

Developing a Traceability Solution for the  
support of ISO 9001 at  
Denel Land Systems

by

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## ABSTRACT

At Denel Land Systems, many problems have come forward relating to a lack of proper traceability and serialisation practices. The principle of traceability is very important, since the ISO 9001 institute for quality standards requires that the traceability of a functionally important product is maintained throughout the completion thereof (Hoyle, 2009). To improve the traceability situation, the problems which have been experienced by the company were documented, analysed and a solution was formulated. The following components forming part of the solution were created or designed whilst performing the continuous verification thereof:

- BPMN Map of “As-Is” business processes
- Traceability Policy
- Serialisation Numbering System
- Serialisation Information System
- Build History Storage Structure
- Traceability Processes
- Supporting Traceability Procedures
- BPMN Map of “To-Be” business processes
- Implementation Roadmap
- Technological “Way forward” Proposal

These components form a system of solutions ensuring that proper and effective traceability will be upheld.

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## LIST OF ABBREVIATIONS AND ACRONYMS

BE	-	Business Excellence
BH	-	Build History
BPM	-	Business Process Management
BPMN	-	Business Process Management Notation
BPR	-	Business Process Re-engineering
COC	-	Classification of Characteristics
CRL	-	Control Requirements List
DFD	-	Data Flow Diagram
DLS	-	Denel Land Systems
HR	-	Human Resources
ICOM	-	Input, Controls, Outputs and Mechanisms
IDEF	-	Integrated Definition
IT	-	Information Technology
ISO	-	International Organisation for Standardisation
PPP	-	Policy, Processes and Procedures
PPPM	-	Preparation, Preservation, Packaging and Marking
SOW	-	Statement of Work

## **1. INTRODUCTION**

### **1.1. BACKGROUND**

Denel Land Systems (henceforth referred to as DLS) forms part of the larger Denel group. DLS is responsible for the manufacturing and design of artillery products, infantry and armour systems, rapid-fire weapons, naval turrets and integrated artillery systems.

Most product lines created by DLS follow the same basic path. Virtually all components, products and weapon systems delivered by DLS are designed and assembled in-house. In other words, almost no part of the design and assembly phase of a product is outsourced. A different situation is however in play when it comes to the manufacturing phase of product components. Here, a component can either be procured from an external supplier, or it can be manufactured by DLS. The final product is then assembled at DLS out of the various individual components.

It is in this manufacturing and assembly of components and products that many problems have come forward throughout the life of the company. Management has linked these problems to a lack of effective traceability practices and business processes, as well as isolated existing processes. The principle of traceability is very important, since the ISO 9001 institute for quality standards - which is followed by DLS - requires that the traceability of a functionally important product is maintained throughout the completion thereof (Hoyle, 2009).

From this, it was determined that in order to improve the traceability situation at DLS, the problems which have been experienced by the company had to be documented, analysed and a solution had to be formulated.

### **1.2. PROJECT AIM**

The goal of this project was to first document the problems that had been experienced by the company. The core problem areas surrounding the manufacturing processes and the causes of the problems had to then be identified. Since management was certain that the problems were related to traceability - or a lack thereof - a traceability solution had to then be formulated, which would support all the traceability-related specifications as stipulated in the ISO 9001 guidelines. The solution would contain certain components which would work together to form a system of efficient business processes which could enable products to maintain traceability from the design phase to the delivering phase. It was also decided that it would be important for the solution to add value to the company and to provide a form of regulation (McSweeney, 2009).

### **1.3. PROBLEM DEFINITION**

Document and investigate the traceability related problems occurring at DLS. From this, design a Traceability Solution which will actively solve these traceability problems.

### **1.4. SCOPE**

Through analysis of the company environment, it was decided that the aforementioned Traceability Solution would only cover the internal traceability of a component or product. This means that the approach was to only track a component from the design phase of a component to the delivering phase thereof. It would not serve to maintain traceability of a component after the component or product had been sold or if a product was to be returned from a client, as a separate system for this purpose was already in its development stage. It is also important to state that, once it had been completed, the Internal Traceability Solution would only be validated by critical stakeholders of the company. This was due to internal policies existing within DLS with regards to newly developed systems.

The project was to commence by first conducting a literature study. This literature study would research the precise traceability guidelines specified by ISO 9001, as well established methods on how to maintain these specifications. Furthermore, the literature study would investigate the available construction methods and best practices related to Business Processes. Finally, the literature review was to inspect proven methods on creating and specifying processes.

After the literature study had been conducted, the current project environment had to be investigated in order to document existing traceability problems and to locate the precise causes and areas of these problems. Thus, the investigation would serve to establish the overall state of the current situation, the methods which were in place and the problems that existed.

Using the above information, the Traceability Solution was to be constructed by focussing on each of the components forming part of the solution.



## **2. LITERATURE REVIEW**

To find the most appropriate tools and techniques for addressing the Internal Traceability Solution, a literature review was conducted. The literature review consisted of three main sections which will now be presented.

### **2.1. ISO 9001 REQUIREMENTS**

#### **2.1.1. Defining Specifications**

Section 7.5.3 of ISO 9001 governs the identification and traceability of products. The section states:

*“Where appropriate, the organisation shall identify the product by suitable means throughout product realisation. The organization shall identify the product status with respect to monitoring and measurement requirements. Where traceability is a requirement, the organisation shall control and record the unique identification of the product.”*

The above specification can be divided into three parts. The first part deals with the identification of a product where appropriate. ISO 9001 Consulting, Training and Auditing Solutions (2010) defines product identification as knowing the precise identity of a product in every possible sense and development stage. This first part also implies that the traceability requirements only apply to certain products or components. Deciding which products should adhere to the requirements must be kept in mind during the application thereof.

The second ISO specification is about identifying the status of a product or component. This means that the quality of a product or component (in the sense of good or bad) must be known throughout all stages of product completion or production.

The final ISO requirement states that the unique identification of a product or component must be controlled and recorded. This means that detailed documentation regarding every aspect of the manufacturing of the product must be kept. This includes information such as test results or material characteristics.

#### **2.1.2. Achieving Specifications**

Hoyle (2009) prescribes that product identification should start at the design thereof. At this stage, the design should receive a unique form of identification (such as a product number) and this identification number must be used on all information relating to the product. Hoyle (2009) also suggests that when the product emerges into production, this unique identification form must be kept, but that an additional serial number must be added to it. The traceability of a process should be of such a nature that a product can be traced throughout the particular process from its origin to its delivery. Furthermore, the manufacturing history of the product must be obtainable.

When ensuring the traceability for a process, ISO 9001 Checklist (2011) recommends that it must first be decided how the status of a product would be determined and identified and which built history records should be kept so as to maintain sufficient traceability. To optimise a manufacturing system, Cheng & Simmons (1994) states that three forms of traceability must be maintained throughout the production of a product. These three forms can be divided into two traceability views. The first view is based on the current situation, where the status of the current products being manufactured is reflected. The second view is a more goal orientated view, where the performance and achievements of the manufactured products are compared to the objectives.

### **2.2. BUSINESS PROCESS SYSTEM**

#### **2.2.1. BPM and BPR**

There currently exists some form of business processes at DLS. Nevertheless, these processes are not necessarily defined as business processes and they also exist in isolation. Two of the most popular methods available for solving this problem are Business Process Management (BPM) and Business Process Reengineering (BPR). These terms are often used interchangeably, but there are slight differences between the two. BPR is a method which brings forth radical changes within a company, while BPM stems from BPR and is more based on continuous improvement. Promoting Thought Leadership (2012) summarises the critical differences between the two methods as shown in Table 1.

**Differences between BPR and BPM**

Aspect	BPR	BPM
<i>Level of change</i>	Radical change	Evolutionary & continuous change
<i>Implementation Time</i>	Long	Short and smooth
<i>Starting point</i>	Drawing board	Current processes and automation levels
<i>Implementation</i>	Effort required for disruptive change	Incremental
<i>Expense</i>	One major process at a time	Flexible - simultaneously across one or more / small or major processes
<i>Methodology</i>	Redesigning of business processes	Process and decision models
<i>Enabling technology</i>	Primarily IT	Primarily process technology
<i>Involvement</i>	Business and process experts	Process experts and all related people
<i>Risk</i>	High	Low
<i>Outcome</i>	Drastic improvement	Incremental improvement
<i>Cultural issues</i>	Major concern	Minor concern
<i>Implementation stress and concern</i>	High	Low

**Table 1: Differences between BPR and BPM**  
**Source: Promoting Thought Leadership, 2012**

When considering the differences between BPR and BPM, it is very difficult to determine which of the two methods should be applied at the DLS situation. While the business processes present in the company should be reviewed, changed and joined with one another, the business processes will also have to be continuously managed and used to support the Internal Traceability System. The characteristics of each method shown in Table 1 which are most applicable to the Traceability System can be summarised as follows:

**Applicable Methods**

Aspect	Method	Description
<i>Level of change</i>	BPR	Radical, one step change
<i>Starting point</i>	BPR and BPM	Drawing Board and Current Processes
<i>Expense</i>	BPM	Flexible - simultaneously across one or more / small or major processes
<i>Methodology</i>	BPR	Redesigning of business processes
<i>Enabling technology</i>	BPM	Primarily process technology
<i>Involvement</i>	BPM	Process experts and all related people
<i>Outcome</i>	BPR	Drastic Improvement / Change

**Table 2: Applicable method per aspect**  
**Source: Promoting Thought Leadership, 2012**

From the above summary, it is seen that there is no clear indication as to which method should be applied. However, research shows that the BPM approach is a better and newer option than BPR (Hammer, 1996 cited in Zandi & Tavana, 2011). As a consequence, the characteristics of BPM will be applied when designing the Business Process solution forming part of the Traceability system, but some of the applicable approaches present in BPR will also be applied. This approach has been used by other companies, such as the case where

the United Defence's Armament Systems Division used the BPM approach while still implementing principles of other best practices (such as BPR). This was done as they did not want the "canned solutions approach" for their Business Process System (Howe, 2004).

Relevant recommendations regarding the construction of a BPM solution System were investigated and the findings will now be presented.

## 2.2.2. BPM System Recommendations and Best Practices

The concepts and beliefs surrounding BPM are as diverse as the applications thereof and as a result, it is very difficult to find exact best practices pertaining to the design and implementation of a Business Process System. Despite this, certain recommendations and details became very clear and can be summarised.

BPM projects usually cover a large area within a business and it is often difficult to know where to start. Leymann & Altenhuber (1994, cited in Aytulun & Guneri, 2008) states that a BPM project can usually be divided into two phases: the "construction" phase and the "running" phase. They define the construction phase as the phase which focuses on creating the process through a top-down approach and the running phase as the phase focused on the implementation of the Business Process System.

The construction phase (explained above) should commence by first analysing and modelling the business processes which are currently in place. This must be done by documenting current process flows in detail (Aytulun & Guneri, 2008 and Silver, 2006). Problems and areas of possible improvement must be identified and each section or process must be scrutinised so as to ensure its necessity, efficiency and its value-adding role. In addition, Chambers (2007) advises that interviews with employees should be focused on document-centred processes, as understanding how content is generated, shared, routed, approved and transformed is the key to analysing a business process.

After the current process has been clearly documented and thoroughly analysed, the new process must be designed. Reijers (2002, cited in Aytulun & Guneri, 2008) suggests that the designing phase of a BPM should be approached strategically, while considering the optimal shape of the business processes. According to Harney (2006), a business process must provide end-to-end visibility and control over all decision points and execution paths of a request. When designing a business process, Kim & Ramkaran (2004) urges one to exploit technology and design interfaces and to remember that each process could have its own web of sub-processes. Kim & Ramkaran (2004) have created BPM best practices from Hammer and Champy's best practices for process re-design (Hammer & Champy, 1993) and is summarised as follows:

1. Combine recurrent tasks, which must be executable through digital interfaces or automated
2. Enable stakeholder participation and let those who receive value from tasks perform them
3. Include the processing of information into the actual work which produces it
4. To avoid problems caused by dispersed resources, use technological interfaces to centralise information
5. Link parallel tasks, instead of only integrating the results of the tasks (similar to concurrent engineering)
6. Use business rules and interfaces to control and check tasks
7. Capture data only once and at its source
8. Design processes with contingencies

Certain common features of successful BPR projects have been documented by Mayer & De Witte (in press). The most prominent and applicable guidelines include:

1. Focus on business processes rather than business functions
2. Challenge assumptions
3. Think Global, Act Local
4. Make use of technology that can support the business processes

In addition to these BPR guidelines, Mayer & De Witte also created business process design principles which must be considered when designing processes. Firstly, Mayer & De Witte advises that multiple process alternatives must be designed. The second principle stresses the importance of knowing the nature of input and output objects. The structure, role, frequency and whether it is fixed or modifiable, controllable or uncontrollable and independent or dependent is important factors to take into account during the design phase. According to the third principle, processes must be decomposed into sub-processes until a level is reached where each sub-process can be allocated to a specific and available resource. The fourth principle states that the input and output type of each sub-process must match the output and input type of the preceding or succeeding sub-process. If a mismatch occurs, an additional sub-process must be created to correct the input or output type. Furthermore, it is advised that the design of a process must make provisions for possible failures. The next principle states that a process must make provisions for the management of undesired by-products which are produced by the process. Finally, it is important to add resource management sub-processes to the system, as multiple triggers of a process could be attempted simultaneously.

After the new business processes have been designed, the “construction” phase is completed and the “running” phase can commence. During the running phase, the business processes which have been constructed - based on the above recommendations and best practices - are transformed into a computerised form where they are supported by IT systems. This exceeds the scope of the project at hand, but as business process improvement is a priority at DLS, the information system integration phase is vital after project-handover has taken place.

### 2.2.3. Business Process Mapping

When mapping Business Processes, there are many available methods to choose from. However, two of these methods have become especially famous over time. The first and oldest of the two is known as Integrated Definition modelling, or IDEF modelling, while the second method is famous as Business Process Management Notation, or BPMN. Each of these methods has its own appropriate uses, strengths and weaknesses.

#### IDEF

The original IDEF modelling technique (IDEF0) is used to model the functional aspect of systems. It was created by the United States Air Force and since then, five additional modelling techniques have been created. Each of the other techniques is used for its own unique purpose, but the IDEF0 technique is best for the modelling of business processes. (Knowledge Based Systems, 2010)

IDEF0 models can be created on interlinked high and low levels and consists of the following main components:

- A central process box for each function, which can be broken down into higher or lower levels
- Inputs, transformed into outputs and formed by the outputs of preceding processes
- Controls, directing the activities of a process box
- Outputs, forming inputs of the succeeding processes or system goals
- Mechanisms, acting as resources used for the completion of the activities contained in the process box

All of the above components are connected to form one model containing all relevant high and low level processes. The following diagram created by Syque (2011) explains the above components clearly. IDEF0 models follow a unique nomenclature structure for identifying the various levels of a model and IDEF0 models are not used to indicate a sequence of activities.

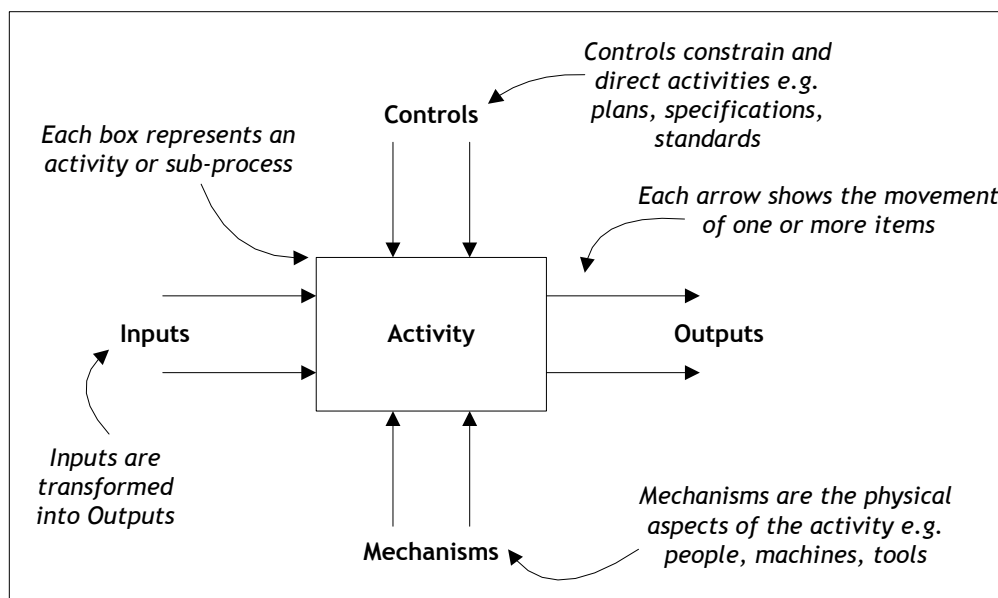


Figure 1: IDEF0 Components  
Source: Syque Quality, 2011

The IDEF0 modelling technique is best used for top down designing and most design practitioners agree that it is the optimum tool for designing “To-Be” processes. This is due to the fact that IDEF0 modelling allows the process designer to think freely about how activities and processes should be performed. Furthermore, the IDEF0 technique forces the designer to focus on each process and related action separately, before combining the system of processes. This allows the designer to think more creatively, as it is not necessary to create a model in too much detail at an early stage. (Sowell - Custom Enterprise Solutions, 2009)

## BPMN

BPMN is a more recent method for process modelling than IDEF0 (Sowell - Custom Enterprise Solutions, 2009). In most cases, BPMN is used in a business environment, where the IDEF family of methods is often also used in software modelling or design. There is a significant difference between the appearance of a process model designed through BPMN and a process model designed through IDEF0. A BPMN model consists of the following main components (Bizagi, 2012):

- Process Pools, containing a single process
- Swim lanes, containing all activities performed by a specific entity, actor, etc
- Activities, which can include activities with sub-processes or tasks
- Gateways, that creates a divergence or convergence in process flows
- Artefacts, signifying objects such as data stores, data objects, etc
- Connecting objects, such as sequential flows or message flows
- Events, which can include start, end and intermediate events of different types

All of these elements can be connected so as to model a process with its interlinked sub-processes. A unique aspect of BPMN is that it can clearly capture the sequence of events. A simple example of a model created through the BPMN technique is shown in Figure 2.

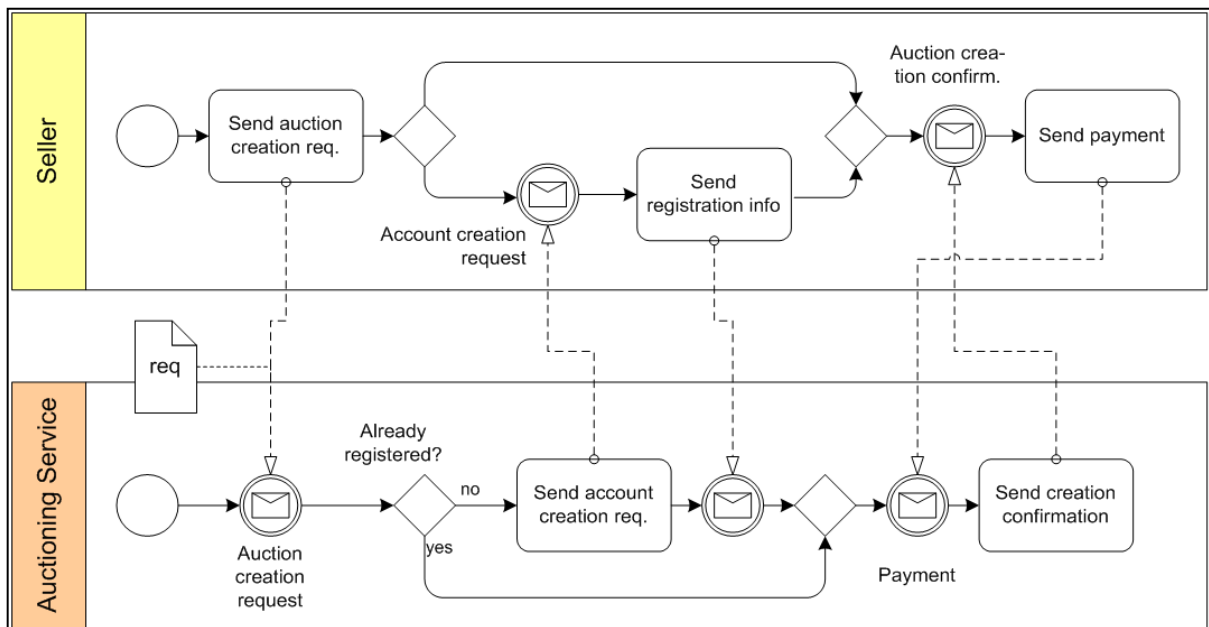


Figure 2: Simple BPMN Model  
Source: BPMN.info, 2008

An advantage of the BPMN method is that it can capture a high level of detail while maintaining its visibility. Due to this high level of detail which needs to be known for the construction of a BPMN model, the technique is best used for mapping “As-Is” situations. In such cases, information regarding sequence, acting parties, etc is more readily available. It is however the opinion of professionals that focussing on this high level of detail might discourage the designer to approach problems in a creative manner. Hence, it is advised that BPMN modelling should not be used in the early design phases of “To-Be” processes, but should only be used to map the final “To-Be” structure. (Sowell - Custom Enterprise Solutions, 2009) Another reason for this is that, as explained by the Object Management Group (2011, pp. 1), BPMN bridges the gap between the design phase of business processes and the implementation thereof.

### **2.3. CONNECTING THE DOTS**

From the preceding sections of the Literature Review, two main areas were identified, namely:

- Traceability specifications within ISO9001
- Business Process Principles

If a feasible traceability solution were to be created, these two components had to work together. In other words, the following segments had to be joined for the solution to be successful:

- ISO9001 Specifications
- Existing Business Processes
- Modified Business Processes
- Newly Created Business Processes

To join the above four segments, and to ensure the successful implementation of the proposed traceability solution, a set of documents known in practice as Triple-P documents, had to be compiled. Triple-P documents consist of a Policy, Processes and Procedures and are used to deconstruct principles into high, medium and low levels. It is vital for these three components to be in place before successful BPM can happen.

#### **2.3.1. Policy**

Bizmanualz (2005) explains a policy as being a guiding principle which is used to set direction in a company. A Policy governs the behaviour of an organisation or a segment of an organisation and can be compared to “Laws” or “Rules”. As it is believed that a policy is the driving force behind processes and procedures, it should be created first and it should act as a guide during decision making. A Policy should be written in a clear and concise manner and it should be understandable for all employees.

#### **2.3.2. Processes**

If one were to say that a Policy exists as the top-level of a situation, then it would be correct to assume that the Processes are the second level which activates the first Policy level. It is commonly agreed that a process is a set of interrelated activities which delivers a specific outcome (Agrasala, 2009). In most business situations, these processes are in the form of Business Processes, which are created using various Process Mapping techniques, such as IDEF0 or BPMN. Processes focus on what should be done so as to “obey” the applicable Policies.

#### **2.3.3. Procedures**

Procedures form the lowest level of the three components and they contain the highest level of detail. Procedures ensure that the “interrelated activities” mentioned in the Processes section are performed in a consistent and effective manner. Procedures consist of specific steps, details and methods and each process is meant for a specific audience. While Processes focus on what needs to be done, Procedures focus on how it should be done.

#### **2.3.4. PPP structure**

When creating the set of PPP documents, it is imperative that a link between all documents is maintained at all times. All the documents must be integrated and created in a holistic manner and each document - whether it is a policy, a process or a procedure - should give the user insight into a different level of the situation. The KCG group (2010) uses the analogy of a road trip to explain the structure and relationship that should exist between Policies, Processes and Procedures. In this analogy, the Policies are the laws and rules of the road, the Processes are the high-level and low-level roadmaps and the Procedures are the specific “Manoeuvres” such as “Turn left, stop at traffic light, etc”. This example is shown in Figures 3, 4 and 5.

**Laws and Rules of the Road**

**Speed Limits**

California has a "Basic Speed Law." This law means you may never drive faster than is safe for current conditions. For example, if you are driving 45 mph in a 55 mph speed zone during a dense fog, you could be cited for driving "too fast for conditions." You may never legally drive faster than the posted speed limit, even if you think it is safe to do so.

Regardless of the posted speed limit, your speed should depend on:

- The number and speed of other vehicles on the road.
- Whether the road surface is smooth, rough, graveled, wet, dry, wide, or narrow.
- Bicyclists or pedestrians walking on the road's edge.
- Whether it is raining, foggy, snowing, windy, or dusty.

**Maximum Speed Limit**

**Policies**

Policies are the guidelines or laws that drive the Processes and Procedures.







Figure 3: Road trip example of a Policy  
Source: KPG Group, 2010

**Processes**

Processes are a high level view. The tasks within the overall process are identified




Figure 4: Road trip example of Processes  
Source: KPG Group, 2010

	Maneuvers	Distance	Maps
	1: Start out going EAST on W SUNSET BLVD toward ARGYLE AVE.	0.6 miles	<a href="#">Map</a>
	2: Merge onto US-101 S.	5.2 miles	<a href="#">Map</a>
	3: Take the LOS ANGELES ST exit.	0.1 miles	<a href="#">Map</a>
	4: Turn RIGHT onto N LOS ANGELES ST.	0.2 miles	<a href="#">Map</a>
	5: Turn RIGHT onto TOM BRADLEY BLVD.	<0.1 miles	<a href="#">Map</a>
	6: End at Los Angeles, CA US		<a href="#">Map</a>
<b>Total Est. Time: 9 minutes</b>		<b>Total Est. Distance: 6.35 miles</b>	

**Procedures**

Procedures are the detailed steps required to perform an activity within a process.




Figure 5: Road trip example of Procedures  
Source: KPG Group, 2010

### **3. PROBLEM AND OPPORTUNITY DOCUMENTATION**

#### **3.1. PIECES FRAMEWORK**

In order to analyse the problems which were arising within the manufacturing division of DLS, they had to be identified and documented thoroughly. This was done using the PIECES framework, as recommended by Bentley and Whitten (2007).

##### **3.1.1. Performance**

- Many mistakes were being made with regards to maintaining traceability and serialisation of products. It had occasionally been experienced that crucial parts exiting the production system had the same serial numbers. In other cases, numbers were allocated to a component, but the meaning of the numbers was then forgotten or they had remained useful only to the person who had allocated them. There was no consistency in the allocation of production, testing or serial numbers and these created opportunities for error, confusion, and a lack in traceability of the component.
- The overall throughput and response time for the initial build history system was very poor. It was very difficult to extract exact knowledge from the build history system and the system lacked structure.
- Employees found it difficult to maintain an efficient performance pace as they struggled to instantaneously know which overall process phase followed the one they might have been in or which documents they had to compile so as to complete the phase they had been in. If they wished to obtain information regarding these matters, enquiries to the relevant people had to first be made and it was often difficult to track these people down or to know who they were.

##### **3.1.2. Information**

- There was a lack of relevant information, business processes or business rules with regards to the traceability and build history processes which needed to be followed. Information regarding these processes was scattered in various separate documents and they were not linked to one another.
- A huge amount of build history information was being collected, but it had not been in a useful format or stored in a structured manner and this made it difficult to extract.

##### **3.1.3. Economics**

- If the traceability of products and components were easier to accomplish, mistakes could be avoided and certain delays could be shortened or completely removed from the system. If components could be produced, tested, assembled and sold with a shorter throughput time, more products could be assembled and delivered. As the issue of late deliveries is a very large problem at DLS, this could be very advantageous to the bottom line of the company.

##### **3.1.4. Control**

- There was no control surrounding the allocation and maintenance of production, testing and serial numbers. Employees on the manufacturing and storage floor were allowed to allocate these numbers in any way they pleased, which caused chaos and inconsistency. Control in this matter had to be improved immensely and specific business rules had to be created.
- The strict security control in the existing information systems at DLS is necessary due to the nature and clients of the company. These control levels present should therefore be kept as it is.

