24
DA.9.10 Client Signature	8
DA.9.11 Return to Config Manager for Rework	24
DA.9.12 Return to Config Manager	24
DA.10 Configure Document	8
DA.11 Distribute Document	24

Appendix C Information flow for completion of design Phase Documentation