##### **3.1.5. Efficiency**

- Due to mistakes which were being made with regards to traceability and serialisation, efficiency levels were low.
- Because there were no specific business processes, methods, or business rules governing traceability and the allocation of serial numbers, efficiency was low.
- As the business processes of the company were scattered, separated and only in document format, employees were unaware of what process steps had to be followed in which situation. This caused many mistakes to be made which had an adverse effect on company efficiency.



### 3.1.6. Service

- Service levels of DLS were low due to late deliveries. This could be improved if mistakes and inefficiencies were to be avoided or minimised.

### 3.2. ISHIKAWA ANALYSIS

In an attempt to further locate the sources of the problems which were discovered in the previous section, an Ishikawa diagram was created as shown in Figure 6.

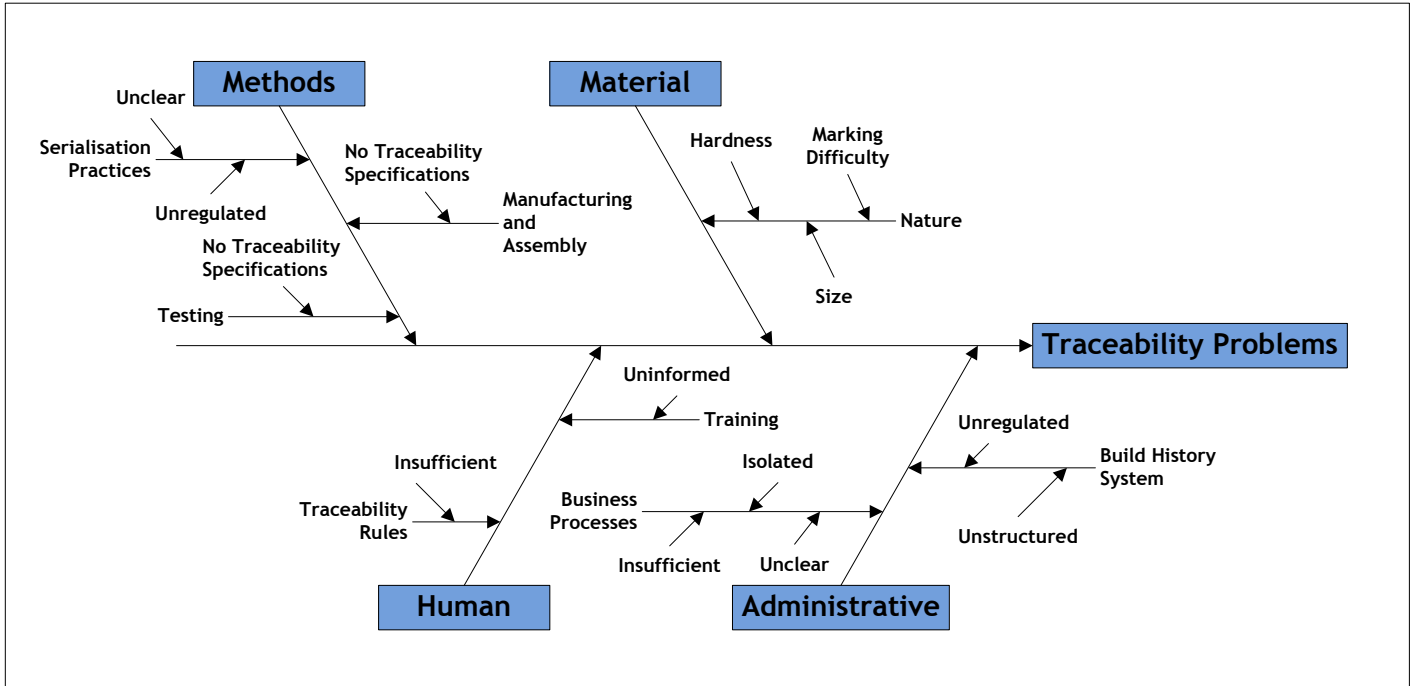


Figure 6: Ishikawa Analysis of existing problems  
Derived from: Niebel's Methods, Standards and Work Design, 2009

### 3.3. VISIONS OF EMPLOYEES

When relevant employees were consulted with regards to their visions for a traceability solution, certain desires became extremely clear. Firstly, they desired a system that is unambiguous, simple and easy to follow and understand. They would like a clear system which will define the processes which a component has to go through. The Business Excellence manager feels it is very important that the traceability requirements of ISO 9001 is maintained and supported by the system. The employees would also like a clear form of serialisation to take place that will support traceability. They desire a structured, easy to follow and integrated process for traceability and build history operations. In the words of the Business Excellence manager (referring to all the isolated and scattered traceability business processes): "Improve, integrate and entrench these processes and practises in DLS."

### 3.4. OPPORTUNITIES FOR IMPROVEMENT

After the PIECES and Ishikawa analysis were performed, the following main causes of problems were identified:

- Existing Traceability Business Processes were isolated and only in document form
- Inefficient Traceability Business Processes were available
- No Serialisation Procedures or Rules existed
- No clear business processes surrounding production or testing have been set
- An unstructured build history storage system was being used

Combining these points with the techniques discovered through the Literature Review, component requirements for the Traceability Solution were derived.

### 3.4.1. Traceability Policy

To ensure compliance to traceability, a specific policy addressing the matter of traceability had to be created. This policy had to govern all activities related to traceability and the adherence to this policy had to result in automatic compliance with ISO traceability specifications.

### 3.4.2. Traceability Processes

From the problems experienced by DLS, it was clear that there was a lack of a clear system of business processes. Business processes were only available in isolated and vague documents and it was extremely difficult to know exactly which processes were in place and which processes were lacking. Gunwoo (2011) states that the competitiveness of a company greatly relies on their knowledge to execute business processes with agility and efficiency. The importance of structured business processes could therefore not be overstated.

To deal with this problem, it would be necessary to first translate and map the relevant business documents into one interlinked business process system. This would be done for all processes running from Component Design to Product Delivery and by conducting numerous interviews with the appropriate people and by researching applicable business documents. From this system of current business processes, the significant areas for improvement could then be made identifiable and new business processes could then be created where necessary. This approach would result in a new, effective and efficient Business Process system.

### 3.4.3. Traceability Procedures

For the Traceability Processes to be physically implementable in the manufacturing and testing environment, specific and detailed traceability procedures had to be written. The various resulting procedures would be written on a level appropriate for the intended user and would enable employees on all levels to adhere to traceability specifications.

## 4. INITIAL BUSINESS PROCESSES

To be able to construct a solution to the identified problems, the existing business processes had to be researched and mapped. These processes were then analysed so as to identify specific problem areas.

### 4.1. INVESTIGATING INITIAL BUSINESS PROCESSES

Recall from previous sections that there were no specific business processes describing or clearly defining the process steps ranging from product design to product delivery. The sources describing the processes were in the form of business documents which were all stored in one database. Most of these documents referred to other related documents, but in some cases these documents had been deleted or replaced. Furthermore, many of the documents were very old or were not being used or followed by the employees.

To gain clarity on the matter, the relevant processes were extracted and mapped using BPM software and notation (See Figure 9 to 11). This was done, as exact details such as the order of processes needed to be indicated. Each action or task present on the business process flow chart was numbered and is explained below.

A process or task depicted with the symbol shown in Figure 7 indicates that a written and specific business document is available describing the particular business process or task. A process/task depicted by the symbol shown in Figure 8 indicates that the process is a physical process being executed by hand.

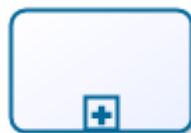


Figure 7: Symbol indicating a task with written procedures

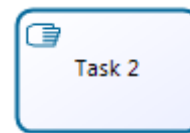


Figure 8: Symbol indicating a manual task

#### 4.1.1. Pre-manufacture and manufacturing

##### *Design, Pre-receiving and Raw Material Receiving*

- 1.1 The process commences by acceptance of a customer requirement. For the purpose of this model, it is assumed that all contracts, SOWs and other applicable milestones have been met and that DLS is capable of producing the required product. Furthermore, it is assumed that all supporting departments or functions (such as HR, IT, etc) are in place.
- 1.2 The applicable product is designed by the Engineering department by focussing on each individual component forming part of the product. A component design document is produced for each component, consisting of a component drawing and any additional component specifications.
- 1.3 For each component, the Engineering department determines whether the component at hand is functionally important or not. In other words, whether the component is necessary for the correct functioning of the total product.
- 1.4 If the component is deemed as functionally unimportant, no traceability is required for the component and no further traceability or serialisation attempts are made for that component. The entire traceability process is ended.
- 1.5 If it is decided that the component is functionally important, a Classification of Characteristics is performed for each characteristic of the specific component. This is done by determining the severity of the outcome if the characteristic would be nonconforming.
  - A Critical classification code is assigned to a characteristic if non-conformance is likely and if non-conformance would create a critical risk. In this case, special control is necessary to ensure 100 % compliance due to the severity level of a critical classification.
  - A Major classification code is assigned to a characteristic if non-conformance is likely and if non-conformance would create a major risk.
  - A minor classification code is assigned to a characteristic if non-conformance is likely and if non-conformance would create a minor risk.

After the COC is completed, it is added to the component design document.

- 1.6 The Control Requirements List document is created with the component design document used as an input. The CRL document defines and communicates the build history requirements, manufacturing process and quality control requirements for each component. A CRL document consist of three parts which include:
  - Build History Requirements and the necessary controls for manufacturing and quality control at Suppliers.
  - Build History Requirements and the necessary controls for manufacturing and quality controls at DLS.
  - A list of all certificates and inspection results that is required.

From this, it can be said that the CRL document governs the rest of the manufacturing, testing and assembly procedures as it describes details for each of these functions.

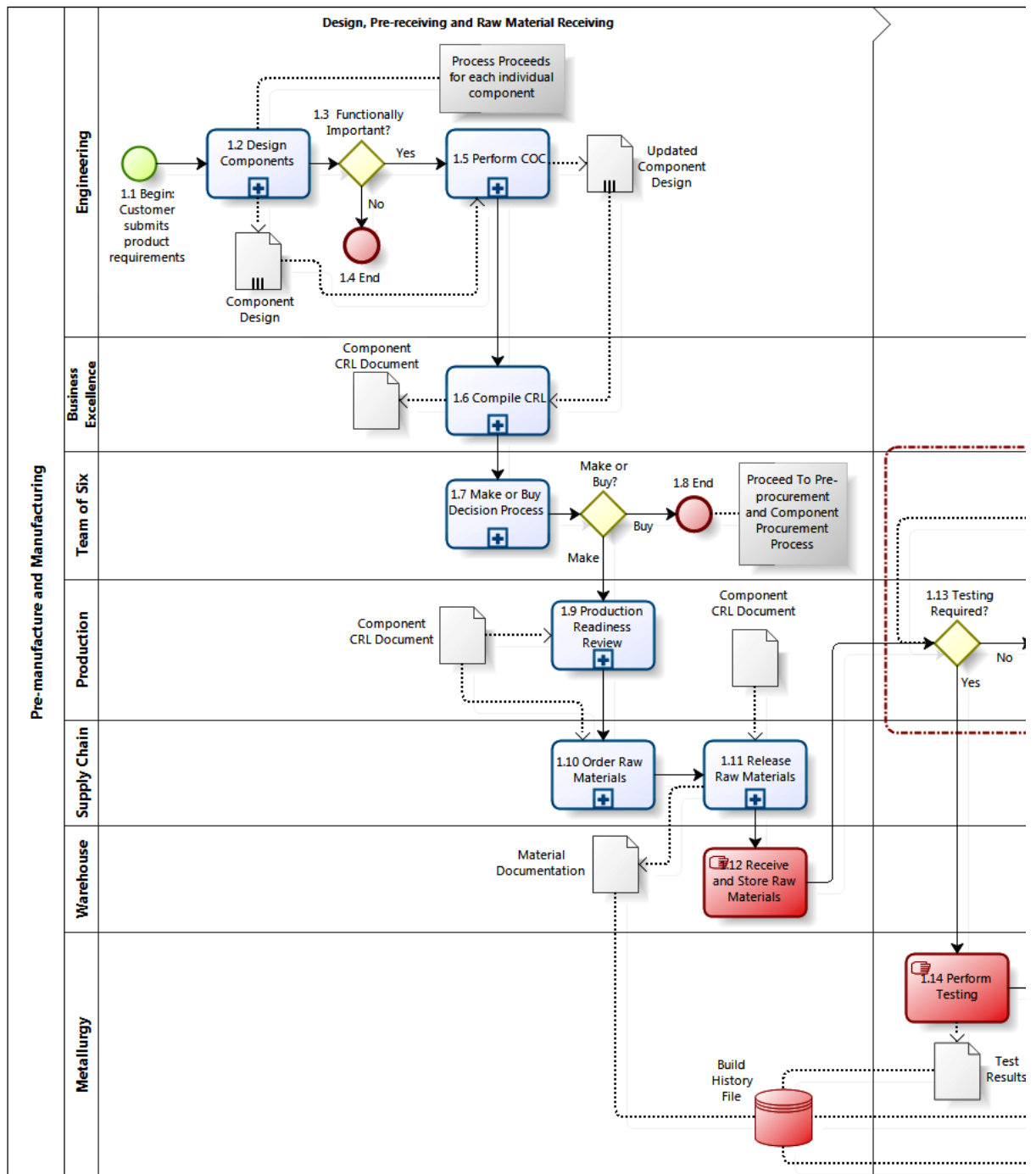
- 1.7 The Make or Buy decision process determines whether a component should be manufactured in-house, or sourced from a supplier. Factors such as cost, quality and competence are factors determining this decision.
- 1.8 If it is decided that the production of a component must be outsourced, the manufacturing process comes to an end and the Component Procurement process is activated.
- 1.9 If it is decided that the production of a component will be done by DLS, the Production Readiness Review process is carried out. This process ensures that production will only commence once the manufacturing department and facilities are able to produce the component successfully. With this step, the CRL document is used as an input.
- 1.10 The raw materials required for the manufacturing of the component is procured. The Supplier is informed of the requirements and is issued a copy of the CRL document so as to insure that the Supplier

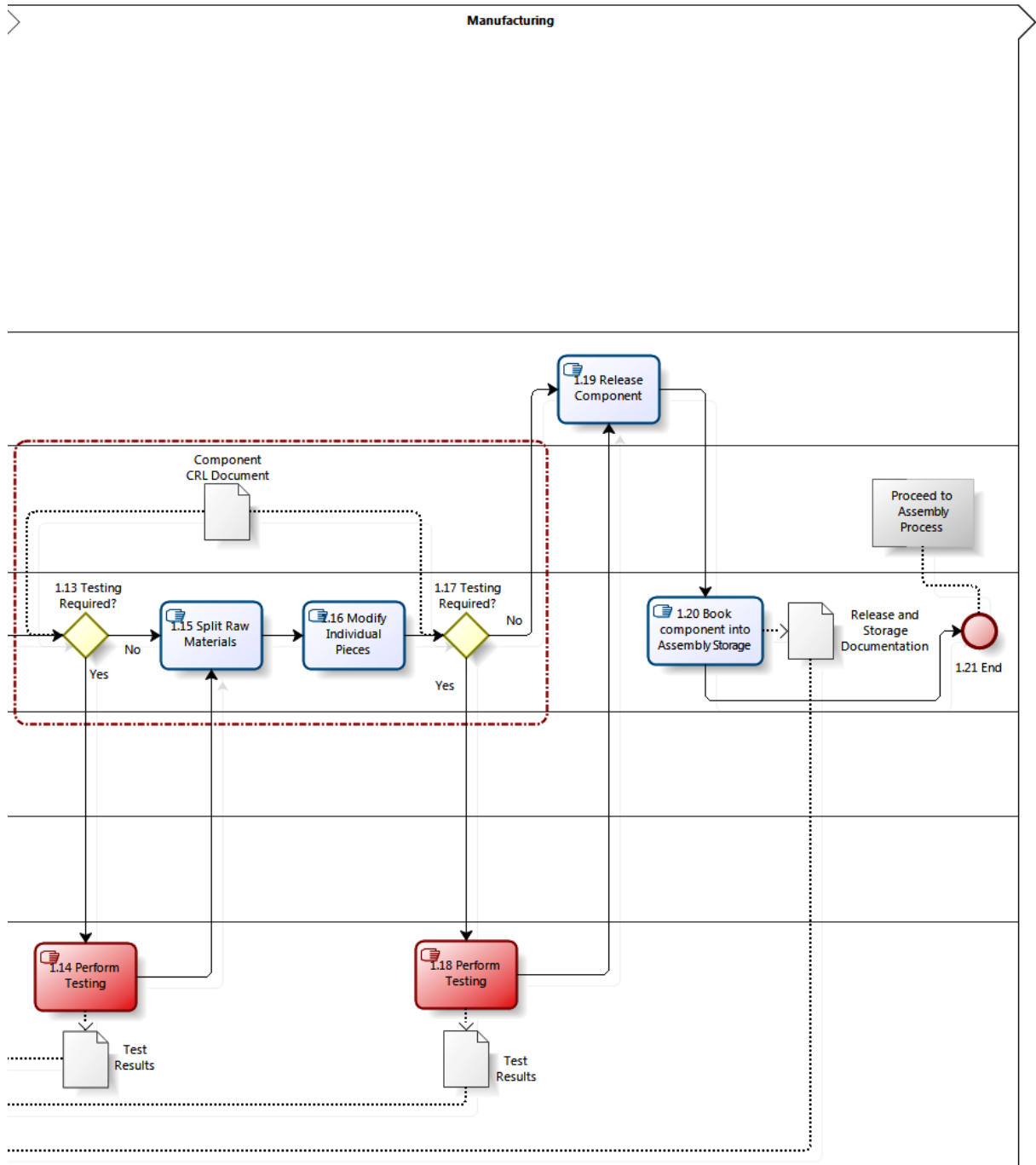
is informed of any and all special requirements. Furthermore, the Supplier is informed of all Build History documentation which must be provided by them.

- 1.11 The raw material order is released at the Supplier by a Supply Chain Representative. The Supply Chain Representative is given the build history documentation which was specified by the CRL document. The material documentation is placed in the Build History repository.
- 1.12 The raw materials are delivered by the Supplier and the Warehouse Foreman logs the arrival at the order information system.

### ***Manufacturing***

- 1.13 Using the detail captured in the CRL document, it is determined whether testing must be done on the raw material which had been received in the previous step or not.
- 1.14 If the CRL document has determined that testing is required at this stage, the testing will be done as specified. The test results of these specific tests are then placed into the Build History. Step 1.15 will then follow.
- 1.15 The raw material is split into smaller parts as required by the design of the component.
- 1.16 After the raw material has been split into smaller pieces, the pieces of raw material will be modified as required by the design of the component.
- 1.17 Using the detail captured in the CRL document, it is determined whether testing must be done on the components which had been created in the previous step or not.
- 1.18 If the CRL document has determined that testing is required of the components, the testing will be done as specified. The test results of these specific tests are then placed into the Build History file. Step 1.19 follows.
- 1.19 The components are released by the Business Excellence department.
- 1.20 The completed components are booked into the Assembly store and the Release and Storage documentation of the components are placed in the Build History file.
- 1.21 The manufacturing process ends and the Assembly processes are activated.





**Figure 9: Pre-manufacture and Manufacturing**

#### **4.1.2. Pre-procurement and procurement**

- 2.1 Starting from the results of the Make or Buy decision, the procurement process commences. It is assumed that consensus regarding the supplier decision is reached before the start of the process.
- 2.2 The component is ordered from the Supplier. The Supplier is informed of the requirements and is issued a copy of the CRL document to insure that the Supplier is informed of any and all special requirements. Furthermore, the Supplier is informed of all Build History documentation which must be provided by them.
- 2.3 The Supplier manufactures and tests the component according to the specifications which are provided to them through the CRL document. The documentation generated by this step is placed in the Build History file.
- 2.4 To ensure conformance of the components ordered from the Supplier, the Supply Chain visits the manufacturer and inspects the components. Hereafter, the components are released by the Supply Chain and Release documentation is created. Release documentation is placed in the Build History file.
- 2.5 The components are delivered by the Supplier and booked into Assembly storage. The Assembly Storage Foreman logs the arrival at the order information system. Storage and additional component documentation is stored in the Build History file.
- 2.6 The Procurement process ends and the Assembly processes are activated.

#### **4.1.3. Assembly**

- 3.1 After the components - from both the manufacturing and procurement side - have been booked into the Assembly Storage, the Assembly Process may begin. It is not necessary for all the components of a product to be available in the assembly storage before assembly may begin. The MPS schedule which is created separately determines when or at what stage of assembly which component must be necessary.
- 3.2 When the MPS schedule informs the Assembly store to release a component, the component is transferred into Assembly.
- 3.3 A serial number for the entire assembled product is requested from Production.
- 3.4 The serial number is created by Production. The format and nature of this serial number is the prerogative of Production and there are no specifications as to how this should be done.
- 3.5 The serial number is received and the product is marked with the number according to product specifications.
- 3.6 The preliminary assembly of the product takes place and the generated documentation is placed in the Build History file.
- 3.7 Production tests the preliminary product and the test results are placed in the Build History file.
- 3.8 Final assembly of the product takes place.
- 3.9 Production tests the final product and the test results are placed in the Build History file.
- 3.10 Final modifications, such as surface treatment and painting take place.
- 3.11 Business Excellence releases the final product and the release documentation is placed in the Build History file.
- 3.12 Appropriate packaging is performed according to specifications.
- 3.13 The final product is shipped and delivered to the customer.

From these “As-Is” processes that were mapped, the problem areas were identified and will be discussed in the preceding section.

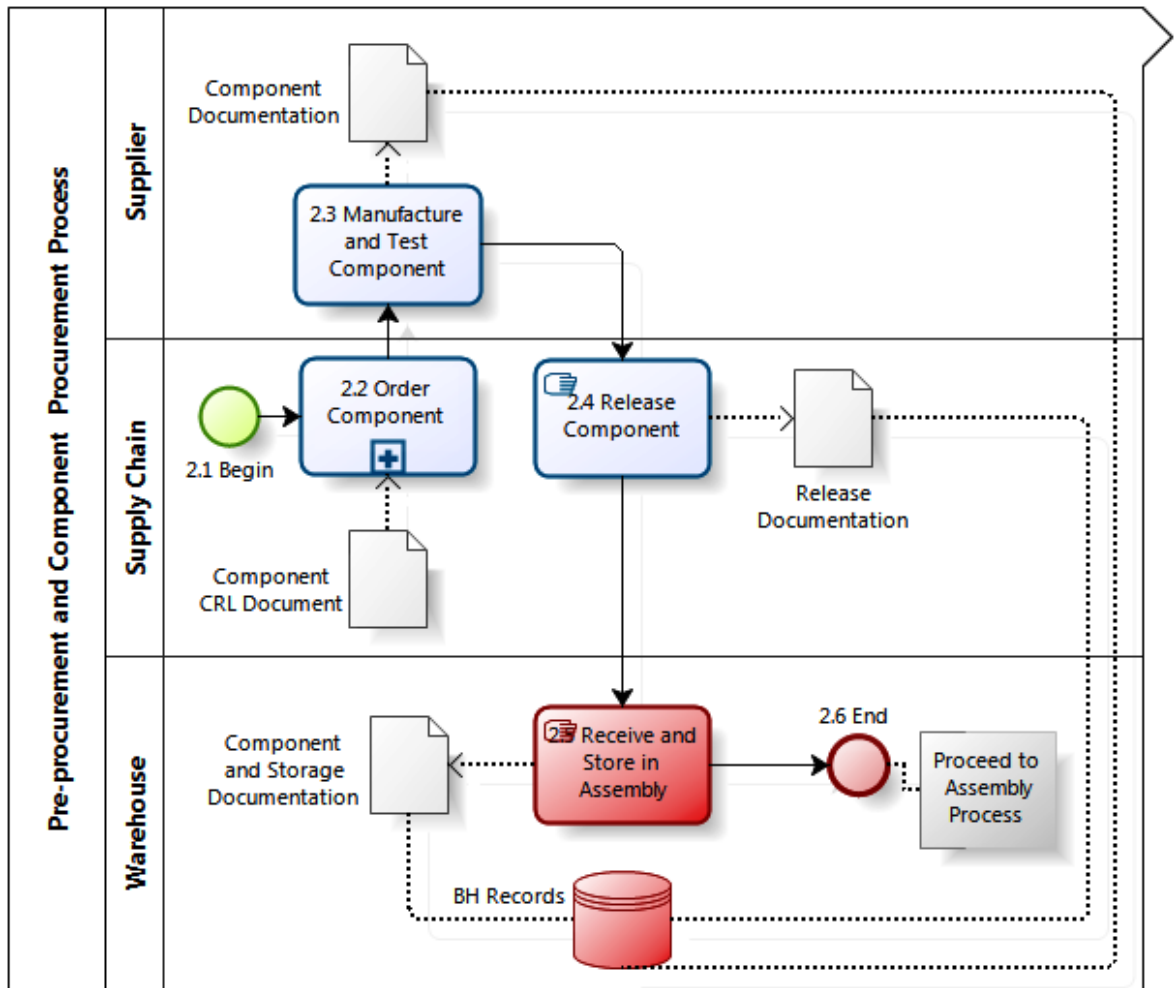


Figure 10: Pre-procurement and Procurement



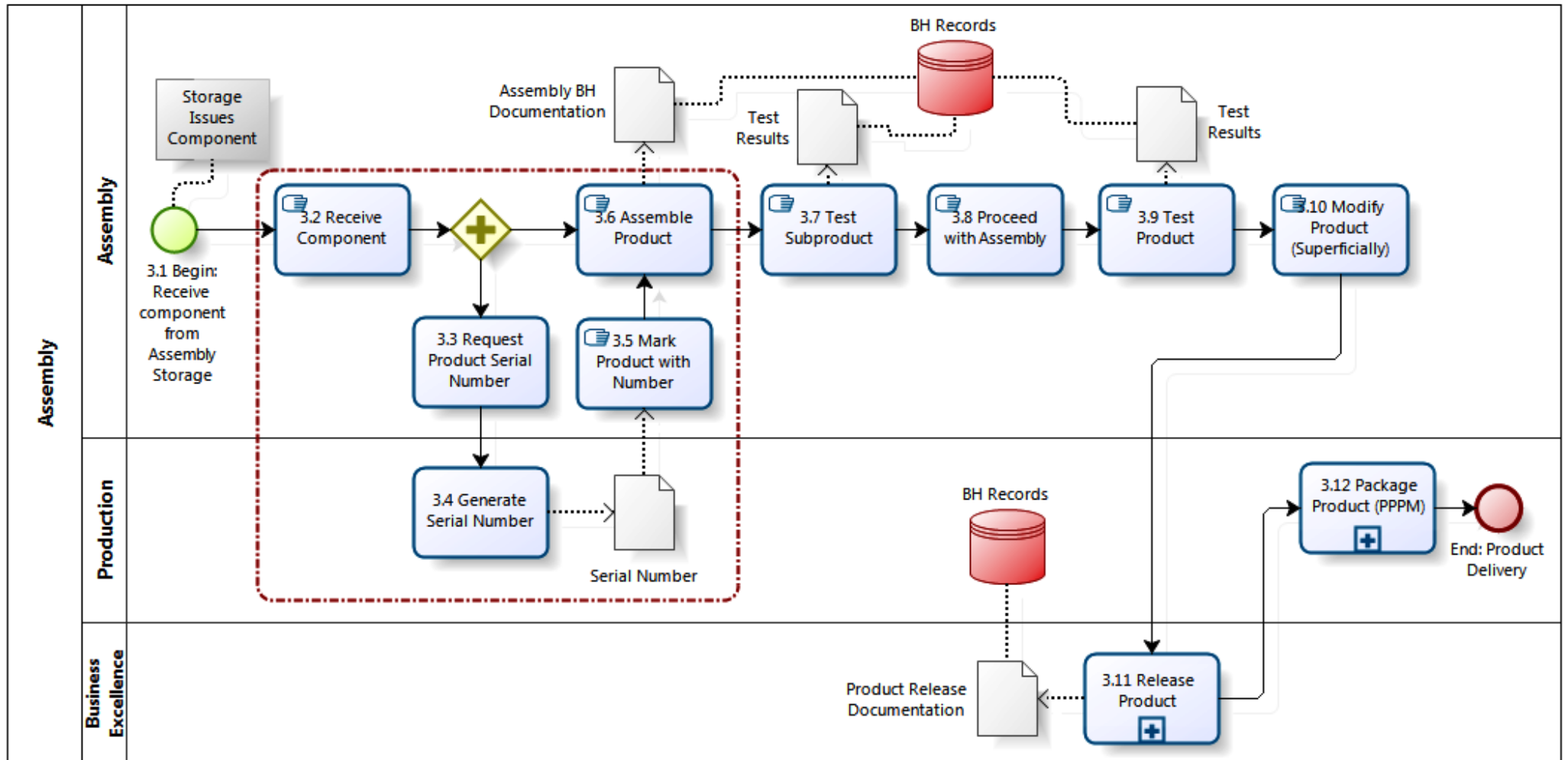


Figure 11: Assembly

## **4.2. ANALYSING CURRENT PROCESSES**

After the processes in Figure 9 to 11 were mapped, they were analysed. It was found that all processes in the diagrams were necessary and added value. The following problems were however identified in each of the sub-processes and had been indicated on the process maps (see marked areas in red).

### **4.2.1. Manufacturing**

When analysing the Pre-manufacture and Manufacturing section of the current processes which have been established, the processes ranging from step 1.12 to 1.18 were identified as a problem areas. This has been indicated in Figure 9. These areas were identified as problem areas due to the lack of processes ensuring traceability. This supports previous investigations which had found that there is no specific process or set of rules for any procedures regarding the serialisation of important components and there is no information system supporting these functions.

### **4.2.2. Procurement**

Step 2.5 in the Procurement sub-process was identified as the main problem area with regards to procurement activities. Here, components are received from suppliers, but no business processes governing the allocation of serial numbers or the appliance of traceability to received components have been established.

### **4.2.3. Assembly**

In the Assembly section of the current processes, a problem area ranging from step 3.2 to 3.6 was identified. This area is indicated in Figure 11. In this problem area, there is again a lack of processes regarding the allocation and generation of product serial numbers and there are also no processes or business rules governing the serialisation of products. Hence, a set of new business processes must be designed so as to improve the state of the identified problem area.

### **4.2.4. Other**

In all processes - ranging from design to delivery - the problem of a chaotic build history storage system was identified. Throughout all the processes, build history documents for each significant component is placed in one build history file. Clearly, this is a problematic method and new processes must be developed.

As the initial processes had now been established and the relevant problem areas had been identified, the traceability solution was created by following the Triple-P solution (as explained in the Literature Review).

## **5. SOLUTION: TRACEABILITY POLICY**

To govern the traceability processes and procedures, a traceability policy had to be created. For the traceability problems at DLS to be eradicated, this policy must be adhered to at all times and management must ensure that the policy is enforced to its fullest extent. Additionally, the implications of the policy must be explained to all employees so as to ensure that workers on all company and education levels understand the contents thereof.

The core contents of the policy will now be presented. The official Traceability Policy Document - as presented and accepted by DLS - is available in Appendix A.

### **5.1 POLICY PURPOSE**

Adhering to the policy statement will automatically ensure compliance with every aspect of the ISO 9001 traceability specification. The policy will govern the behaviour of all applicable employees and it will ensure that all relevant parties have a mutual understanding concerning traceability principles and rules. Finally, compliance to the policy will enable the entire company to move in the same direction regarding traceability.

### **5.2 APPLICABILITY**

The following departments must take note of and adhere to the Internal Traceability Policy:

- Engineering
- Business Excellence
- Manufacturing / Production
- Supply Chain
- Warehousing

- Metallurgy
- Assembly

If any employee or party within the applicable departments fail to comply with this policy, strong action will be taken.

### **5.3 RELATED DOCUMENTATION**

- Procedure for the Classification of Characteristics (Existing Procedure)
- Procedure for the Compilation and Registration of a CRL (Existing Procedure)
- ISO9001:2008 clause 7.5.3

### **5.4 POLICY STATEMENT**

#### **5.4.1 Classification of Components**

The classification of every component forming part of a product shall occur during the design thereof. Each component type shall bear a classification code which will either be “Minor” or “Functionally important”.

#### **5.4.2 Traceable Components**

If a component design receives the classification of “Functionally important”, traceability of all units of said component shall be maintained throughout the completion thereof. This shall enable all components to be traceable through all processes stretching from material origin to component delivery.

#### **5.4.3 Unique Identification**

All functionally important components shall remain uniquely identifiable throughout the completion thereof. This unique identification shall be recorded in an appropriate manner and at all times. Linked to this, the status of the particular component will remain known throughout all stages of production.

#### **5.4.4 Build History Accumulation**

All manufacturing history - as specified by the CRL documentation of a functionally important component - will be obtainable and shall be recorded in an appropriate manner. The link between a component and its build history shall never be broken.

### **5.5 POLICY AUTHORITY**

This policy has been created by the Business Excellence Department of DLS. The abeyance of this policy is the responsibility of each employee working within the above-listed departments, but the policy will be enforced by the Business Excellence department.

### **5.6 SPECIAL CIRCUMSTANCES**

If an employee finds himself in a situation where he believes this policy is not applicable, the employee must discuss the matter with a Business Excellence representative immediately. The employee may not make decisions regarding supposed special circumstances without the knowledge of the Business Excellence department. Any divergence from the standard Internal Traceability policy must be approved by the Business Excellence department.

## 6. SOLUTION: SERIAL NUMBERING SYSTEM

Before new traceability business processes could be created, a serial numbering system had to be designed. This numbering system would then be used within the newly created business processes. To ensure a proper numbering system, research was first conducted with regards to this.

### 6.1. SERIAL NUMBER GUIDELINES

To ensure effortless transferral of serial numbers onto a product, all serial numbers must be kept as short as possible. This is especially true in the case of weapons manufacturing as serial numbers must often be transferred onto armour steel which can be a gruelling task. The length of a serial number should only be long enough to sustain a sufficient number of unique combinations. Furthermore, to minimise the length of a serial number, no specific meaning should be linked to it. In other words, no information should be imbedded in the serial number. This is known as “smart” serial numbers and it is advised that the use thereof is avoided as far as possible.

Contrary to popular belief, it is not compulsory for serial numbers to be allocated sequentially. While serialisation information systems may generate numbers in a sequential fashion, it is not essential. In order to avoid potential problems during the implementation of a serialisation information system, it is advisable not to have a serial number start with the number zero. Additionally, characters other than letters and numbers must be avoided as these characters might lead to problems within the implementation of a serialisation information system.

It is best to avoid the use of letters which could be confused with certain numbers. Hence, letters such as “O”, “I”, “S” and “Z” must not form part of a serial number. Finally, the numbers allocated to a product by its supplier should not be used as the serial number or form part of the serial number. The serial numbering system existing within a company should be uniform and making use of numbers allocated by suppliers will disrupt the uniformity of the serial numbering system. (ClearlyInventory, 2011)

### 6.2. NUMBERING STRUCTURE

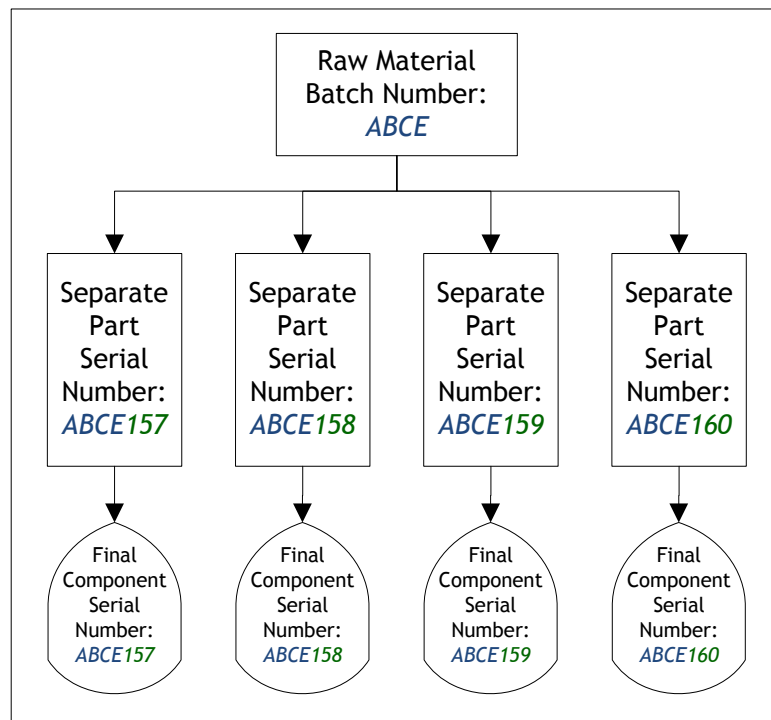
There existed a lack of uniformity in the serial numbers allocated to components and products. This was because there was no control over the serialisation process. Each person forming part of the manufacturing or assembly process followed their own instincts in this matter and the problems caused as a result were unimaginable. Hence, a new serial numbering format was designed. Different variants of the numbering process were created for components which have been procured externally, manufactured internally, or final products assembled by DLS.

#### 6.2.1. Manufactured Component Number

The new serial number format for components manufactured internally will consist of two parts. Each of these parts will be “activated” as the component moves through the various production stages. As the component is then transformed, a randomly generated serial number evolves with it. Table 3 shows the two serial number phases, with Figure 12 depicting the component and number transformation.

<i>Stage</i>	<i>Number Type</i>	<i>Number Format</i>	<i>Example</i>
1	Raw Material Batch Number	AAAA	ABCE
2	Manufactured Component Serial Number	AAAA000	ABCE157

Table 3: Serial Number Progression of a Manufactured Component



**Figure 12: Manufactured Component and Number Transformation**

From Figure 12, it can be explained that when a batch of raw material is received from a supplier, the batch receives a unique four-character Batch Number. From this, when the piece of raw material is split into smaller parts, each part receives a unique number with the format “AAAA000”. This will then become the final component’s serial number. Each smaller piece will have the same first four letters as their mother batch and piece, but each will have unique number characters following the first four letters. This process will result in a seven-character serial number which will be unique for every component, whilst linking it to its original mother material or batch.

### 6.2.2. Procured Component Number

The serial number format for components procured from external suppliers will have the same basic format as the manufactured components, but the full serial number will be assigned to the component on arrival and no further changes will then be made to it. The serial number will consist of three letters and four numbers.

As a result, each procured component will have a unique serial number allocated to it with the format “AAA0000”. For example, if a barrel was to be delivered to DLS, the barrel would immediately be assigned a serial number such as “FGL3821”.

### 6.2.3. Assembled Product Number

A serial number resembling the component serial numbers will be assigned to a product or assembly. The product number will be of the format “AAA000”, with one less letter-character at the beginning and end of the number. The serial number is assigned to a product or assembly as soon as the assembly thereof commences and remains upon the product throughout the life thereof.

## 6.3. SERIALISATION INFORMATION SYSTEM

To support the above Serial Numbering System, a proposed information system was designed. Due to scope restrictions, the design of this Information System only supports basic necessities. As a way forward, the IT department at DLS should use this as a base in creating a fully functional Serialisation Information System. This information system is designed in a way such that it will be able to function upon the current platform being used at DLS.

To model the system requirements for this proposed Serialisation Information System, a Use Case diagram was first created (as shown in Figure 13). Following this, a logical System DFD was designed to aid in the visualisation of information flows (Figure 14). Finally, a Class Diagram was designed so as to model actions which will have to be carried out by the information subsystem (Figure 15).

### 6.3.1. Use Case

#### Actor Glossary

Each of the Actors that will play a significant role in the functioning of the Serialisation Information Subsystem will be explained so as to clarify the Serialisation Information Subsystem Use Case in Figure 13.

<i>Term</i>	<i>Synonym(s)</i>	<i>Description</i>
<b>Storage Foreman</b>	Raw Material Storage Foreman / Storage Manager / Warehouse Foreman	The Storage Foreman actor represents any person who is in charge of the Raw Material Storage area or warehouse. The manager is in control of accepting material deliveries and issuing raw material on request. The manager is also in control of the paperwork that is issued with material deliveries and updating the build history of a product.
<b>Business Excellence Representative</b>	Quality Assurer	The BE Representative actor symbolises any person who is responsible for the verification of the conformance of a component or product. The Representative occasionally has to sign off on a component or product before it may proceed through the remaining processes.
<b>Assembly Storage Foreman</b>	Assembly Storage Manager	The Assembly Storage Foreman actor represents any person who manages the Assembly Storage area or warehouse. This manager controls the issuing of components for assembly and accepting completed components.
<b>Assembly Foreman</b>	Assembly Manager	The Assembly Foreman actor symbolises any person who is in charge of the assembly of a product. The Assembly Foreman collects components from the Assembly Storage and controls the paperwork that is generated throughout production. Decisions such as the necessity of product testing are also governed by this actor.
<b>Procurement Agent</b>	Supply Chain Employee	The Procurement Agent actor represents any person who places an order and who loads an order onto the existing order database.
<b>Production Foreman</b>	Production Manager	The Production Manager actor represents any person who is in charge of the production of a component or the production plant in itself. The manager decides if testing of a component is necessary and which manufacturing processes should be applied to a component. This manager is responsible for updating the build history of a component.

**Table 4: Serialisation Use Case Actor Glossary**

### *Use-Case Glossary*

To clarify the Use-Cases displayed in Figure 13, an explanation on how they are activated and under what conditions they are activated, will now be presented.

<i>Use-Case Name</i>	<i>Use-Case Description</i>	<i>Participating Actors and Roles</i>
<b>Generate New Raw Material Batch Number</b>	This Use-Case is activated when new raw material is received from an external supplier which has to be serialised.	Storage Foreman (Primary Business)
<b>Allocate new Batch Number to Material Batch or Part</b>	This Use-Case is initiated when new raw material is received from an external supplier and after a new batch number has been created for the received material.	Storage Foreman (Primary Business)
<b>Log Material Order Arrival</b>	The Actor performs this Use-Case after a Material order has arrived at the warehouse.	Storage Foreman (Primary Business)
<b>Informs of Material Serialisation Requirements</b>	This Use-Case is activated after the Actor has logged the arrival of the order. The information system notifies the Actor whether serialisation is a requirement.	Storage Foreman (Primary Business)
<b>Finalise Material Batch Number</b>	This Use-Case is performed when a Material Batch has been allocated a Batch Number and the Batch Number has been checked and confirmed	Storage Foreman (Primary Business)
<b>Specify Order Serialisation Requirements</b>	This Use-Case is initiated when an order is placed and loaded onto the (existing) order information system.	Procurement Agent (Primary Business)
<b>Finalise Serial Number for each component</b>	This Use-Case is performed when a component is completed and when the component should be signed off.	Business Excellence Representative (Primary Business)
<b>Finalise Serial Numbers in product</b>	This Use-Case is activated when a product has to be signed off. The Use-Case entails the actor ensuring that all component serial numbers are linked to the final product number and that no mistakes have been made.	Business Excellence Representative (Primary Business)
<b>Extend Batch Numbers after Raw Material Split</b>	After the raw material is split into smaller raw pieces, this Use-Case is performed.	Production Foreman (Primary Business)
<b>Allocate Component Serial Number for each separated part</b>	This Use-Case is activated after the raw material has been split into smaller raw pieces and after the serial numbers has been extended.	Production Foreman (Primary Business)
<b>Log Component Order Arrival</b>	The Actor performs this Use-Case after a component has arrived at the assembly store.	Assembly Storage Foreman (Primary Business)
<b>Informs Component Serialisation Requirements</b>	This Use-Case is activated after the Actor has logged the arrival of the order. The information system notifies the Actor whether serialisation is a requirement.	Assembly Storage Foreman (Primary Business)
<b>Generate New Component Serial Number</b>	This Use-Case is takes place when entire components are received from external suppliers which have to be serialised.	Assembly Storage Foreman (Primary Business)

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<b>Allocate Serial Number to Component</b>	This Use-Case is initiated when components are received from an external supplier and after a new serial number has been created for the received components. For components too small for individual marking (such as bolts or nuts), the entire batch receives a serial number. In general however, each component is allocated a serial number.	Assembly Storage Foreman (Primary Business)
<b>Generate Main Product Serial Number</b>	When a product enters assembly, this Use-Case is activated and a serial number is created.	Assembly Foreman (Primary Business)
<b>Finalise Component Serial Number</b>	This Use-Case is activated after a procured component has been received and a Serial Number has been allocated to the component	Assembly Storage Foreman (Primary Business)
<b>Allocate Product Serial Number to Product</b>	This Use-Case is initiated after a Main product serial number has been created.	Assembly Foreman (Primary Business)
<b>Generate Product Serial Number</b>	When a product has finished assembly, and the final surface treatment has been carried out, this Use-Case is activated and a Final serial number is created.	Assembly Foreman (Primary Business)
<b>Allocate Final Serial Number to Product</b>	This Use-Case is initiated after a Final product serial number has been created.	Assembly Foreman (Primary Business)
<b>Link Component and Product Serial Numbers</b>	As components are added to the product assembly, this Use-Case is activated.	Assembly Foreman (Primary Business)

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**Table 5: Use-Case Glossary**



Use-Case Diagram

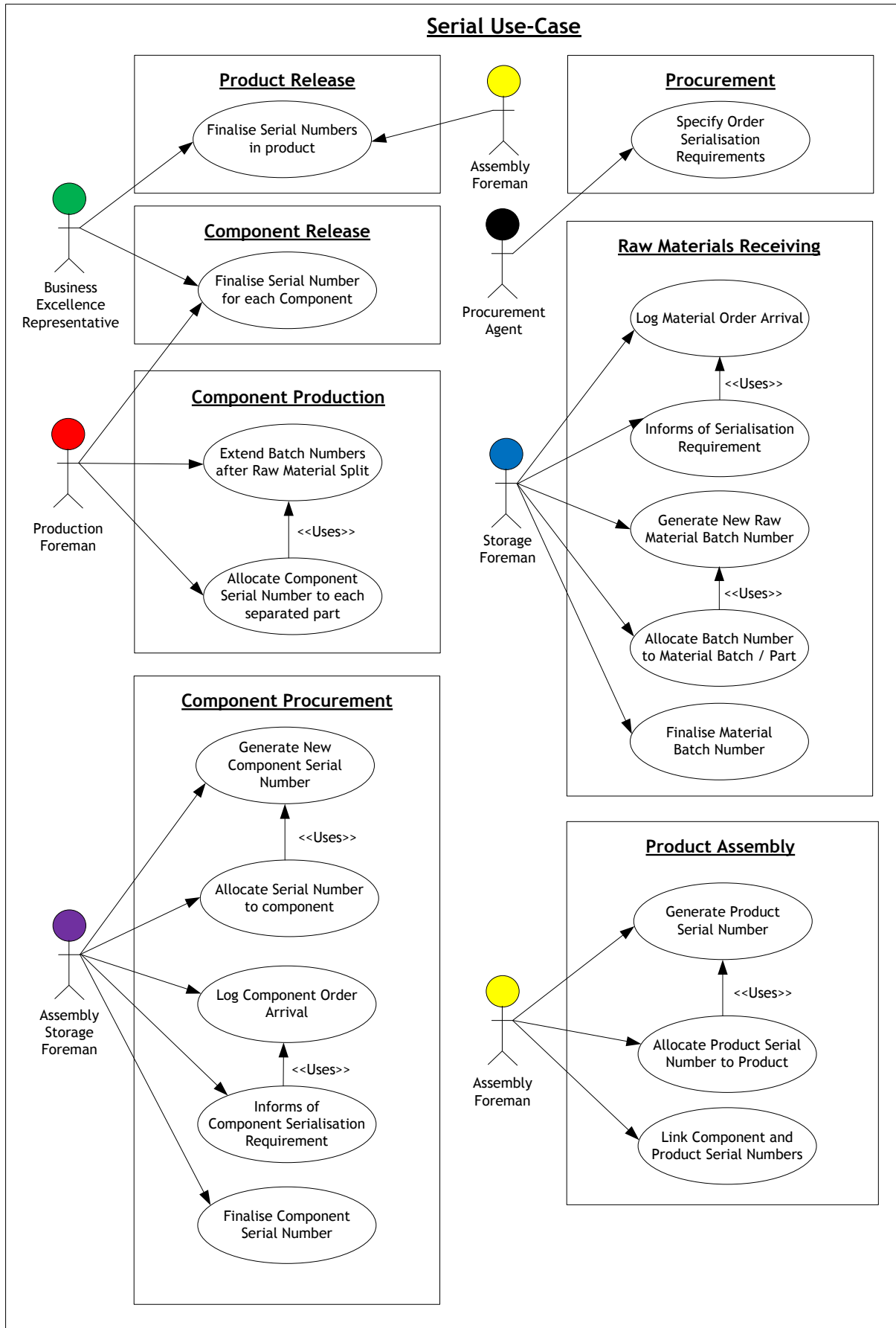


Figure 13: Serialisation Subsystem Use Case

6.3.2. Logical System Data Flow Diagram

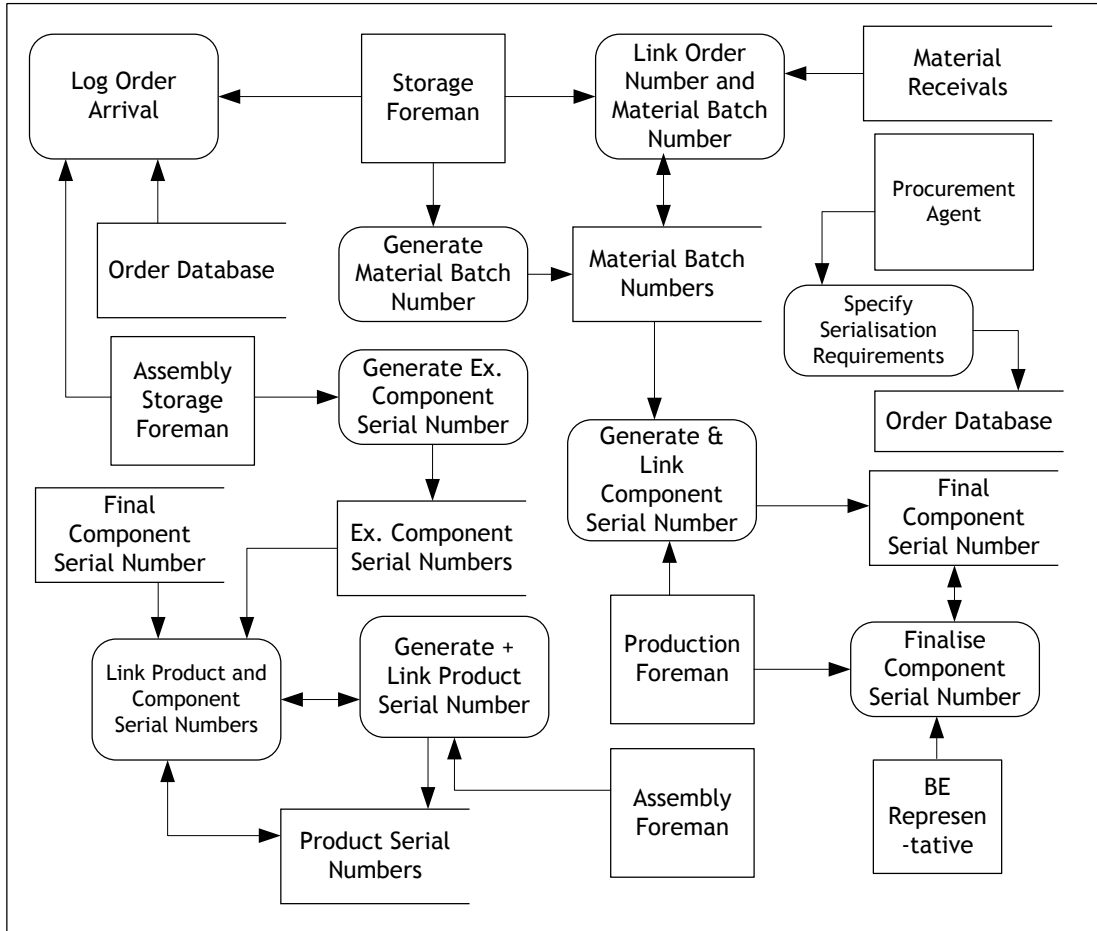


Figure 14: Serialisation Subsystem DFD

### 6.3.3. Class Diagram

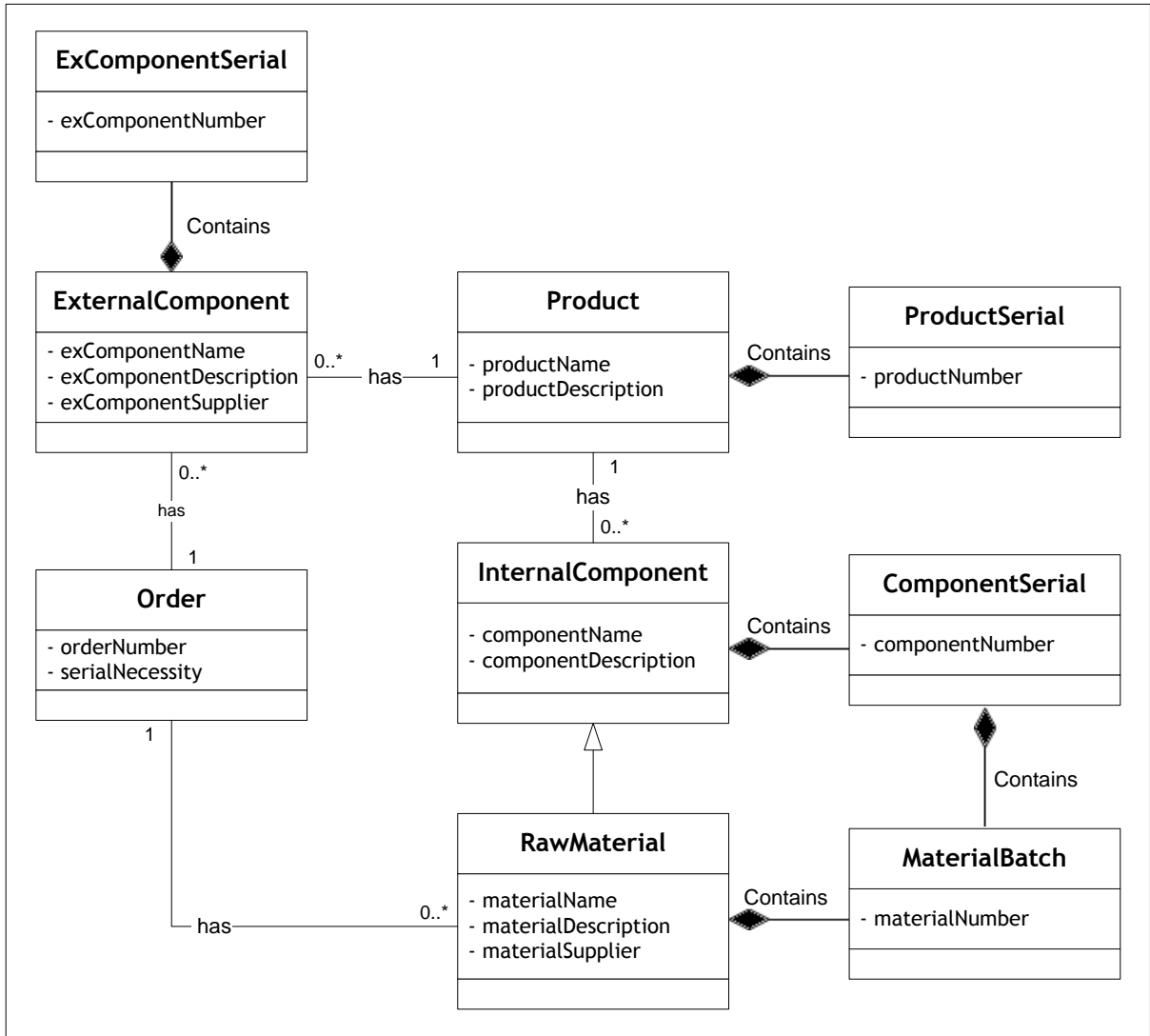


Figure 15: Serialisation Class Diagram

## 7. SOLUTION: BUILD HISTORY STORAGE STRUCTURE

As was discovered in Chapter 4.2, a system supporting the accumulation of build history documents - which are generated throughout the completion of a product - was required. To create a new storage structure for build history documents, it had to be determined which documents and document types usually form part of the build history records. This was done by analysing the Business Process maps in the preceding sections, as well as relevant DLS business documents. The build history documents that are accumulated during product realisation were divided into three main groups, namely the Process Record group, the Item Record group and the Raw Material group.

### 7.1. DOCUMENT GROUPS

#### 7.1.1. Process Record Documents

The process record documents contain important process conditions to which the functionally important component or product will be or has been subjected to. These documents also record the serial numbers of other components or products that were processed together with the specific component or product in question. Process Documents include:

- Process Batch Certificates
- Process and Operator Qualification Certificates

#### 7.1.2. Item Record Documents

The item record documents catalogue important component or product characteristics that have resulted due to the manufacturing processes which it has gone through. This set of information is used so as to confirm that the particular component conforms to all requirements. Item Documents include:

- Inspection and Test Results
- Inspection Certificates of Conformance
- Concessions and Deviations
- Assembly Configuration Records and Serial Numbers

#### 7.1.3. Raw Material Documents

Raw Material documents contain the physical and / or chemical characteristics of procured Raw Material orders. These documents can also include results and reports regarding tests that have been performed on batches of raw material.

### 7.2. REPOSITORY STRUCTURE

Using these document types, the structure of the proposed document repository was designed and is shown in Figure 16. Storing all generated build history documents of each product type and each individual product following this structure will ensure easy retrieval of the documents. This is apposed to the current system where all files of a product or assembly is stored in a single file with no specific order, information system or method and without following any specific rules or business processes. The main elements present in the structure (Figure 16) are explained in Table 7.

<i>Element</i>	<i>Parent</i>	<i>Detail</i>
Raw Material Batch	None	Every Batch of Delivered Raw Material, such as a sheet of metal with serial number GQTX
Product	None	Each different product, such as a G6, a Mini SS, a Rooikat, etc
Individual Product BH	Product	Each individual product, such as a G6 with serial number FPA182
Component BH	Individual Product BH	All build history documentation related to the specific parent product
CRL Documents	Component BH	All CRL Documentation forming part of the product Build History
Process Records	Component BH	All Process Records forming part of the product Build History
Item Records	Component BH	All Item Records forming part of the product Build History

Table 6: Build History Structure Elements

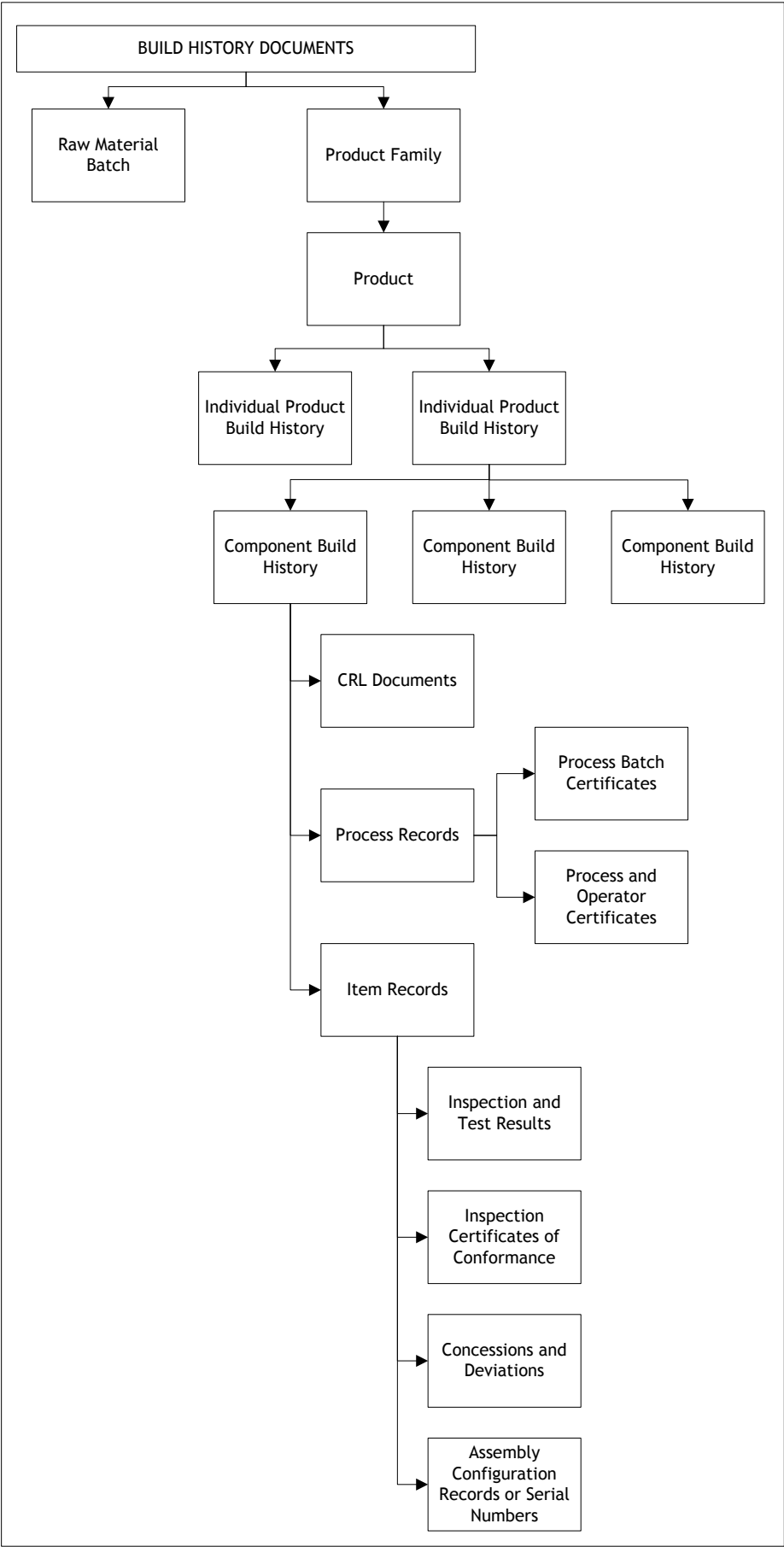


Figure 16: Build History Storage Structure

## 8. SOLUTION: TRACEABILITY PROCESSES

### 8.1. RAW MATERIAL RECEIVING AND STORING PROCESS

Recall from the initial BPMN model of Pre-manufacturing (Figure 9) the problems surrounding activity number 1.12 (Receive and Store Raw Materials). To solve this problematic process, a new network of processes and sub-processes was created using the IDEF0 modelling technique (see Literature Review for reference).

Figure 17 shows the decomposition of the different levels of IDEF0 diagrams. Figure 18 shows the main process and is further expanded into different levels of detail in succeeding Figures 19 to 21. An explanation of each activity will follow the figure of each diagram level.

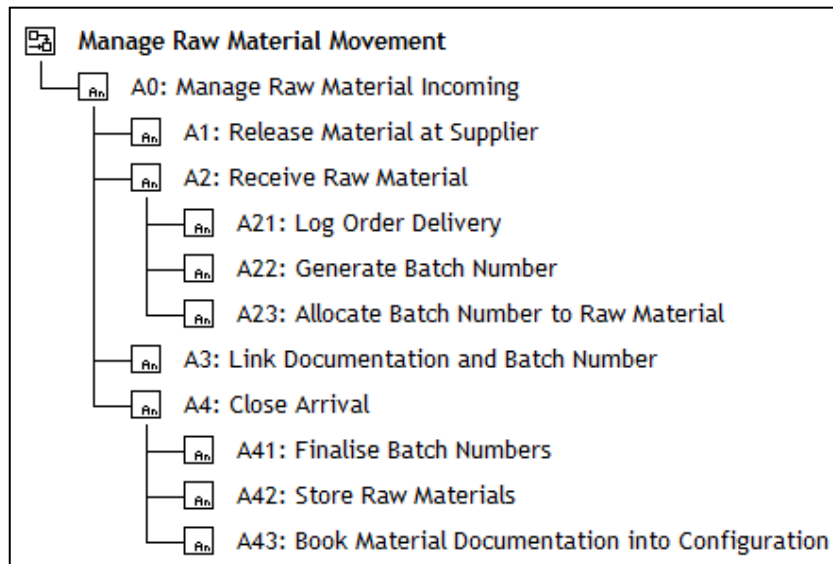


Figure 17: Raw Material Receiving and Storage Model Levels

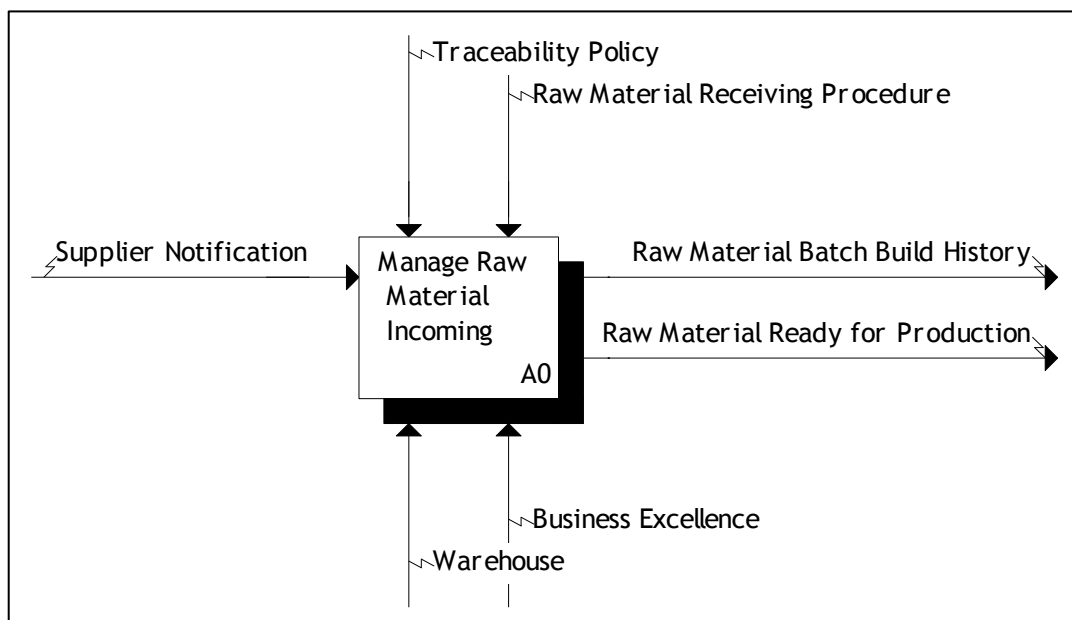


Figure 18: Main Material Incoming ICOMs

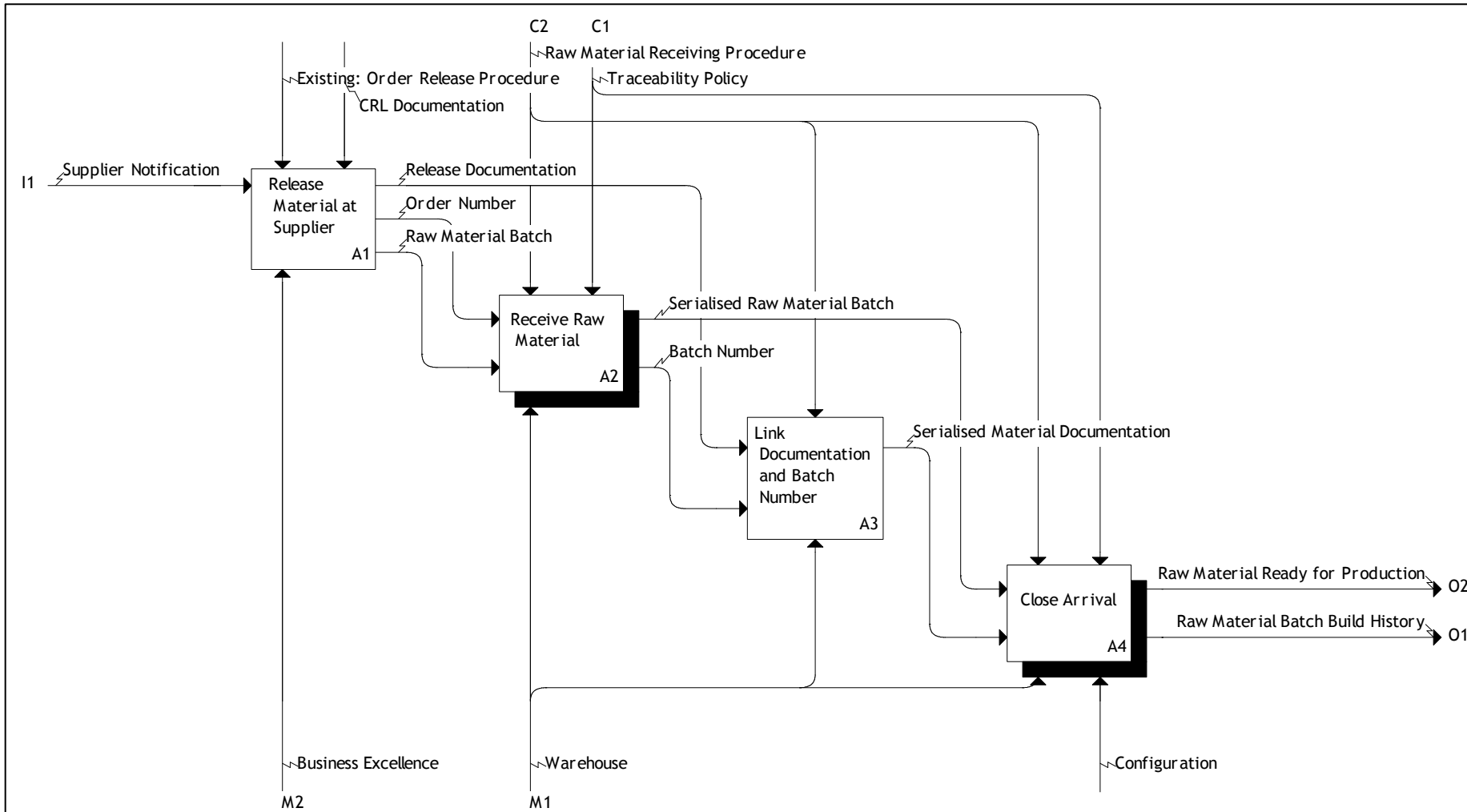


Figure 19: Raw Material Receiving and Storage Model Level x

### **8.1.1. Manage Raw Material Incoming: Model level x**

#### ***A1 - Release Material at Supplier***

- The Supplier notifies the company that the batch of material has been produced
- As an existing sub-process, the Business Excellence department (rather than the Procurement department) visits the Supplier, inspects the material batch (using the CRL documentation) and releases the batch through an existing process (where the Business Excellence department gives the order number of the batch to the Supplier)
- The Business Excellence representative takes the raw material build history documentation (which had been specified in the ordering process) from the Supplier and indicates the order number on the documentation
- The Business Excellence representative takes the documentation back to DLS and hands it to the Warehouse Foreman
- The Supplier ships the raw material batch to DLS, which is accompanied by the order number of the batch

#### ***A2 - Receive Raw Material***

- The Warehouse receives the raw material batch with its accompanied order number
- The raw material batch is serialised with a batch number

#### ***A3 - Link Documentation and Batch Number***

- The Raw Material Build History documentation and the batch number is linked so as to connect the batch number to its specific documentation
- Build History documentation is serialised

#### ***A4 - Close Arrival***

- The arrival of the raw material is finalised and closed
- The raw material is stored
- The Build History documentation is saved

### **8.1.2. Manage Raw Material Incoming - Receive Raw Material: Model level 2x**

#### ***A21 - Log Order Delivery***

- The Warehouse receives the raw material batch with its accompanied order number
- The Warehouse Foreman logs the received order onto the existing order database by means of the accompanied order number
- The order database notifies the Warehouse Foreman whether the received batch must be serialised (this data must be included during the existing procurement process)

#### ***A22 - Generate Batch Number***

- The Foreman generates the batch number using the proposed Serialisation Information System
- The Serialisation Information System will produce a unique batch number with the format "AAAA" (see Chapter 6)

#### ***A23 - Allocate Batch Number to Raw Material***

- The received batch of material is marked with the newly acquired batch number
- The Raw Material Receiving Procedure and Marking Procedure is followed with regards to this



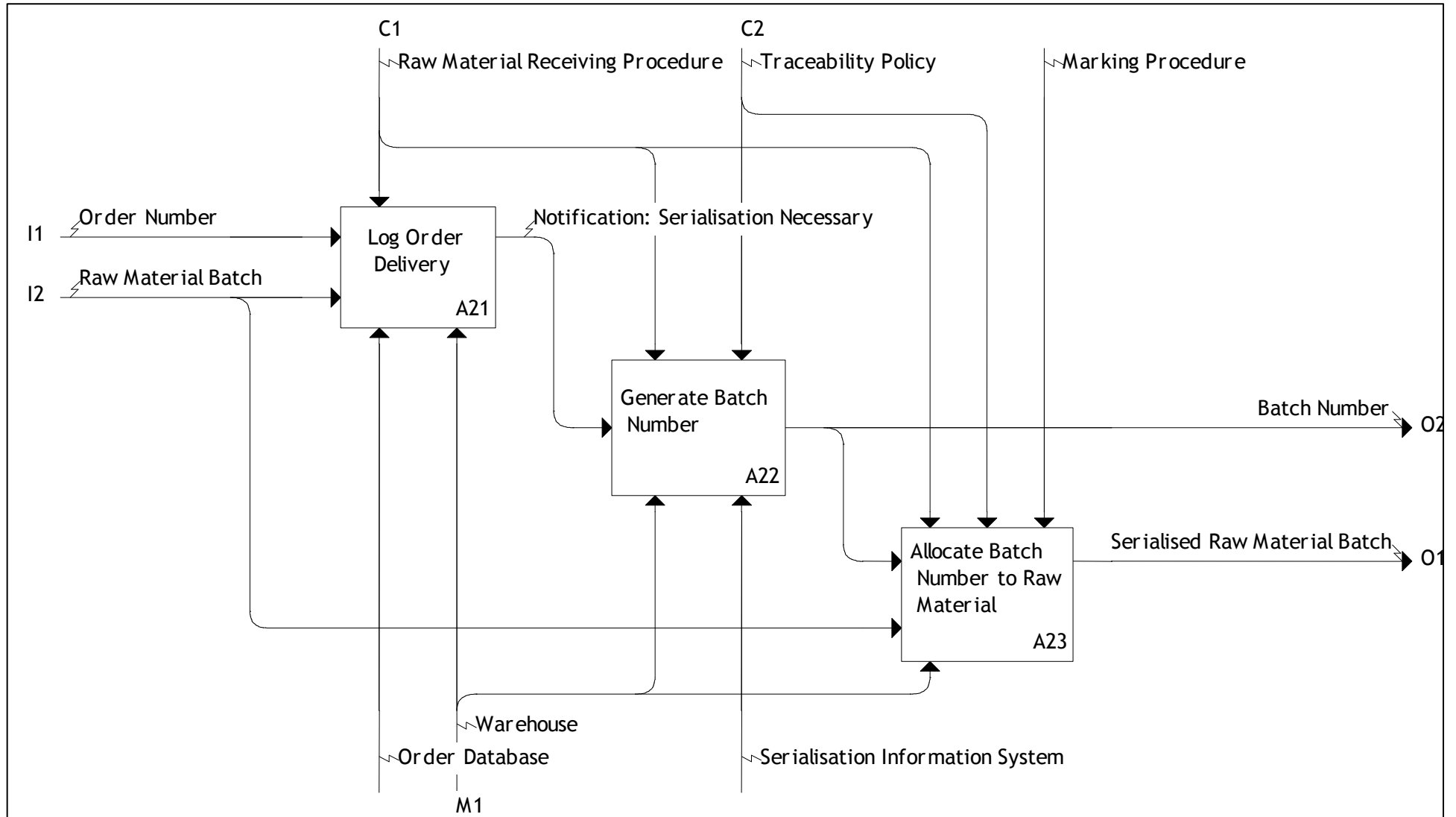


Figure 20: Raw Material Receiving and Storage Model Level 2x

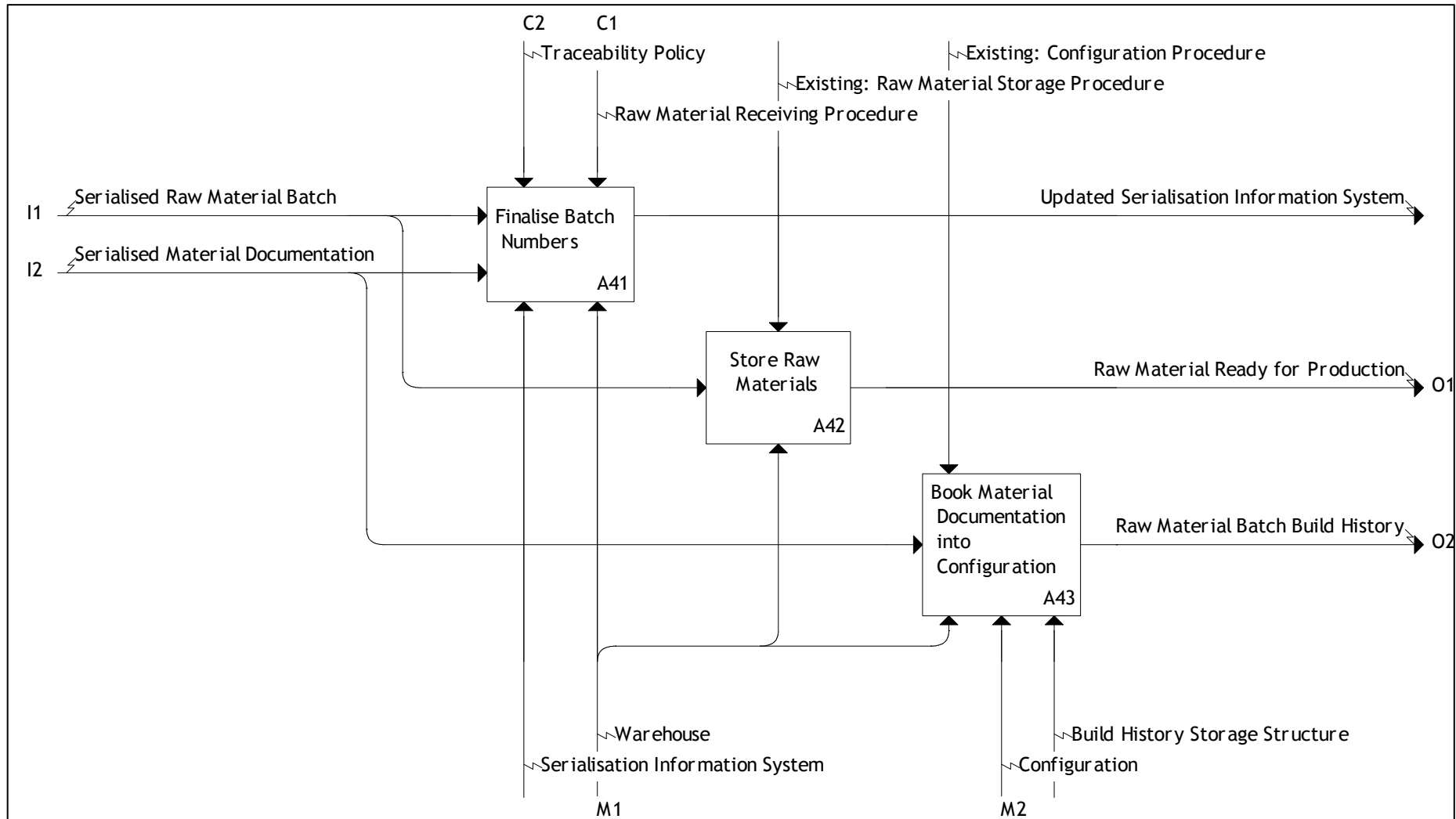


Figure 21: Raw Material Receiving and Storage Model Level 4x

### 8.1.3. Manage Raw Material incoming - Close Arrival: Diagram level 4x

#### A41 - Finalise Batch Numbers

- The serialised documentation and raw material are received
- The batch number on the material and on the documentation is verified to ensure that the two numbers align
- The batch number is verified and finalised on the Serialisation Information System

#### A42 - Store Raw Materials

- The raw material batch is stored following the existing Storage Procedure

#### A43 - Book Material Documentation into Configuration

- The Warehouse Foreman books the material documentation in at Configuration
- The Configuration Personnel stores the documentation using the existing Configuration procedure and the proposed Build History Storage Structure specified in Chapter 7.

The procedures mentioned throughout these processes will be presented in Chapter 9. The next process which was created will now follow.

## 8.2. COMPONENT MANUFACTURING PROCESS

To prevent the problems occurring during activity number 1.13 (Decide if Testing is required) to 1.20 (Test final component) of the current process, a new set of processes and sub-processes was created. Figure 22 shows the main ICOMs of the process, while Figure 23 shows the decomposition of the different levels of IDEF0 diagrams. From Figure 23, the further expanded levels of IDEF0 models are shown in succeeding Figures 24 to 31. An explanation of each activity will follow the figure of each diagram level.

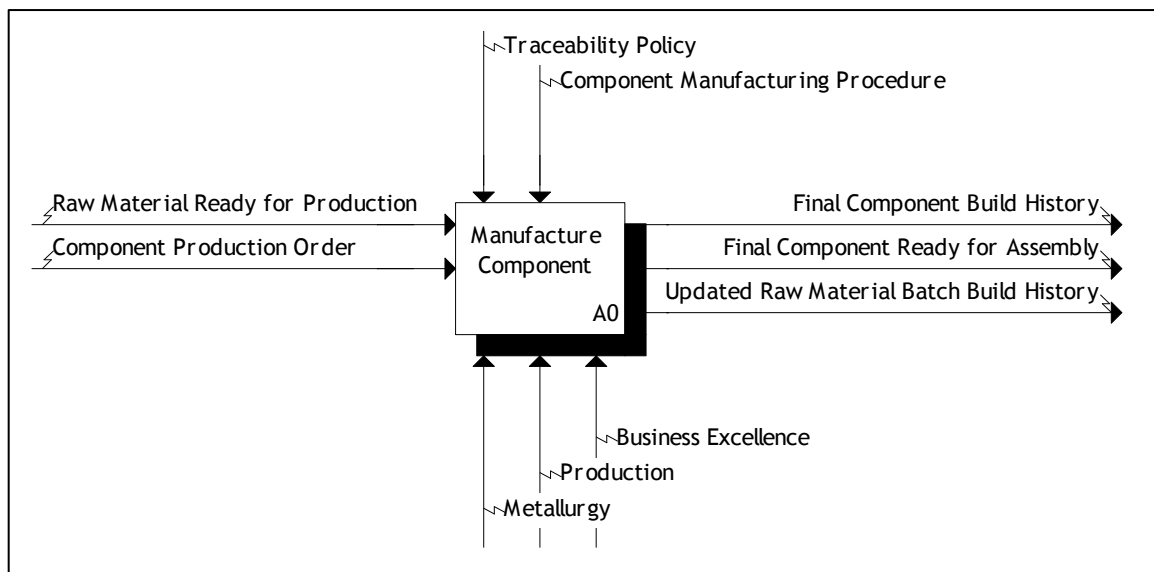


Figure 22: Main Manufacturing Component ICOMs

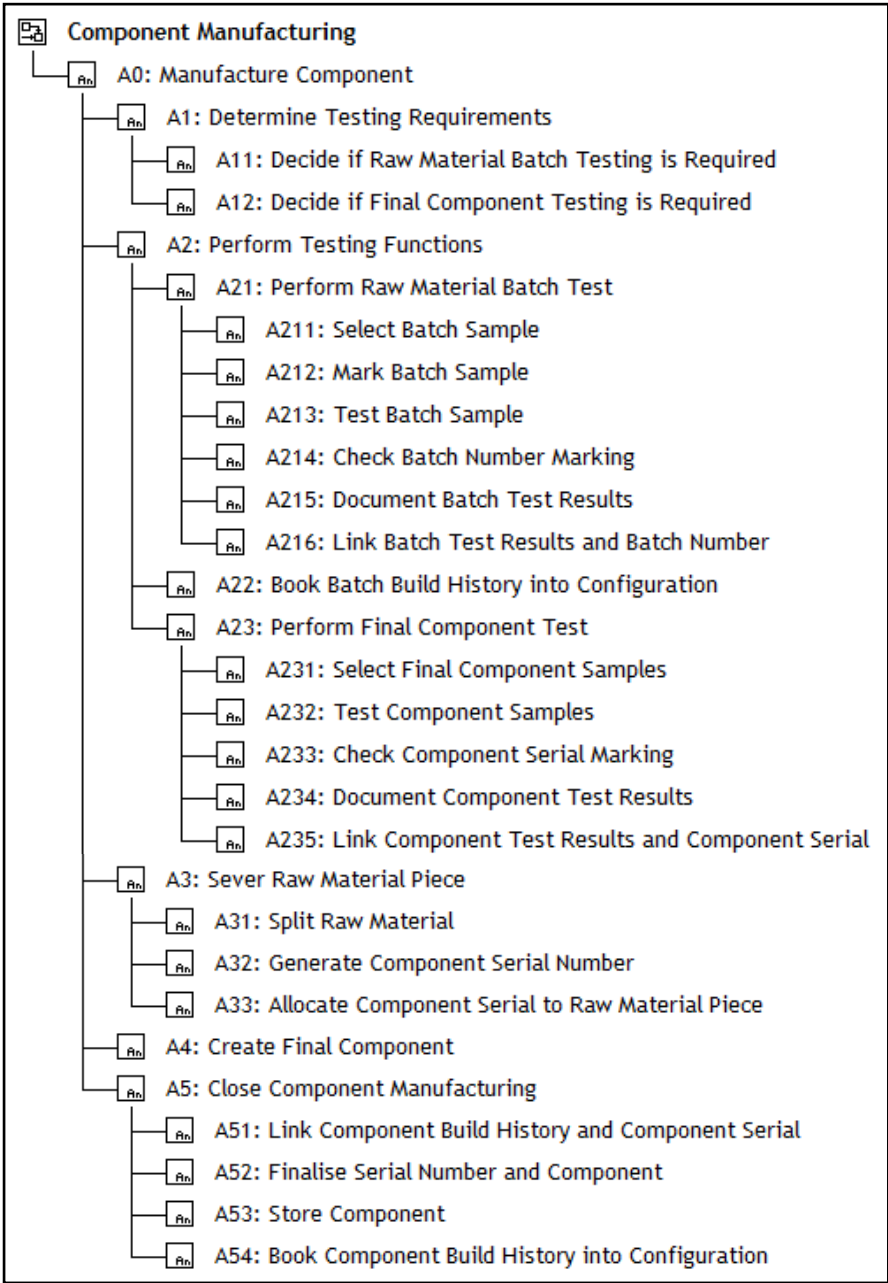


Figure 23: Component Manufacturing Model Levels

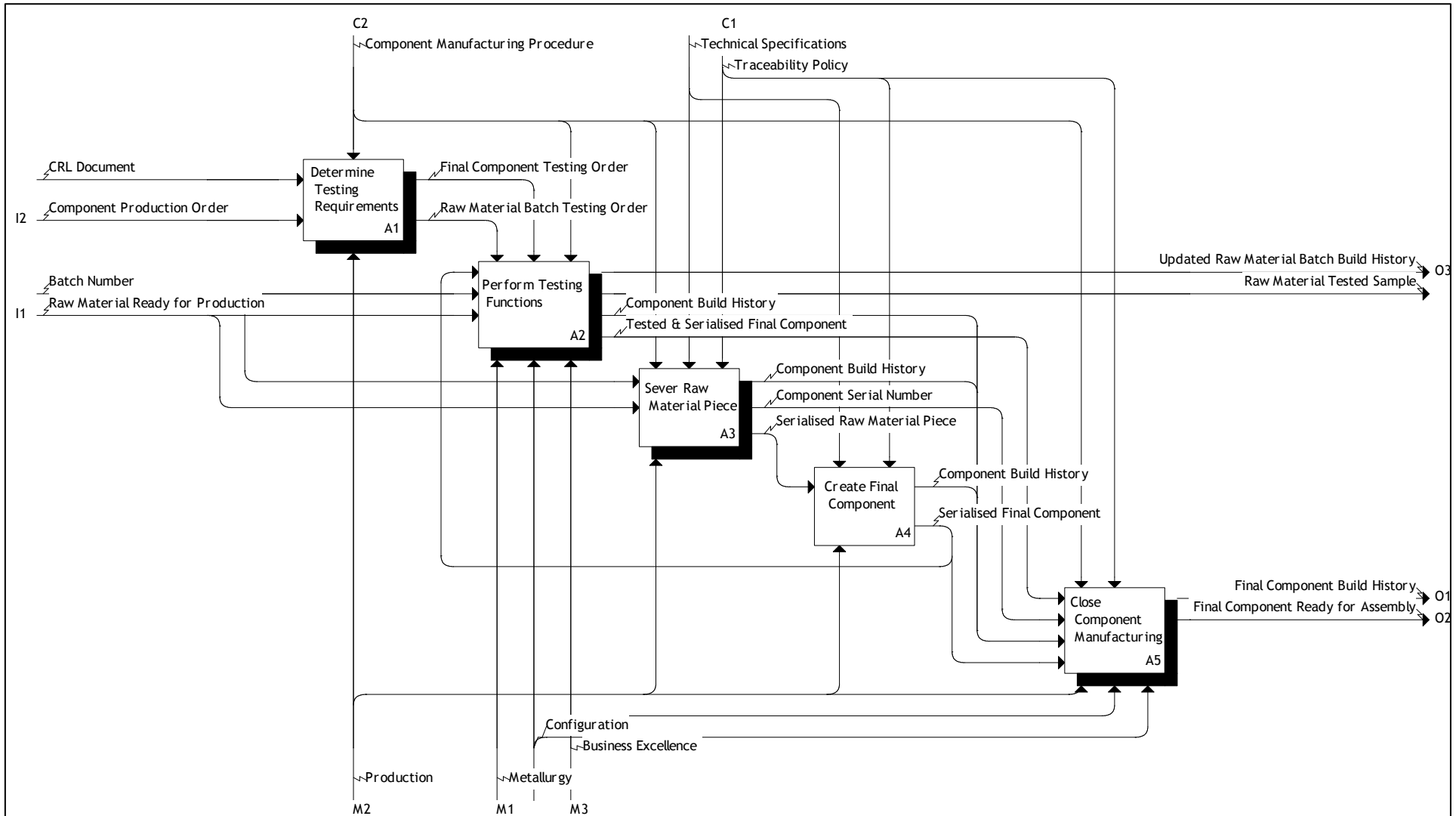


Figure 24: Component Manufacturing Model Level x

## **8.2.1. Manufacture Component: Model level x**

### ***A1 - Determine Testing Requirements***

- During various stages in the component realisation, it is decided whether further testing must be performed
- The decision process may result in a testing order throughout various phases of component realisation
- The decision process is guided by the CRL documentation

### ***A2 - Perform Testing Functions***

- Whenever a testing order is issued, the Metallurgist or Business Excellence representative is required to perform a certain test
- The testing function may be performed throughout the realisation of a component
- The actual tests (for example Rockwell tests) forming part of the testing process are carried out through established scientific methods
- Raw material and component build history may be created during these activities

### ***A3 - Sever Raw Material Piece***

- During the first stages of production of a component, the initial piece of raw material (forming part of the larger raw material batch) is cut, removed, severed, etc, from its mother piece
- Traceability is maintained throughout this process
- Component build history is generated during this activity

### ***A4 - Create Final Component***

- The final component is manufactured using the severed piece of raw material
- The manufacturing process generates component build history

### ***A5 - Close Component Manufacturing***

- The component manufacturing is finalised and closed
- The component is stored
- The Build History Documentation is saved

## **8.2.2. Manufacture Component - Determine Testing Requirements: Model level 1x**

### ***A11 - Decide if Raw Material Batch Testing is required***

- Before component production commences, it is decided if further in-house testing needs to be done on the raw material batch
- Information regarding this is provided by the CRL document
- A raw material batch testing order is reached out to Metallurgy

### ***A12 - Decide if Final Component Testing is required***

- After the separate final component has been created and machined, it is decided whether the component needs to be tested
- Information regarding this is provided by the CRL document
- A final component testing order is reached out to the Business Excellence department

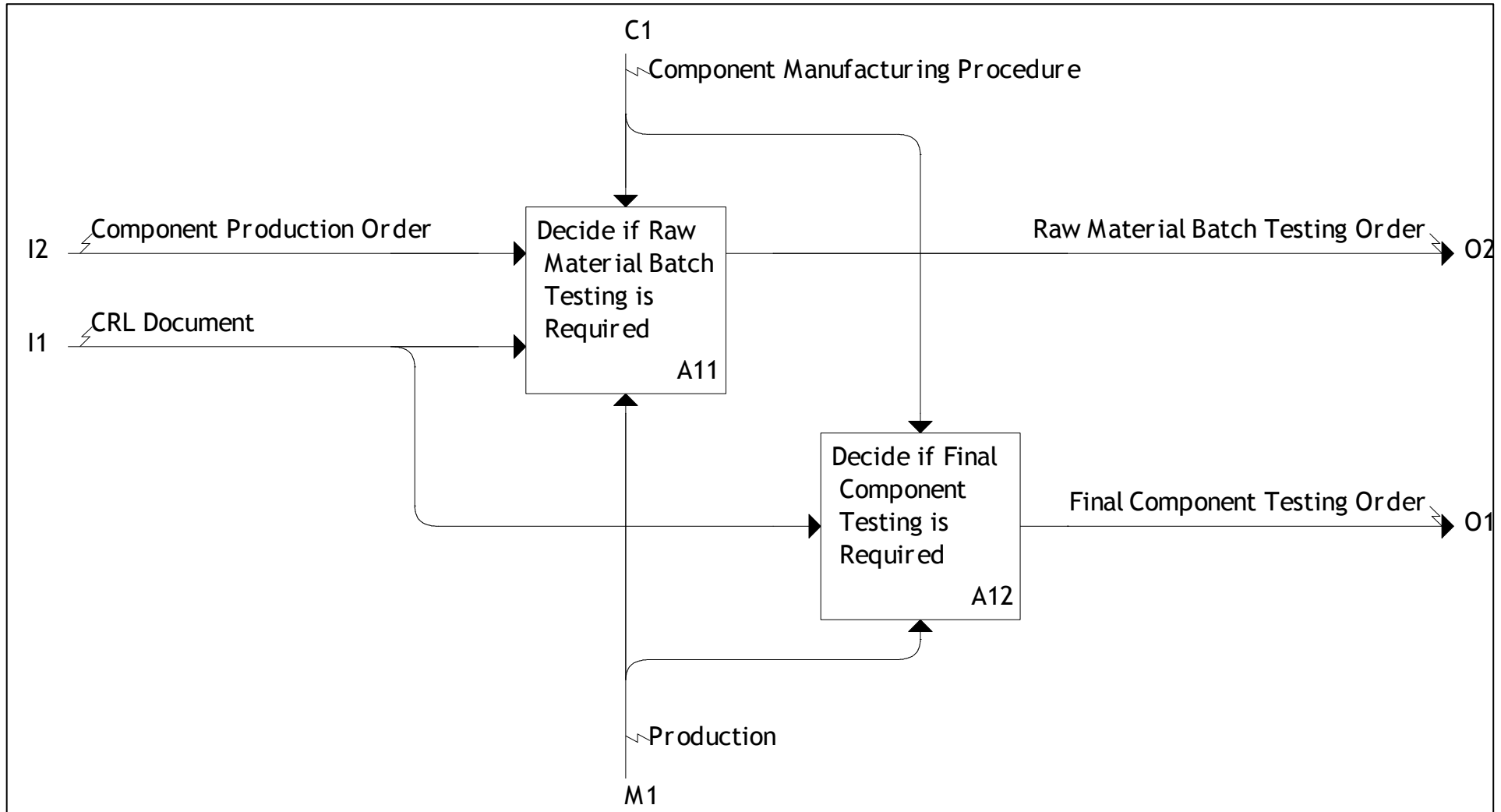


Figure 25: Component Manufacturing Model Level 1x

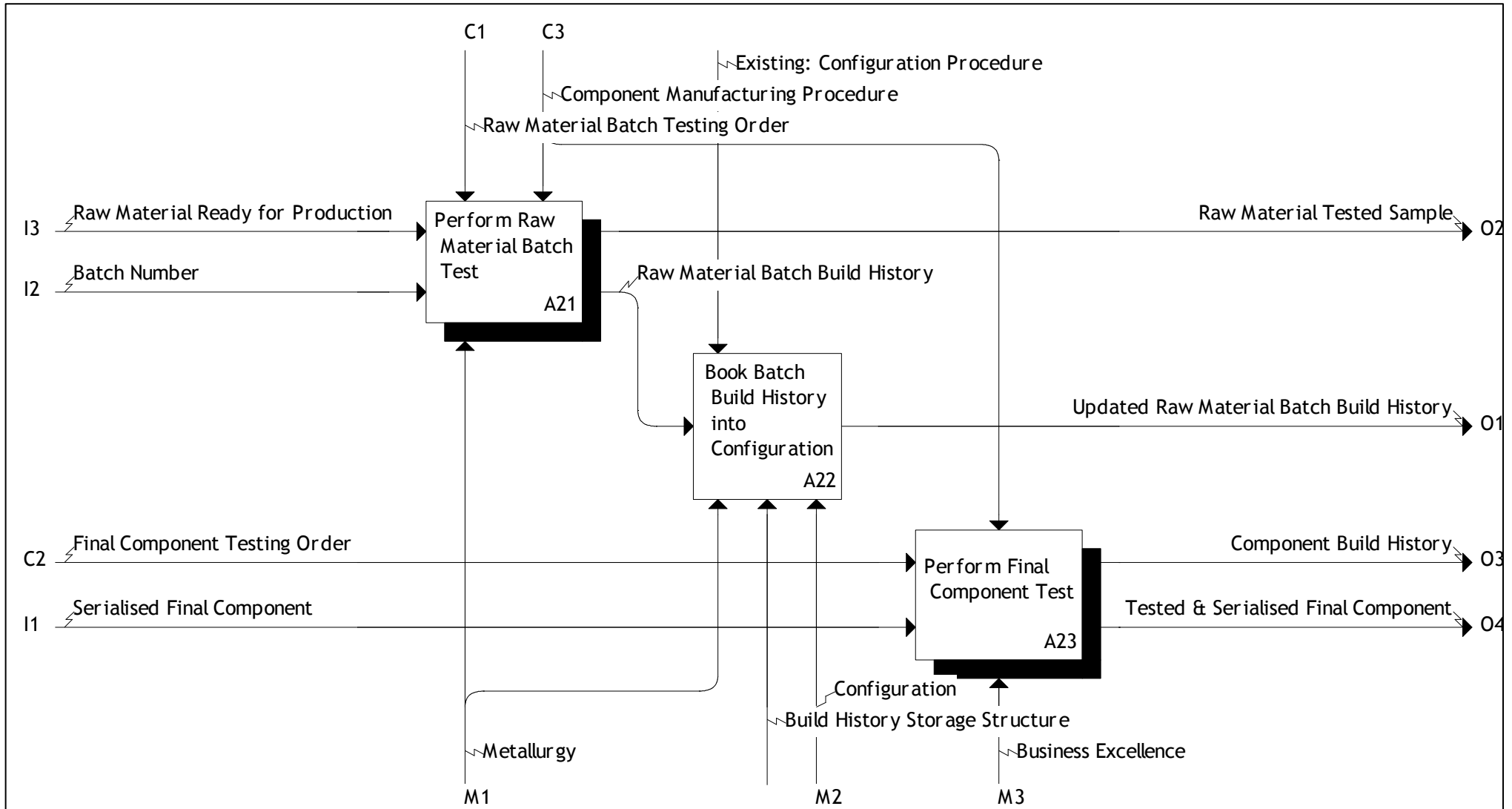


Figure 26: Component Manufacturing Model Level 2x



### **8.2.3. Manufacture Component - Perform Testing Functions: Model level 2x**

#### ***A21 - Perform Raw Material Batch Test***

- The raw material batch testing order is received and controls the testing function
- The raw material batch is located and tested
- The batch number of the batch being tested is noted throughout
- Raw Material Batch Build History is generated through the testing procedure

#### ***A22 - Book Batch Build History into Configuration***

- As the Raw Material Batch Build History forms part of the build history documentation of the original batch, the new addition of Material Batch Build History is booked into Configuration
- The Build History is added to the initial raw material batch build history

#### ***A23 - Perform Final Component Test***

- The final component testing order is received
- The component is tested according to the testing order
- Component Build History is generated through the testing procedure

### **8.2.4. Manufacture Component - Perform Raw Material Batch Test: Model level 21x**

#### ***A211 - Select Batch Sample***

- The sample is removed or selected from the raw material batch
- The process is governed by the Testing Order

#### ***A212 - Mark Batch Sample***

- The sample is marked with the batch number of its parent
- The process is governed by the Testing Order

#### ***A213 - Test Batch Sample***

- The sample is tested as in the testing order
- Test results are generated

#### ***A214 - Check Batch Number Marking***

- It is ensured that the Batch number present on the sample is intact
- The process is governed by the Testing Order

#### ***A215 - Document Batch Test Results***

- Test Results are documented appropriately
- The process is governed by the Testing Procedure

#### ***A216 - Link Batch Test Results and Batch Number***

- The batch number of the sample is transferred to the Test Result Documentation
- A new addition to the Raw Material Batch Build History is created
- Through the transferral of the batch number, the Raw Material Batch Build History is serialised and identifiable by the batch number of its parent

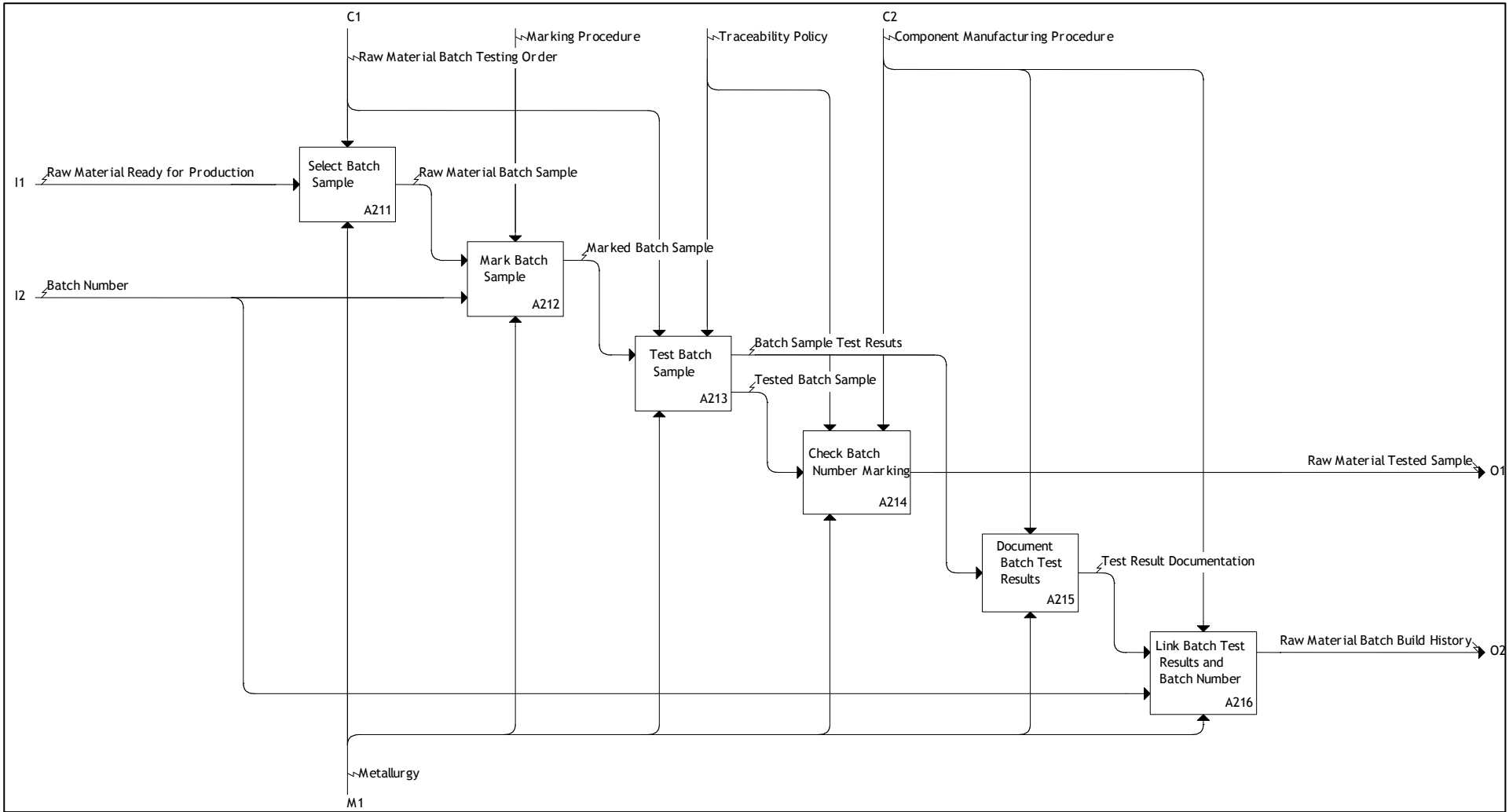


Figure 27: Component Manufacturing Model Level 21x

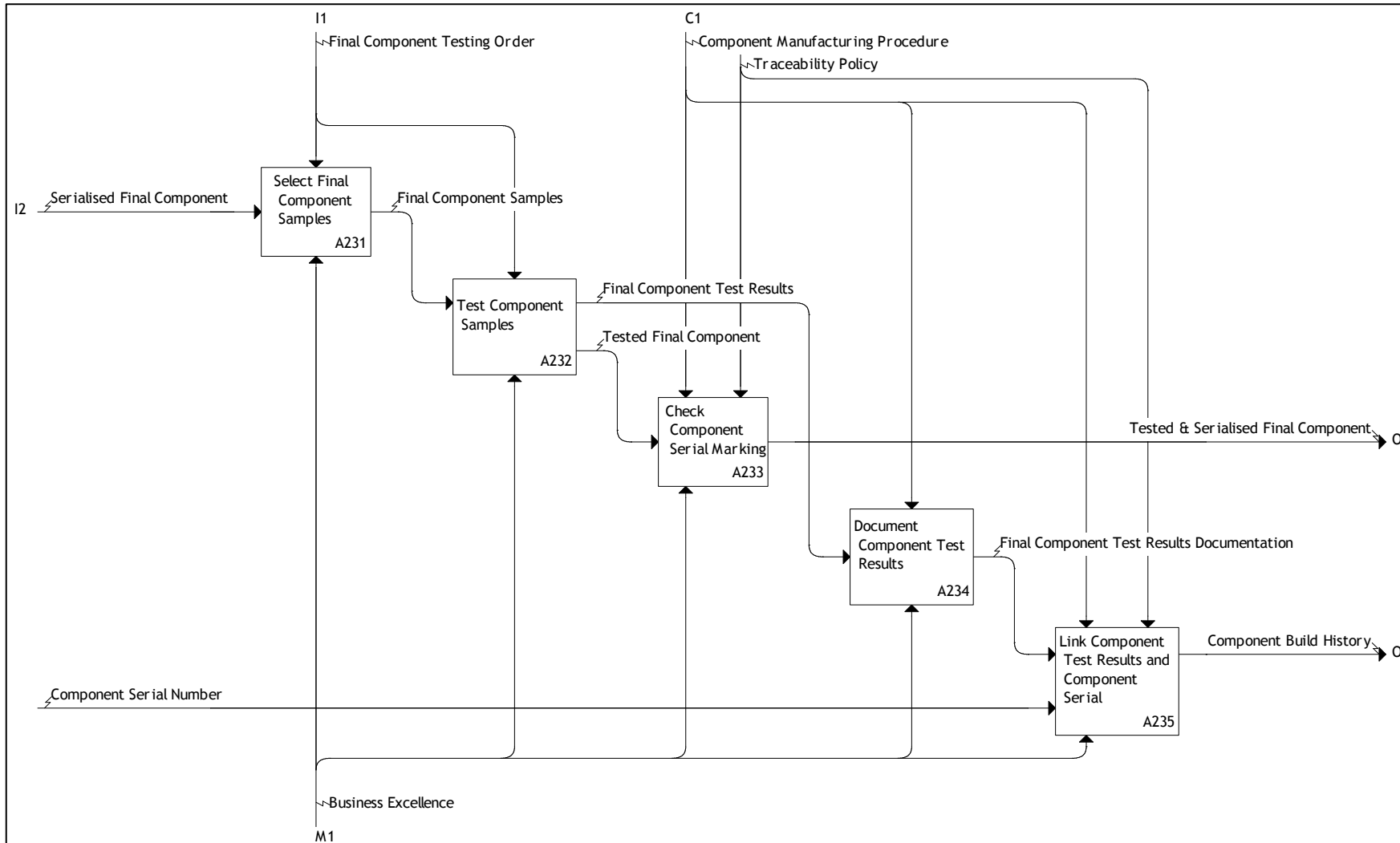


Figure 28: Component Manufacturing Model Level 23x

## **8.2.5. Manufacture Component - Perform Final Component Test: Model level 23x**

### ***A231 - Select Final Component Samples***

- The component sample is selected according to the testing order
- The process is governed by the Testing order

### ***A232 - Test Component Samples***

- The sample component is tested
- Test results are generated

### ***A233 - Check Component Serial Marking***

- The tested component is checked to ensure that the Component Serial Number is still present after the testing has been completed
- The tested piece is returned to Production

### ***A234 - Document Component Test Results***

- Test Results are documented appropriately
- The process is governed by the Manufacturing Procedure

### ***A235 - Link Component Test Results and Component Serial***

- The Component serial number of the component is transferred to the Test Result Documentation
- The Test Result Documentation forms part of the Component Build History
- The Test Result Documentation is identifiable by the Component Serial Number which is allocated to it

## **8.2.6. Manufacture Component - Sever Raw Material Piece: Model level 3x**

### ***A31 - Split Raw Material***

- The part of raw material (which will later become the component) is severed or removed from the raw material batch
- The Component Manufacturing Procedure governs this process which ensures that the batch number of the mother material is transferred to the severed part
- The process generates Build History

### ***A32 - Generate Component Serial Number***

- The Production Foreman uses the batch number present on the raw material part to generate the Component Serial Number
- The Serialisation Information System is used for this activity

### ***A33 - Allocate Component Serial Number to Raw Material Piece***

- The Component Serial Number which have been generated is allocated to the raw material piece
- The material piece is marked through the Marking Procedure
- The Activity results in a serialised raw material piece

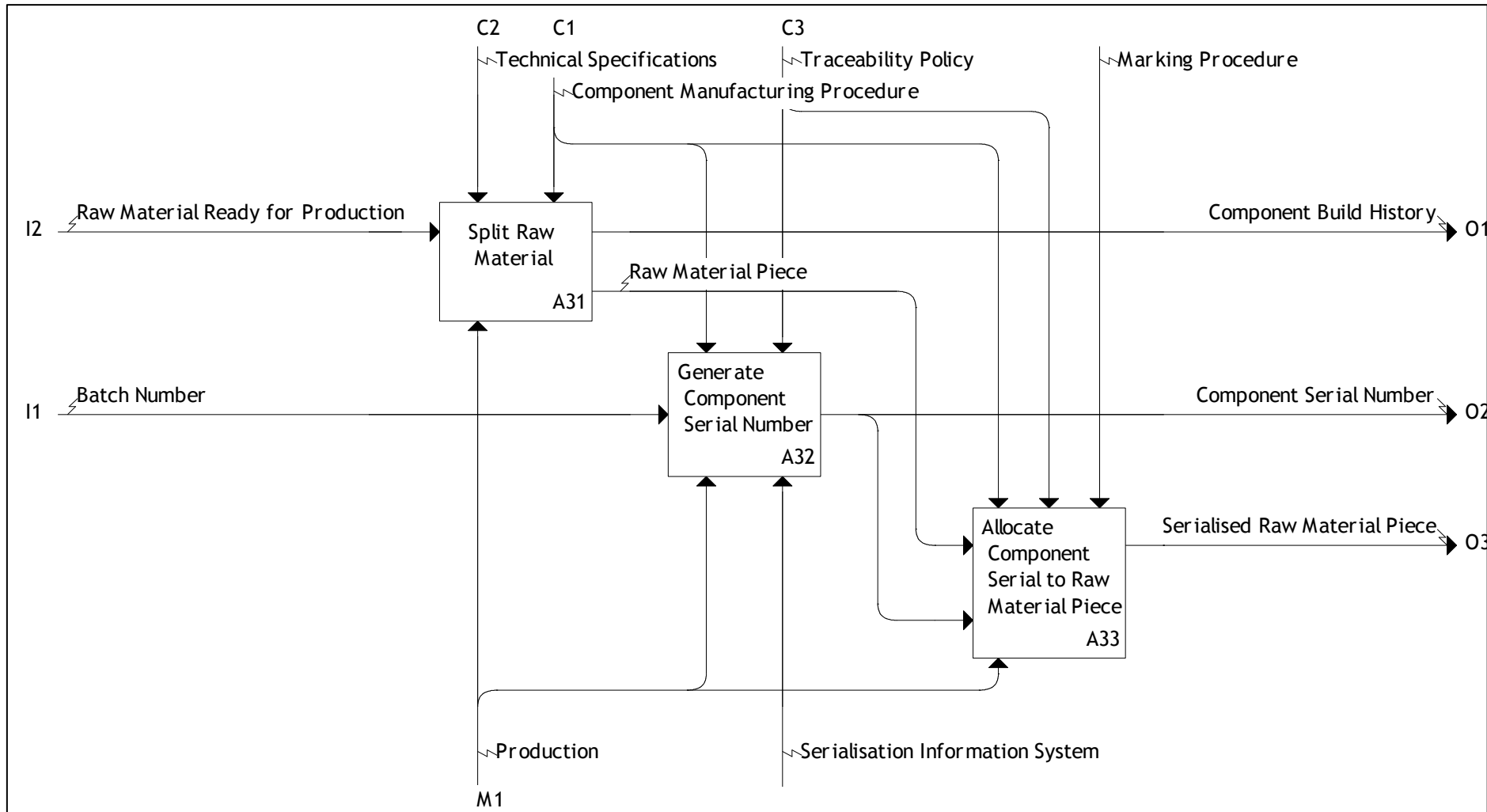


Figure 29: Component Manufacturing Model Level 3x

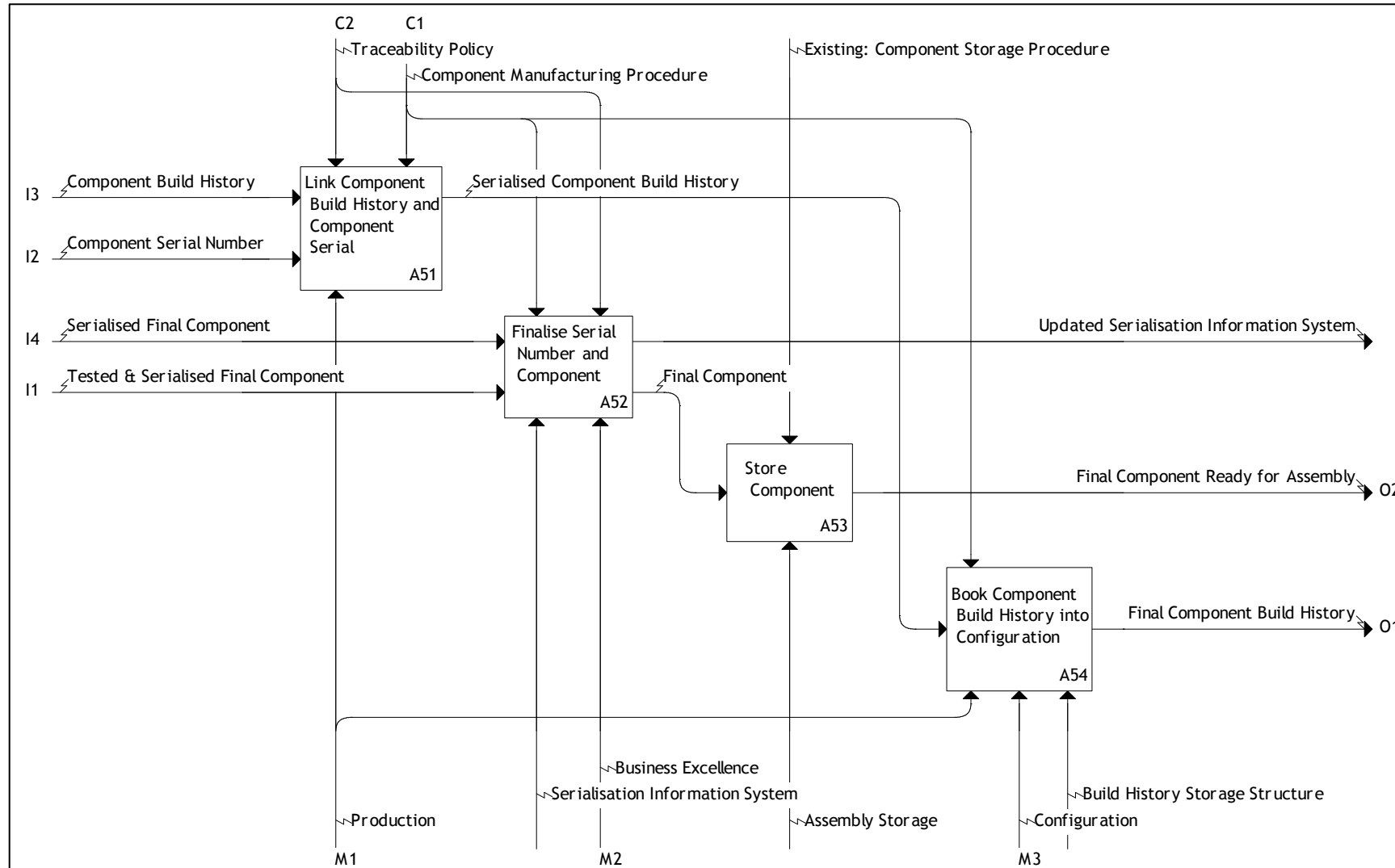


Figure 30: Component Manufacturing Model Level 5x

### 8.2.7. Manufacture Component - Close Component Manufacturing: Model level 5x

#### A51 - Link Component Build History and Component Serial Number

- The Component Build History which have been allocated throughout component realisation is collected
- The Component Serial Number is allocated to all the Component Build History
- The Component Build History becomes identifiable by the Component's Serial Number

#### A52 - Finalise Serial Number and Component

- The Serialised Final Component is inspected by the a Business Excellence representative
- The Serial Number upon the component is checked and confirmed on the Serialisation Information System.

#### A53 - Store Component

- The final component is stored according to the Existing Storage Procedure
- The component becomes ready for assembly

#### A54 - Book Component Build History into Configuration

- The final and serialised component Build History is booked into Configuration
- The Configuration personnel store the documentation according to the Build History Storage Structure specified in Chapter 7

The procedures mentioned throughout these processes will be presented in Chapter 9. The next process which was created will now follow.

### 8.3. COMPONENT RECEIVING PROCESS

To prevent the problems occurring during activities surrounding the receiving of external components, a new set of processes and sub-processes was created. Figure 31 shows the main ICOMs of the process, while Figure 32 shows the decomposition of the different levels of IDEF0 diagrams. From Figure 32, the further expanded levels of IDEF0 models are shown in succeeding Figures 33 to 39. An explanation of each activity will follow the figure of each diagram level.

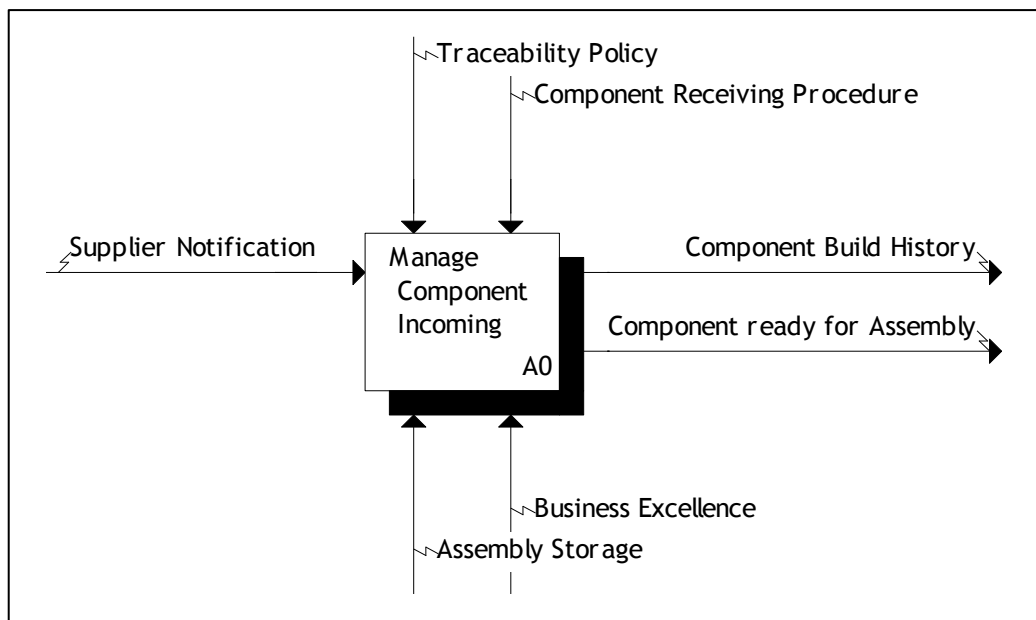


Figure 31: Main Component Receiving ICOMs

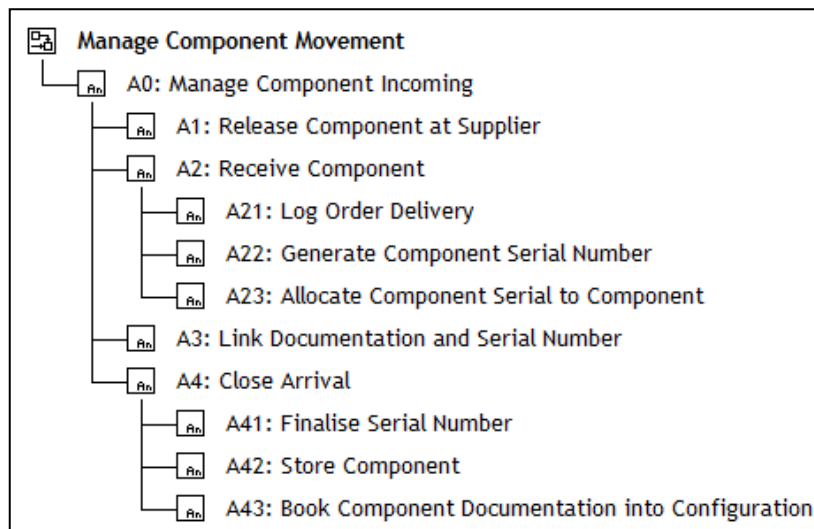


Figure 32: Component Receiving Model Levels

### 8.3.1. Manage Component Incoming: Model level x

#### *A1 - Release Component at Supplier*

- The Supplier notifies the company that the component(s) has been produced
- As an existing sub-process, the Business Excellence department (rather than the Procurement department) visits the Supplier, inspects the component(s) (using the CRL documentation) and releases the component(s) through an existing process (where the Business Excellence department gives the order number of the batch to the Supplier)
- The Business Excellence representative ensures that all required component testing has been performed at the Supplier and that the test results have been documented
- The Business Excellence representative takes the component build history documentation (which had been specified in the ordering process and which includes the test results) from the Supplier and indicates the order number on the documentation
- The Business Excellence representative takes the documentation back to DLS and hands it to the Assembly Storage Foreman
- The Supplier ships the component(s) to DLS, which is accompanied by the order number thereof

#### *A2 - Receive Component*

- Assembly Storage receives the component(s) with its accompanied order number
- The component(s) is serialised with a full serial number

#### *A3 - Link Documentation and Serial Number*

- The Component Build History documentation and the serial number is linked so as to connect the serial number with its specific documentation
- Build History Documentation is serialised and is identifiable by the serial number of the component

#### *A4 - Close Arrival*

- The arrival of the component is finalised and closed
- The component is stored
- The Build History Documentation is saved



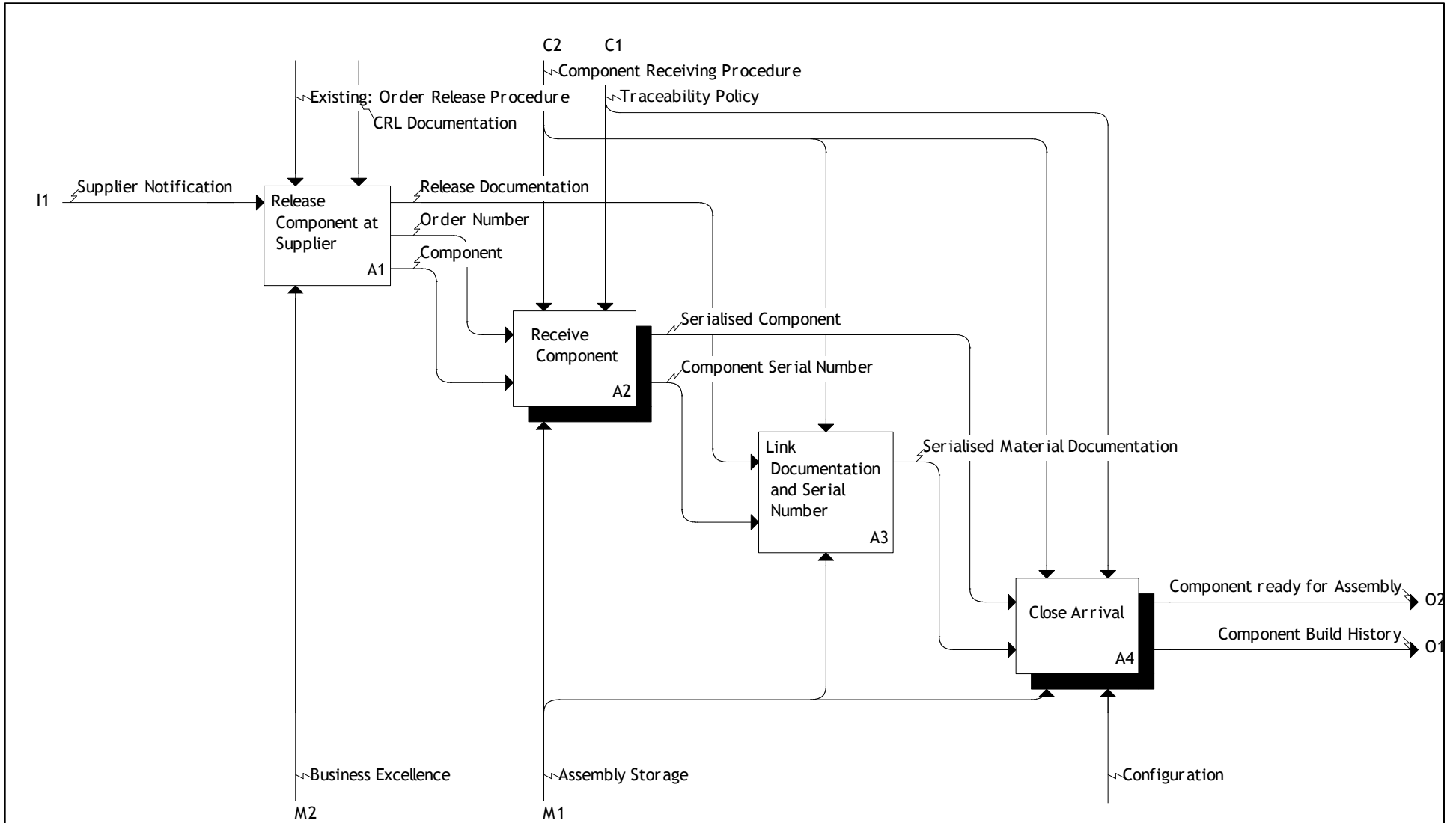


Figure 33: Component Receiving Model Level x

### **8.3.2. Manage Component Incoming - Receive Component: Model level 2x**

#### ***A21 - Log Order Delivery***

- Assembly Storage receives the component(s) with its accompanied order number
- The Assembly Storage Foreman logs the received order onto the existing order database by means of the accompanied order number
- The order database notifies the storage foreman whether the received component(s) must be serialised (this data must be included during the existing procurement process)

#### ***A22 - Generate Serial Number***

- The Foreman generates the serial number using the proposed Serialisation Information System
- The Serialisation Information System will produce a unique serial number with the format "AAAA000" (see Chapter 6)

#### ***A23 - Allocate Component Serial to Component***

- The received component(s) is marked with the newly acquired serial number
- The Component Receiving Procedure and Marking Procedure must be followed with regards to this

### **8.3.3. Manage Component incoming - Close Arrival: Diagram level 4x**

#### ***A41 - Finalise Serial Number***

- The serialised documentation and component are received
- The serial number on the component and on the documentation is verified to ensure that the two numbers align
- The serial number is verified and finalised on the Serialisation Information System

#### ***A42 - Store Component***

- The component is stored following the existing Storage Procedure

#### ***A43 - Book Component Documentation into Configuration***

- The Assembly Storage Foreman books the material documentation in at Configuration
- The Configuration personnel stores the documentation using the existing Configuration procedure and the proposed Build History Storage Structure specified in Chapter 7

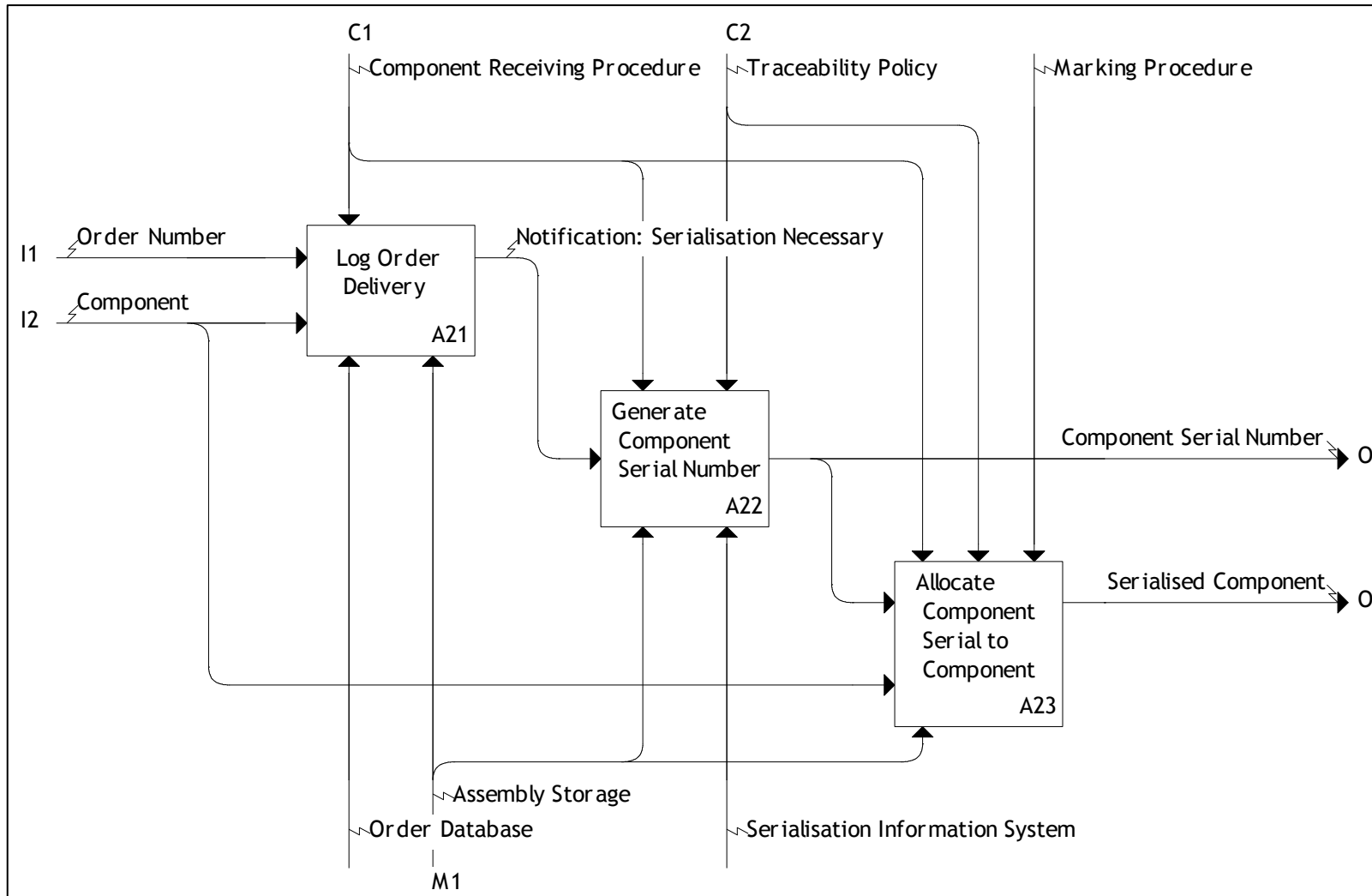


Figure 34: Component Receiving Model Level 2x

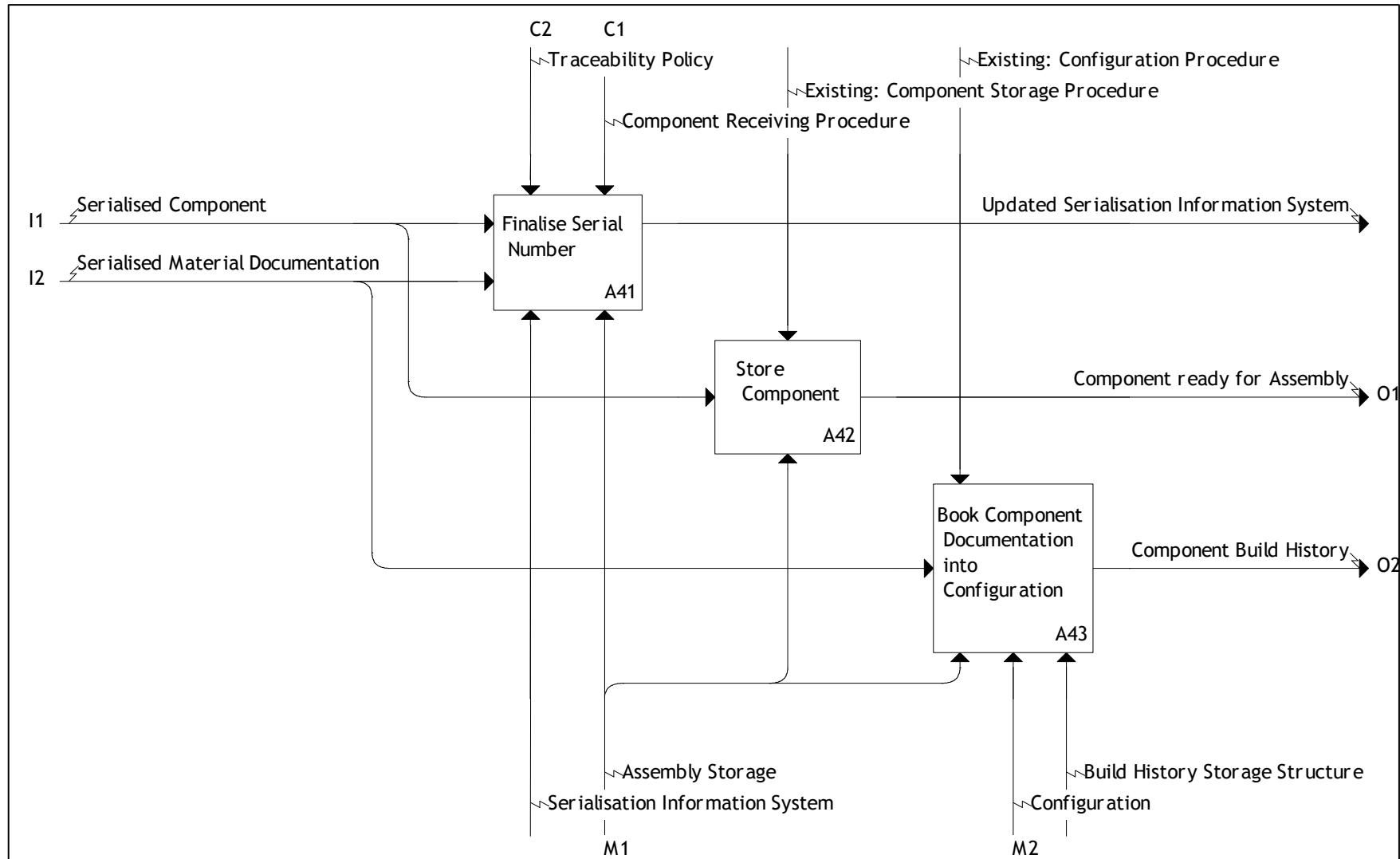


Figure 35: Component Receiving Model Level 4x

#### 8.4. PRODUCT ASSEMBLY PROCESS

To prevent the problems occurring during activities surrounding the assembly of final products, a new set of processes and sub-processes was created. Figure 36 shows the main ICOMs of the process, while Figure 37 shows the decomposition of the different levels of IDEF0 diagrams. From Figure 37, the further expanded levels of IDEF0 models are shown in succeeding Figures 38 to 42. An explanation of each activity will follow the figure of each diagram level.

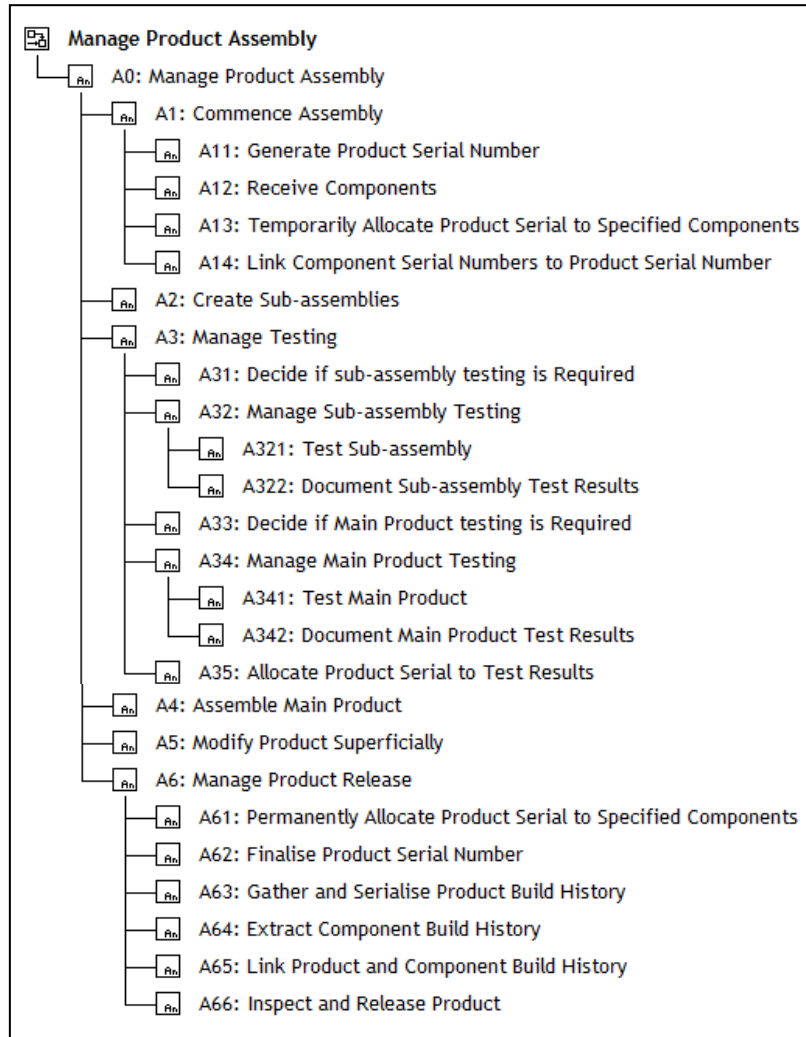


Figure 36: Product Assembly Model Levels

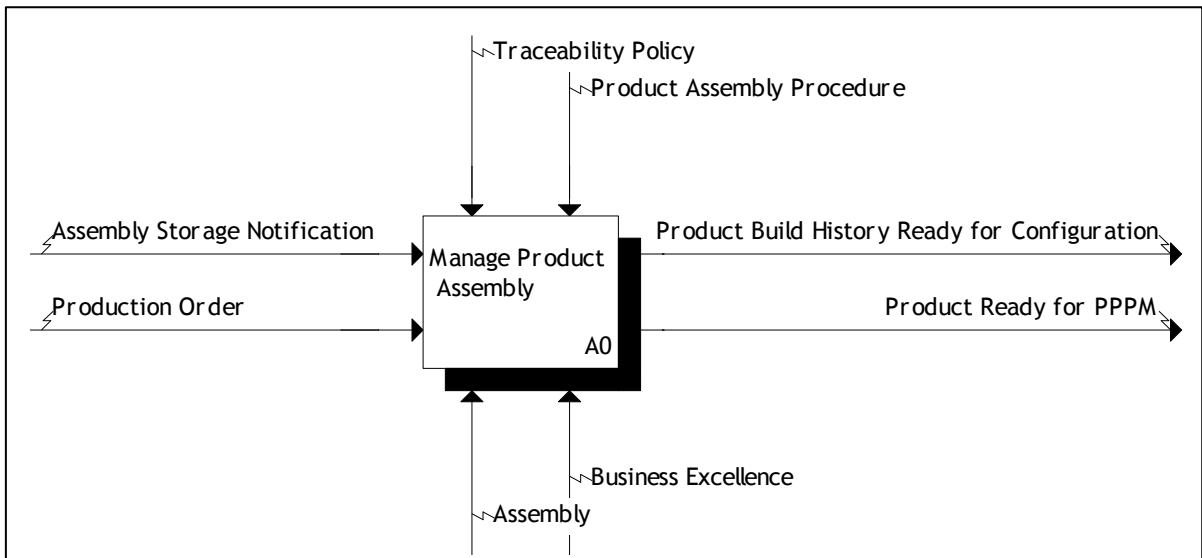


Figure 37: Main Product Assembly ICOMs

#### 8.4.1. Manage Product Assembly: Model level x

##### A1 - Commence Assembly

- The Assembly Foreman is notified that the components of a product have been released by the Assembly Store
- The Assembly Foreman receives a Product Production Order specifying details surrounding the assembly of a product
- The components are received onto the assembly floor
- The Product Serial Number is generated and allocated to certain components according to specifications

##### A2 - Create Sub-assemblies

- The various sub-assemblies forming part of the final assembly are created according to specifications
- Product build history is created during this phase

##### A3 -Manage Testing

- At various stages of product realisation, it is determined whether product testing is required
- Whenever necessary, the product or a sub-assembly is tested
- Through testing, product build history is accumulated

##### A4 -Assemble Main Product

- By assembling the various sub-assemblies of a product, the main product is created
- Product build history is generated in this phase

##### A5 - Modify Product Superficially

- The main product receives all final necessary surface treatments as specified in Technical Specifications

##### A6 - Manage Product Release

- The Product Serial Number is allocated to the final product
- The Product Serial Number is checked and finalised
- Product build history documentation is gathered and serialised
- The build history documentation of the components is joined with the build history documentation of the Product
- The Final Product is inspected and released

#### **8.4.2. Manage Product Assembly - Commence Assembly: Model level 1x**

##### ***A11 - Generate Product Serial Number***

- The Assembly Foreman is notified that the components of a product have been released by Assembly Storage. This is done by means of the existing Production Schedule information system
- The Assembly Foreman receives a Product Production Order containing various significant details regarding the manufacturing of a Product
- Using the Serialisation Information System, a Product Serial Number is generated. This Number will be in the form of "AAA000"

##### ***A12 - Receive Components***

- The released components are received onto the assembly floor. This will be the components forming the product, such as a tank or a rifle

##### ***A13 - Temporarily Allocate Product Serial to Specified Components***

- The Product Serial Number is temporarily allocated to the specified components
- The Technical Specifications determine where, how and on which components a product serial number must be placed

##### ***A14 - Link Component Serial Numbers to Product Serial Number***

- The serial numbers of the components and the Product Serial Number of the Product are linked on the Serialisation Information System. The components become a child of the product or assembly, and linking the serial numbers will support this principle.

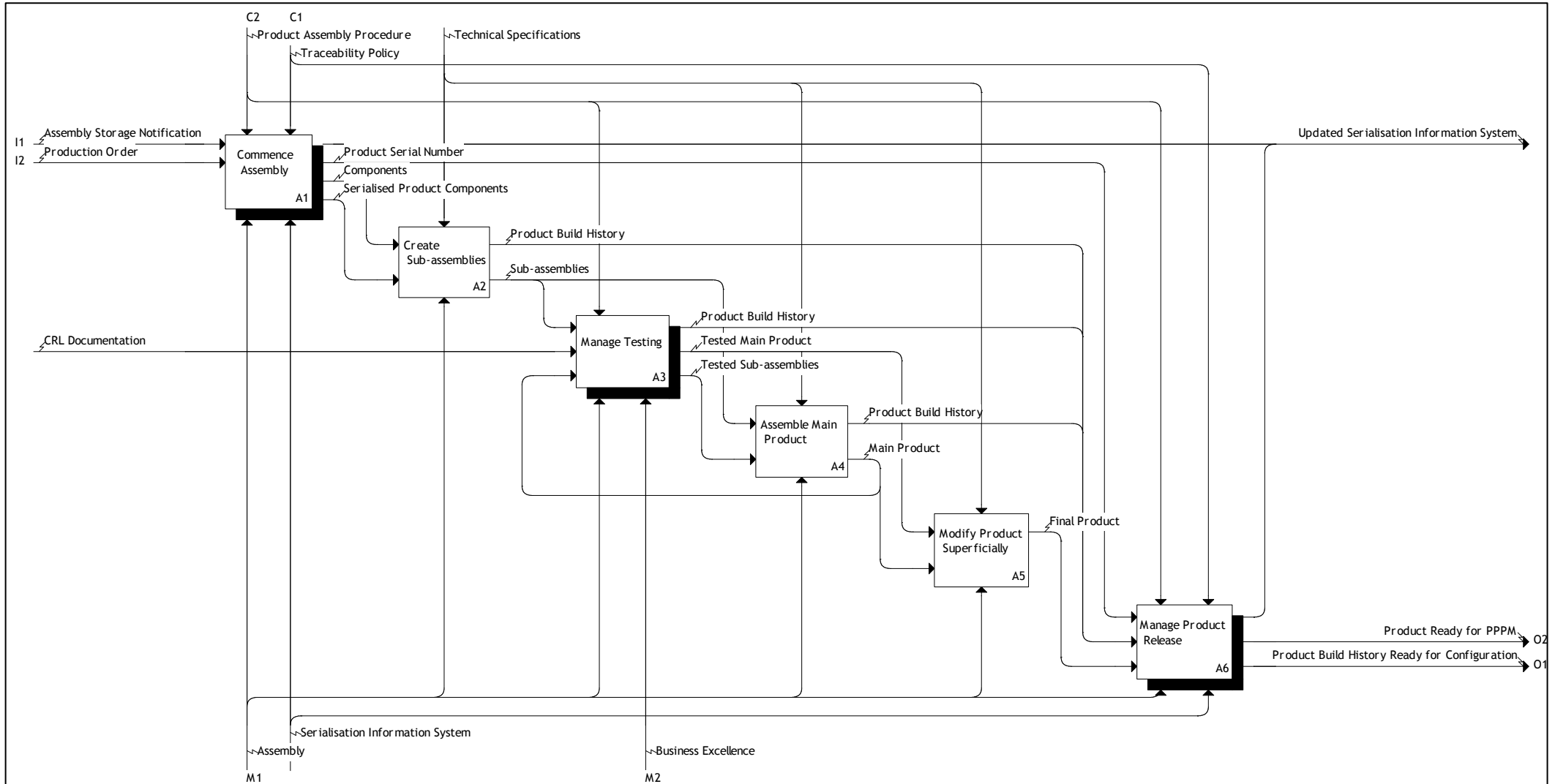


Figure 38: Product Assembly Model Level x



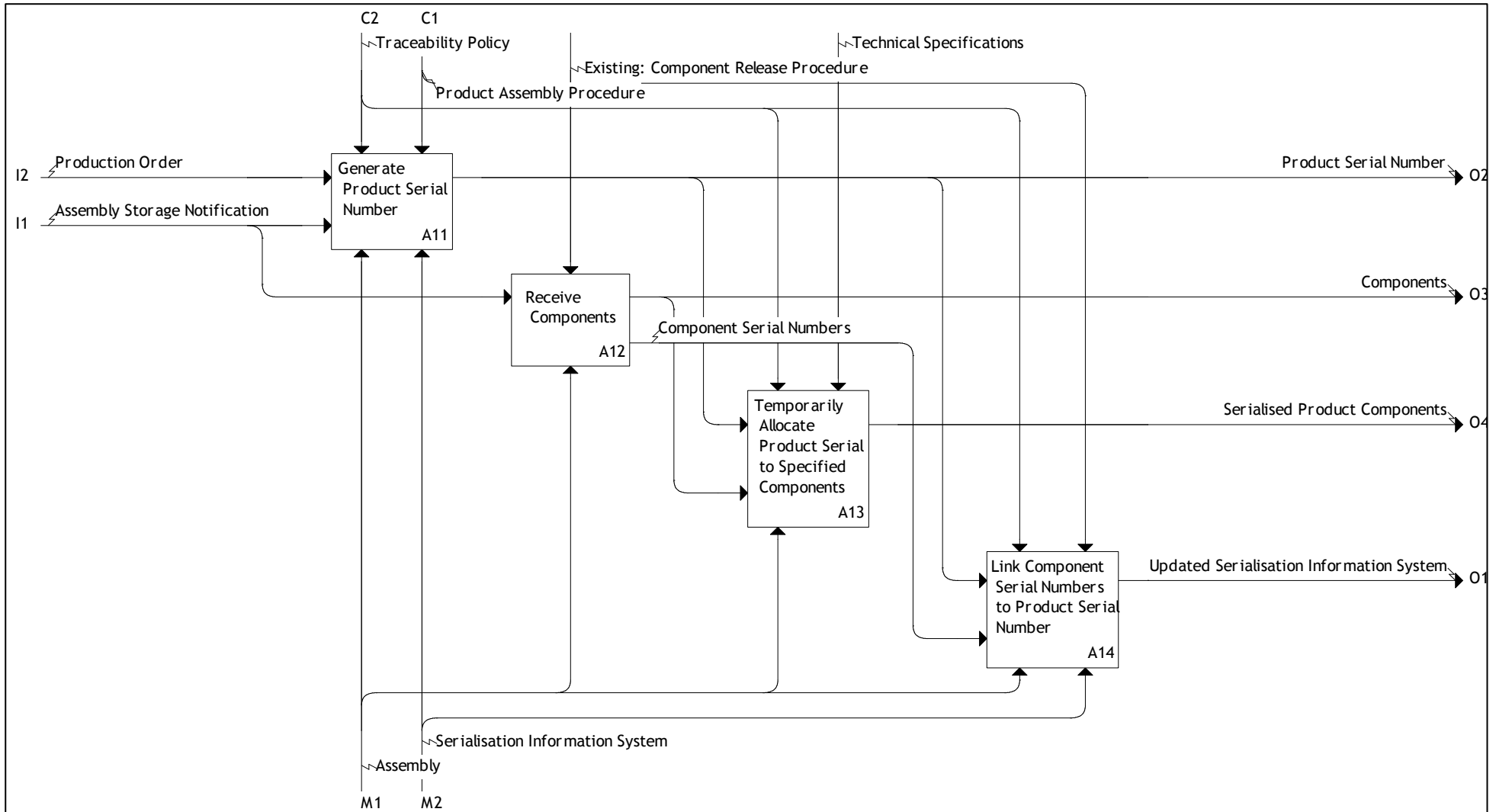


Figure 39: Product Assembly Model Level 1x

#### **8.4.3. Manage Product Assembly - Manage Testing: Model level 3x**

##### ***A31 - Decide if Sub-assembly testing is required***

- Using the CRL documentation, it is determined whether testing of any of the sub-assemblies are necessary or required
- If testing is required, a Sub-assembly testing order is created by the Assembly Foreman

##### ***A32 - Manage Sub-assembly Testing***

- The Sub-assembly Testing Order is used to carry out the testing of the respective sub-assemblies
- Assembly carries out the tests and test results are generated through this process

##### ***A33 - Decide if Main Product Testing is required***

- Using the CRL documentation, it is determined whether the testing of the Main product is necessary or required
- If testing is required, a Main Product testing order is created by the Assembly Foreman and given to the Business Excellence department

##### ***A34 - Manage Main Product Testing***

- The Main Product Testing Order is used to carry out the testing of the respective sub-assemblies
- Business Excellence carries out the tests and test results are generated through this process

##### ***A35 - Allocate Product Serial to Test Results***

- The various documented test results are allocated the Product Serial Number of the product which have been tested
- The documentation become identifiable by the serial number of the product

#### **8.4.4. Manage Product Assembly - Manage Sub-assembly Testing: Model level 32x**

##### ***A321 - Test Sub-assembly***

- The Sub-assembly Testing Order is received together with the related sub-assembly
- The Sub-assembly is tested according to the Testing Order
- Test results are generated through the testing procedure

##### ***A322 - Document Sub-assembly Test Results***

- The generated test results are documented as Sub-assembly Test Results and form part of Product build history

#### **8.4.5. Manage Product Assembly - Manage Main Product Testing: Model level 34x**

##### ***A341 - Test Main Product***

- The Main Product Testing Order is received together with the Main Product
- The Main Product is tested according to the Testing Order
- Test results are generated through the testing procedure

##### ***A342 - Document Main Product Test Results***

- The generated test results are documented as Product Test Results and form part of Product build history

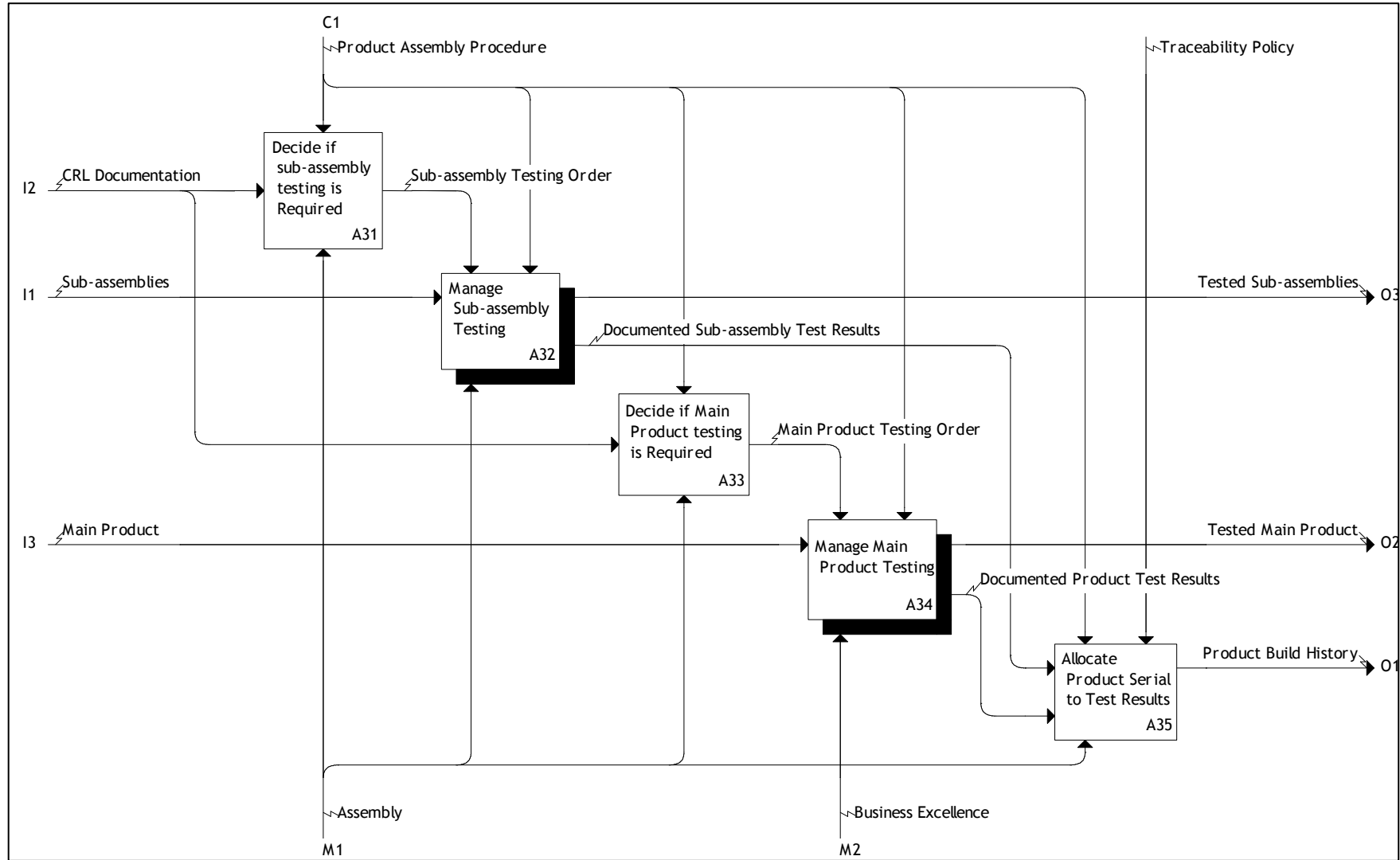


Figure 40: Product Assembly Model Level 3x

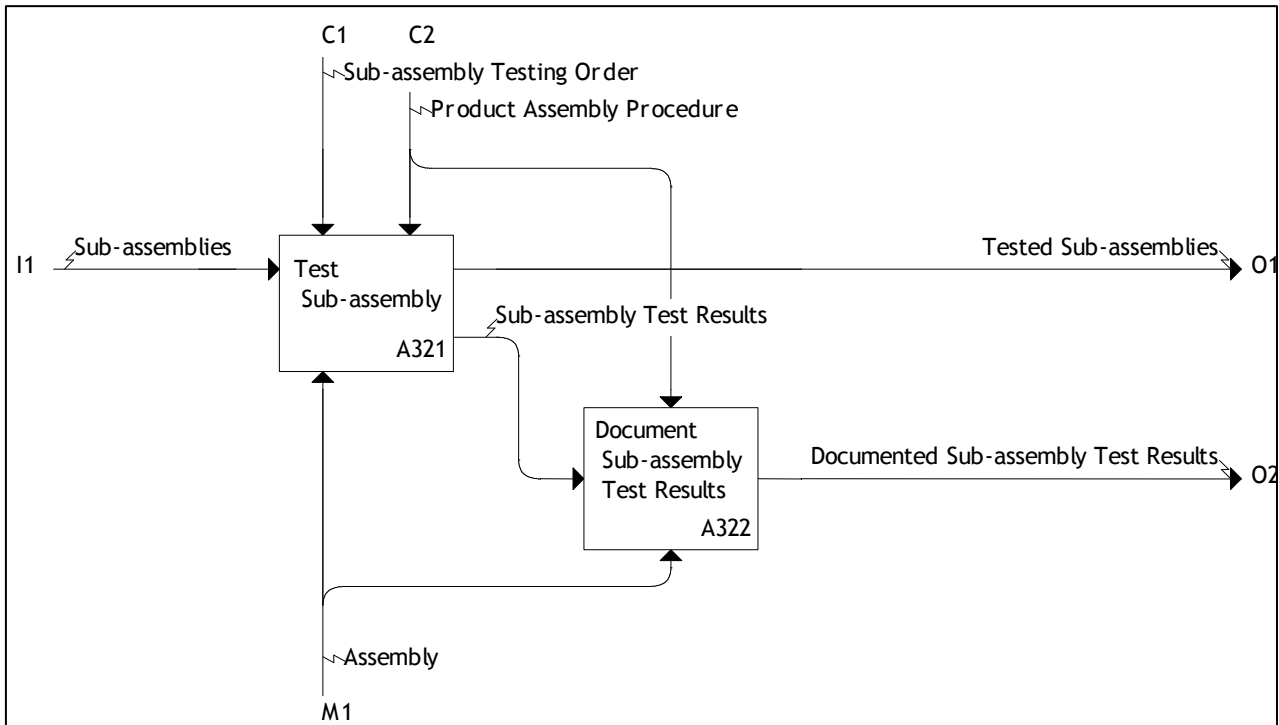


Figure 41: Product Assembly Model Level 32x

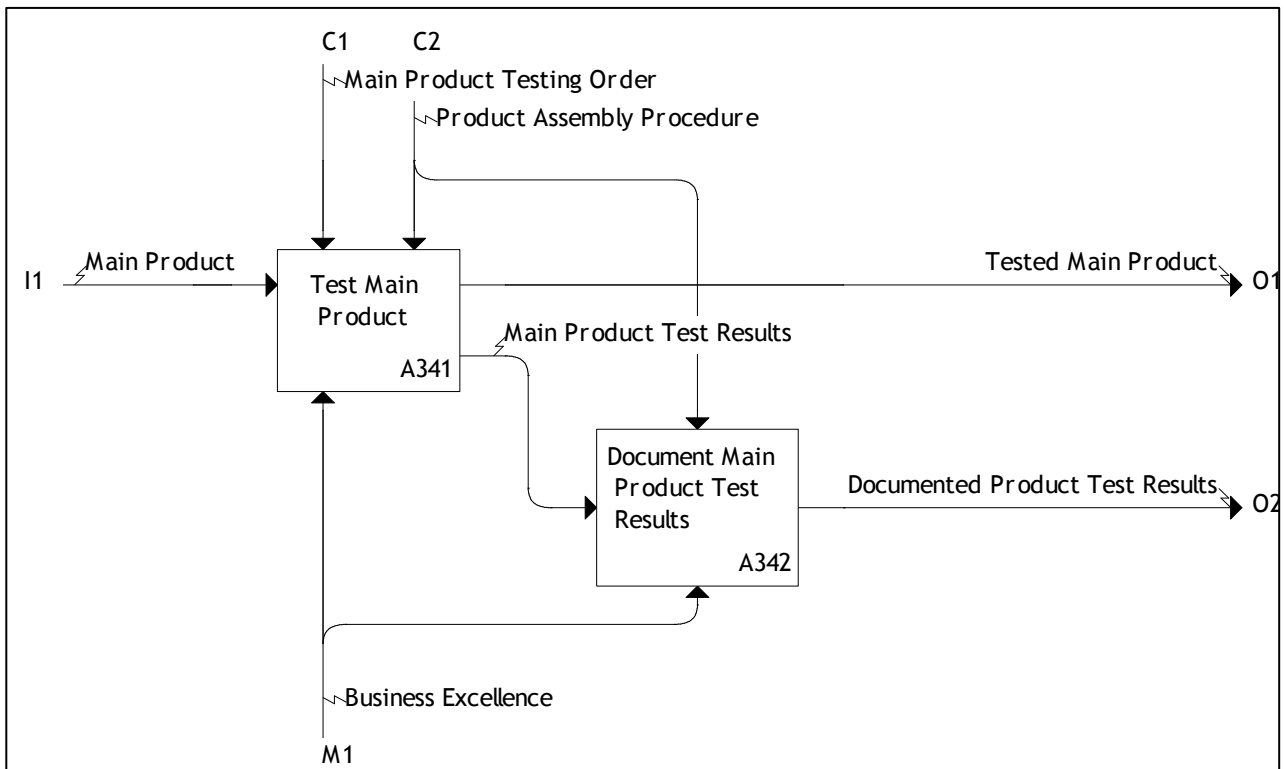


Figure 42: Product Assembly Model Level 34x

#### **8.4.6. Manage Product Assembly - Manage Product Release: Model level 6x**

##### ***A61 - Permanently Allocate Product Serial to Specified Components***

- The temporary Product Serial Number is replaced by a permanent Serial Number Marking. The Product Serial Number is permanently attached onto the Product.

##### ***A62 - Finalise Product Serial Number***

- The Product Serial Number is checked and confirmed on the Serialisation Information System

##### ***A63 - Gather and Serialise Product Build History***

- All the accumulated Product build history is collected
- It is ensured that the Product build history is complete
- The Product Serial Number is finally allocated onto the Product build history

##### ***A64 - Extract Component Build History***

- Using the parent-child structure of the Product (within the Serialisation Information System) and the Build History Storage Structure, the build history Documentation of all the components are retrieved
- As a result, all the documentation of the components forming part of the Product is retrieved

##### ***A65 - Link Product and Component Build History***

- The build history Documentation of the components is joined with the build history Documentation of the Product
- The Product build history becomes the parent of the Components' build history
- The Product Serial Number is allocated onto the build history and the Consolidated build history Documentation becomes identifiable by the Product Serial Number and is ready to be placed into Configuration

##### ***A66 - Inspect and Release Product***

- The Final Product is inspected and released
- The Product is sent to Packaging for PPPM

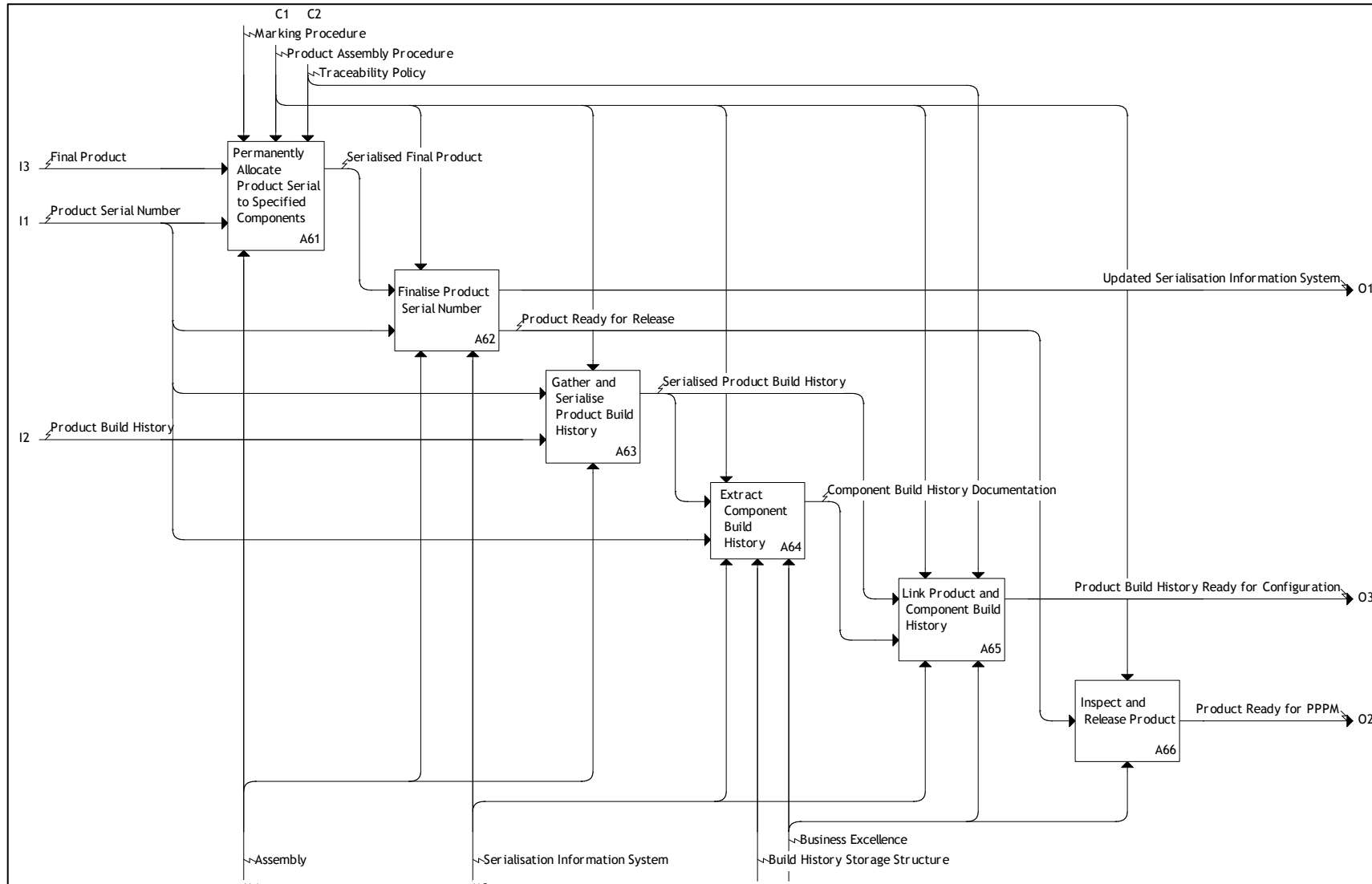


Figure 43: Product Assembly Model Level 6x

## **9. SOLUTION: TRACEABILITY PROCEDURES**

The procedures enabling the Traceability Processes will now be presented. These procedures must be followed whenever indicated in the Traceability Processes and will be relevant to the employees performing the specific tasks. If these procedures are followed correctly, traceability will be maintained in an effortless manner. Only the main content of the procedures will be presented in the report. The full documentation, as presented to DLS, is available in Appendix B to E.

### **9.1. RAW MATERIAL RECEIVING PROCEDURE**

#### **9.1.1. Purpose**

The Raw Material Receiving Procedure will guide the process of receiving raw material batches from a supplier. The procedure will ensure that traceability is maintained with regards to raw materials and will assist the relevant employees in conducting warehouse operations properly.

#### **9.1.2. Procedure Responsibility**

The maintenance of the Procedure is the responsibility of the Business Excellence Department and the Business Excellence Department must insure adherence to the procedure. The onus however lies on each Warehouse Employee to follow the procedure as specified.

#### **9.1.3. Applicable Documents**

- Procedure for the Compilation and Registration of a CRL (Existing Procedure)
- Build History Record System Procedure (Existing Configuration Procedure)
- Procedure for Releasing an Order at Supplier (Existing Procedure)
- Raw Material Storage Procedure (Existing Procedure)
- Traceability Policy
- Marking Procedure

#### **9.1.4. Procedure**

##### ***Assumptions***

Before the procedure commence, it is assumed that a Business Excellence Representative has inspected and released a raw material order at the Supplier. It is further assumed that the Business Excellence Representative has allocated the correct order and part number to the raw material batch as well as the Release Documentation. It is finally assumed that the Procurement Agent has logged the Serialisation necessity of the order onto the Order Database.

##### ***Steps to follow***

- Step 1: The Warehouse (Storage) Foreman receives the Release Documentation (with the order and part number on it) from the Business Excellence Representative.
- Step 2: The Warehouse Foreman files the Release Documentation at Warehouse Administration.
- Step 3: The Warehouse receives the Raw Material Batch (accompanied by its part and order number) at the Warehouse Receiving end.
- Step 4: The Warehouse Foreman extracts the Release Documentation with the identical order number from Warehouse Administration.
- Step 5: The Warehouse Foreman uses the order number to log the delivery of the Material Batch on the order database.
- Step 6: The order database presents a notification which specifies whether the Material Batch must be traceable or not.  
If no traceability is required, proceed directly to Step 14 and end at Step 15.
- Step 7: The Warehouse Foreman uses the Serialisation Information System to generate a Material Batch Number.
- Step 8: The Warehouse Foreman documents the Material Batch Number and ensures that it has been documented correctly.

- Step 9: The Warehouse Foreman moves a copy of the documented Material Batch Number to the physical Material Batch and orders a Warehouse Employee to transfer the Batch Number onto the Material.
- Step 10: A Warehouse Employee transfers the Batch Number onto the Material Batch by following the Marking Procedure.
- Step 11: The Warehouse Foreman takes the same documented Material Batch Number and transfers it onto the Release Documentation.  
The Release Documentation must be clearly identifiable by the Batch Number only.
- Step 12: The Warehouse Foreman checks that the Release Documentation and the Material Batch contains identical Batch Numbers.
- Step 13: The Warehouse Foreman notifies the Serialisation Information System that the Batch Numbers have been checked.
- Step 14: The Warehouse Foreman orders that the Raw Material Pieces are stored.
- Step 15: Warehouse Employees store the Raw Material Pieces by following the existing Raw Material Storage Procedure.
- Step 16: The Warehouse Foreman books the initial Release Documentation into Configuration.
- Step 17: Configuration stores the Documentation by following the Configuration Procedure and the Proposed Build History Storage Structure.



## 9.2. COMPONENT MANUFACTURING PROCEDURE

### 9.2.1. Purpose

The Component Manufacturing Procedure will guide the processes followed during the production of a component. The procedure will ensure that traceability is maintained throughout every manufacturing phase and it will assist the relevant employees in upholding traceability operations properly.

### 9.2.2. Procedure Responsibility

The maintenance of the Procedure is the responsibility of the Business Excellence Department and the Business Excellence Department must insure adherence to the procedure. The onus however lies on each Warehouse and Metallurgy Employee to follow the procedure as specified.

### 9.2.3. Applicable Documents

- Procedure for the Compilation and Registration of a CRL (Existing Procedure)
- Build History Record System Procedure (Existing Configuration Procedure)
- Component Storage Procedure (Existing Procedure)
- Traceability Policy
- Marking Procedure

### 9.2.4. Procedure

#### *Assumptions*

Before the procedure commences, it is assumed that the Raw Material Receiving Procedure has been followed and that the relevant raw material contains a Batch Number. It is further assumed that the Release Documentation of the applicable Raw Material Batch is saved correctly at Configuration by following the Configuration Procedures and the Build History Storage Structure. Finally, the realistic assumption is made that all Production Employees are aware of the fact that Build History is generated throughout the realisation of a Component.

#### *Steps to follow*

##### *Step 1: Production Commences*

- 1.1 The Production Foreman receives the order to produce a component together with the required Raw Material.
- 1.2 The Production Foreman uses the CRL document to decide whether the Raw Material Batch, which will be used for production, needs to undergo additional tests.
- 1.3 If it is decided that testing is required, Production compiles a Testing Order specifying the tests which must be performed.  
If no testing is necessary, the process proceeds to Step 3.
- 1.4 Production gives the Testing Order to Metallurgy.

##### *Step 2: Perform Raw Material Batch Tests*

- 2.1 The Metallurgist receives the Testing Order.
- 2.2 The Metallurgist takes an appropriate sample(s) from the Raw Material Batch.  
The Metallurgist shall ensure that the Batch Number on the Raw Material is not removed from the mother piece when taking the sample. For example, if the Batch Number is located at End A of a casting, he may not remove the sample from End A, but rather End B. This will ensure that the Batch Number on the casting is not lost due to testing.
- 2.3 The Metallurgist documents the precise and full Batch Number of the Raw Material Batch he is testing.
- 2.4 The Metallurgist transfers the written Batch Number onto the Sample. This must be done immediately and by following the Marking Procedure.
- 2.5 The Metallurgist performs the required tests on the Sample.

- 2.6 The Metallurgist checks that the Batch Number is still intact on the Sample, as the testing procedure could have removed it.
- 2.7 The Metallurgist documents the Test Results.
- 2.8 The Metallurgist links the Documentation and Sample by transferring the Batch Number onto the Documentation.  
The Batch Number must be indicated clearly on the Documentation.
- 2.9 The Metallurgist books the Documentation in at Configuration.  
The Documentation shall be booked as part of the Documentation belonging to the Raw Material Batch and not as part of any particular component.  
The Documentation must be identifiable by the Batch Number only.  
The Configuration Procedure and the Build History Storage Structure must be followed.

*Step 3: Sever Raw Material Piece from Mother Material*

- 3.1 The Production Foreman gives clear production orders to the Artisan / Production Employee.
- 3.2 After receiving the applicable production orders, the Artisan locates the Raw Material Batch which must be used for the manufacturing of the component.
- 3.3 The Artisan removes the required Raw Material Piece from the Mother Material Batch or Piece.  
The Artisan shall take care not to remove the Batch Number from the Mother Batch in the process. For example, if the Batch Number is located at End A of a casting, he may not remove the Material Piece from End A, but rather End B. This will ensure that the Batch Number of the casting is not lost during production.
- 3.4 The Artisan immediately documents the Batch Number of the Mother Piece correctly and takes it to the Production Foreman.
- 3.5 The Production Foreman takes the Batch Number from the Artisan and, using the Serialisation Information System, generates a Component Serial Number for the newly-severed Material Piece.
- 3.6 The Production Foreman immediately documents the Component Serial Number and hands it to the Artisan.
- 3.7 Following the Marking Procedure, the Artisan transfers the Component Serial Number onto the Material Piece correctly.
- 3.8 The Artisan notifies the Production Foreman of the successful transferral of the Serial Number onto the Material Piece.

*Step 4: Create Final Component*

- 4.1 The Artisan takes the Serialised Raw Material Piece and performs all required manufacturing, machining and surface operations onto the piece until it is transformed into a complete component.
- 4.2 All Artisans must ensure that the Component Serial Number remains on the component throughout the entire production phase.  
To aid in this, the Component Serial Number must be documented before any manufacturing operation is performed. For example, the Artisans must ensure that the numbers are not machined off and if it is machined off, it must be replaced immediately.
- 4.3 Throughout manufacturing, all Build History Documentation which may be created must have the applicable Component Serial Number on it and must be kept in the temporary Build History folder of the Production Foreman.  
All generated Build History Documentation must be identifiable by the Component Serial Number only.

*Step 5: Final Component Testing Decision*

- 5.1 After the component has been manufactured, the Production Foreman uses the CRL Document to decide whether the component must undergo Final Testing.
- 5.2 If it is decided that Final Testing is required, the Production Foreman creates a Final Component Testing Order and hands it to the Business Excellence Representative.  
If no further testing is required, proceed directly to Step 7.

*Step 6: Perform Final Component Test*

- 6.1 The Business Excellence Representative receives the Final Component Testing Order.
- 6.2 The Business Excellence Representative chooses an applicable sample(s) based on the Testing Order.
- 6.3 The Business Excellence Representative documents the Component Serial Number of the Component Sample(s).
- 6.4 The Business Excellence Representative performs the required tests on the Sample(s).
- 6.5 The Business Excellence Representative checks that the Component Serial Numbers are still intact after the testing has been completed.
- 6.6 The Business Excellence Representative documents the test results correctly and in full.
- 6.7 The Business Excellence Representative links the Component Serial Number to the Documentation by transferring the Component Serial Number onto the Documentation.  
The Documentation must be identifiable by the Component Serial Number only.
- 6.8 The Business Excellence Representative hands the serialised Documentation to the Production Foreman.
- 6.9 The Production Foreman places the Documentation in a temporary Build History folder.

*Step 7: Close the Component Manufacturing*

- 7.1 Using the CRL Document, the Production Foreman ensures that all the necessary Build History Documentation has been accumulated.
- 7.2 The Production Foreman ensures that all necessary testing has been performed and that the component is in its final form.
- 7.6 The Business Excellence Representative ensures that the Component Serial Number of the component is present on every piece of Build History Documentation. Every piece of Documentation must be identifiable by the Component Serial Number only.
- 7.7 The serial number on the component and on the documentation is verified to ensure that the two numbers align. The Business Excellence Representative finalises the Component Serial Number on the Serialisation Information System.
- 7.7 The Production Foreman orders storage of the component by making use of the Component Storage Procedure.
- 7.8 The Production Foreman books the entire component Build History Documentation in at Configuration. The Documentation must be identifiable by the Component Serial Number only. The Configuration Procedure and the Build History Storage Structure must be followed.

### **9.3. COMPONENT RECEIVING PROCEDURE**

#### **9.3.1. Purpose**

The Component Receiving Procedure will guide the process of receiving components from a supplier. The procedure will ensure that traceability is maintained with regards to externally procured components and will assist the relevant employees in conducting Assembly Storage operations properly.

#### **9.3.2. Procedure Responsibility**

The maintenance of the Procedure is the responsibility of the Business Excellence Department and the Business Excellence Department must insure adherence to the procedure. The onus however lies on each Assembly Storage employee to follow the procedure as specified.

#### **9.3.3. Applicable Documents**

- Procedure for the Compilation and Registration of a CRL (Exiting Procedure)
- Build History Record System Procedure (Existing Configuration Procedure)
- Procedure for Releasing an Order at Supplier (Existing Procedure)
- Component Storage Procedure (Existing Procedure)
- Traceability Policy
- Marking Procedure

#### **9.3.4. Procedure**

##### ***Assumptions***

Before the procedure commences, it is assumed that a Business Excellence Representative has inspected and released a component order at the Supplier. It is further assumed that the Supplier has performed all required tests. It is finally assumed that the Business Excellence Representative has allocated the correct order number to the Component as well as the Release Documentation.

##### ***Steps to follow***

- Step 1: The Assembly Storage Foreman receives the Release Documentation (with the order number and part number on it) from the Business Excellence Representative.
- Step 2: The Assembly Storage Foreman files the Release Documentation at Assembly Administration.
- Step 3: Assembly Storage receives the component(s) (accompanied by its order number and part number) at the Assembly Storage Receiving end.
- Step 4: The Assembly Storage Foreman extracts the Release Documentation with the identical order number from Assembly Administration.
- Step 5: The Assembly Storage Foreman uses the order number to log the delivery of the component(s) on the order database.
- Step 6: The order database presents a notification which specifies whether the component must be traceable or not.  
If no traceability is required, proceed directly to Step 14 and end at Step 15.
- Step 7: The Assembly Storage Foreman uses the Serialisation Information System to generate a Serial Number.
- Step 8: The Assembly Storage Foreman documents the Serial Number and ensures that it has been documented correctly.
- Step 9: The Assembly Storage Foreman temporarily attaches a copy of the documented Serial Number to the physical component and orders the Serial Number to be transferred onto the Component.  
Each component receives its own Serial Number - regardless of batch size or nature.
- Step 10: Following the Marking Procedure, an Assembly Storage employee permanently marks the Component with the Serial Number.  
The Assembly Storage Employee checks that the Serial Number has been transferred correctly and then disposes of the documented Serial Number.

- Step 11: The Assembly Storage Foreman takes the same documented Serial Number and transfers it onto the Release Documentation.  
The Release Documentation must be clearly identifiable by the Component Serial Number only.
- Step 12: The Assembly Storage Foreman checks that the Release Documentation and the Component contains identical Serial Numbers.
- Step 13: The Assembly Storage Foreman notifies the Serialisation Information System that the Serial Numbers have been checked.
- Step 14: The Assembly Storage Foreman orders that the Component is stored.
- Step 15: Assembly Storage Employees store the component by following the existing Component Storage Procedure.
- Step 16: The Assembly Storage Foreman books the Release Documentation into Configuration.
- Step 17: Configuration stores the Documentation by following the Configuration Procedure and the Proposed Build History Storage Structure.

## **9.4. PRODUCT ASSEMBLY PROCEDURE**

### **9.4.1. Purpose**

The Product Assembly Procedure will guide the processes followed during the assembly of a product. The procedure will ensure that traceability is maintained throughout every assembly phase and it will assist the relevant employees in upholding traceability operations properly.

### **9.4.2. Procedure Responsibility**

The maintenance of the Procedure is the responsibility of the Business Excellence Department and the Business Excellence Department must insure adherence to the procedure. The onus however lies on each Assembly Employee to follow the procedure as specified.

### **9.4.3. Applicable Documents**

- Procedure for the Compilation and Registration of a CRL (Existing Procedure)
- Build History Record System Procedure (Existing Configuration Procedure)
- Traceability Policy
- Marking Procedure

### **9.4.4. Procedure**

#### ***Assumptions***

Before the procedure commences, it is assumed that the Component Manufacturing Procedure and the Component Receiving Procedure have been followed and that all relevant components contain a Serial Number. It is further assumed that the Build History Documentation of all relevant components have been saved correctly at Configuration by following the Configuration Procedures and the Build History Storage Structure. Furthermore, the realistic assumption is made that all Assembly Employees are aware of the fact that Build History is generated throughout the realisation of a Product. It is finally assumed that - prior to the assembly of a product - the Assembly Foreman is informed of the technical specifications or requirements thereof.

#### ***Steps to follow***

##### ***Step 1: Commence Assembly***

- 1.1 The Assembly Foreman is notified that the components of a product have been released by Assembly Storage and that the assembly of the Product may commence. A Product Production Order is received with this which contains Technical Specifications.
- 1.2 Using the Serialisation Information System, the Assembly Foreman generates a Product Serial Number for the Product which will be assembled. This Number will be of the form "AAA000". The Assembly Foreman documents this Product Serial Number correctly.
- 1.3 The Assembly Foreman receives the released components onto the Assembly Floor and ensures that the components are the correct components.
- 1.4 Using the Technical Specifications, the Assembly Foreman determines on which component the Product Serial Number must be placed. The Assembly Foreman temporarily attaches the Product Serial Number onto the relevant component(s).
- 1.5 The Assembly Foreman connects the Product Serial Number with the serial numbers of the Components. This is done using the Serialisation Information System. The Component Serial Numbers become the children of the Product Serial Number.

##### ***Step 2: Create Sub-assemblies***

- 2.1 Using the Technical Specifications, the various Sub-assemblies forming part of the Final Product are produced by the Assembly Employees.
- 2.2 Throughout the creation of these Sub-assemblies, Product Build History is generated and placed in a temporary Build History file. The Assembly Employees allocates the Product Serial Number to each generated piece of Product Build History documentation. All Build History items must be identifiable by the Product Serial Number.

- 2.3 After an Assembly Employee has produced a Sub-assembly, the Employee must ensure that none of the permanent component Serial Numbers or the temporary Product Serial Numbers have been removed in the process. If it is found that a Serial Number has been removed or damaged, it must be ratified immediately through aid of the Parent-Child structure within the Serialisation Information System.

*Step 3: Manage Sub-assembly Testing*

- 3.1 After the completion of each Sub-assembly, the Assembly Foreman uses the CRL Documentation to determine whether a particular Sub-assembly must undergo tests.
- 3.2 If it is decided that a Sub-assembly must be tested in any way, the Assembly Foreman generates a Sub-assembly Testing Order. This Order must specify which tests must be carried out on which component.
- 3.3 The testing order is used as a guideline and the applicable Sub-assembly is tested accordingly. Testing is performed by an Assembly Employee and Sub-assembly Test Results are generated through the testing.
- 3.4 The Assembly Employee ensures that all Serial Numbers are still intact after the testing process. If it is found that a Serial Number has been removed or damaged, it must be ratified immediately through aid of the Parent-Child structure within the Serialisation Information System.
- 3.4 The Assembly Employee documents the Sub-Assembly Test Results appropriately and correctly.
- 3.5 The Product Serial Number of the Product (which the Sub-assembly forms part of) is allocated to the Test Results Documentation. The Documentation becomes identifiable by the Product Serial Number only.
- 3.6 The Assembly Employee transfers the documented Test Results to the Assembly Foreman. The Assembly Foreman places the documentation in a temporary Build History folder.

*Step 4: Assemble Main Product*

- 4.1 After all the Sub-assemblies have been produced according to the Technical specifications and after all the required Sub-assembly tests have been performed, the Assembly Employees assemble the Main Product.
- 4.2 Throughout the assembly of the Main Product, Product Build History is generated and placed in a temporary Build History file. The Assembly Employees allocate the Product Serial Number to each generated piece of Product Build History documentation. All Build History items must be identifiable by the Product Serial Number.
- 4.3 After Assembly has produced the Main Product, the Employee must ensure that none of the Permanent component Serial Numbers or the Temporary Product Serial Numbers have been removed in the process. If it is found that a Serial Number has been removed or damaged, it must be ratified immediately through aid of the Parent-Child structure within the Serialisation Information System.

*Step 5: Manage Main Product Testing*

- 5.1 After the entire product has been assembled and no further components must be added to it, the Assembly Foreman determines whether the product must be tested. This is done by using the CRL document.
- 5.2 If testing is specified in the CRL document, the Assembly Foreman compiles a Main Product Testing Order and notifies the Business Excellence Department of the matter.
- 5.3 After the Business Excellence department has been informed of the testing requirements, the applicable tests are performed on the Main Product. The Testing Order is used as a guideline and the Main Product is tested accordingly. Main Product Test Results are generated through testing.
- 5.4 The Business Excellence Representative ensures that all Serial Numbers are still intact after the testing process. If it is found that a Serial Number has been removed or damaged, it must be ratified immediately through aid of the Parent-Child structure within the Serialisation Information System.
- 5.5 A Business Excellence representative documents the test results and allocates the Product Serial Number onto it.

- 5.6 The Business Excellence representative transfers the documented Test Results to the Assembly Foreman. The Assembly Foreman places the documentation in a temporary Build History folder.

*Step 6: Modify Product Superficially*

- 6.1 After Business Excellence has performed all the required tests, the Assembly Foreman is notified that Surface Treatment may commence.
- 6.2 Using the Technical Specifications and Instructions, the Assembly Foreman instructs the Assembly Employees to perform the final superficial modifications on the product.
- 6.3 The Assembly Employees perform the final surface modifications according to Technical Specifications.
- 6.4 After Assembly has modified the Final Product, it must be ensured that none of the Component Serial Numbers present on any of the components have been removed in the process. If it is found that a Component Serial Number has been removed or damaged, it must be ratified immediately through aid of the Parent-Child structure within the Serialisation Information System.
- 6.5 After all surface treatment has been performed; the Assembly Employee permanently attaches (marks) the Product Serial Number onto the Product by following the Marking Procedure.

*Step 7: Manage Product Release*

- 7.1 The Assembly Foreman checks the Product Serial Number on the Product and confirms it on the Serialisation Information System.
- 7.2 The Assembly Foreman retrieves all the Product Build History which has been accumulated during the Product Assembly phase.
- 7.3 The Assembly Foreman transfers the Final Product and all Product Build History into the custody of the Business Excellence department.
- 7.4 Using the parent-child structure of the Product (within the Serialisation Information System) and the Build History Storage Structure, the Business Excellence department extracts the Build History Documentation of all the components forming part of the Final Product.
- 7.5 Business Excellence joins the Build History Documentation of the components with the Build History Documentation of the Product by making the Product Build History the parent of the Components' Build History. The Product Serial Number is allocated onto the Consolidated Build History and is structured according to the proposed Build History Storage Structure.
- 7.6 A Business Excellence representative inspects the Final Product and releases it.
- 7.7 Business Excellence books the full consolidated Product Build History in at Configuration.



## **9.5. MARKING PROCEDURE**

### **9.5.1. Purpose**

The Marking Procedure will guide the process of marking raw material batches, components and assemblies. The procedure will ensure that Serial Numbers are transferred correctly and will assist the relevant employees in maintaining traceability.

### **9.5.2. Procedure Responsibility**

The maintenance of the Procedure is the responsibility of the Business Excellence Department and the Business Excellence Department must insure adherence to the procedure. The onus however lies on each relevant employee to follow the procedure as specified.

### **9.5.3. Applicable Documents**

- Traceability Policy
- Component Manufacturing Procedure
- Raw Material Receiving Procedure
- Assembly Procedure
- Component Receiving Procedure

### **9.5.4. Procedure**

#### ***Assumptions***

It is assumed that viable methods for material and component marking are readily available, that the relevant employees are aware of these methods and that the employees are familiar with the marking methods. It is further assumed that the employees responsible for carrying out the marking procedure have a basic education and are literate.

#### ***Steps to follow***

##### ***Raw Material Batch Marking***

A Batch Number is a unique four-character number which links components to their mother Batch or Material. An example of a Batch number would be "ACGT" or "RSTY".

A Batch of Raw Material must be marked whenever a new Batch has arrived at DLS and the order database has notified the Warehouse Foreman that traceability is a requirement for the particular Batch.

These steps must be followed to ensure proper marking of Raw Material Batches:

Step 1: The Warehouse Foreman documents the Material Batch Number and ensures that it has been documented correctly.

Step 2: The Warehouse Foreman moves a copy of the documented Material Batch Number to the physical Material Batch.

Step 3: The Warehouse Employee is ordered to transfer the documented Batch Number onto the Raw Material Batch.

Step 4: The Warehouse employee takes the documented Batch Number and attaches it onto the related Batch using a temporary adhesive such as masking tape.

Step 5: The Warehouse Employee retrieves the applicable marking tools or machinery and brings it to the Raw Material Batch.

Step 6: The Batch is permanently marked according to the following discretion:

- Batches containing large Material Units (castings, sheet metal, etc.):  
The Batch Number is transferred onto each unit individually. This may, for example, be done by engraving each unit or by punching each unit.  
Each unit forming part of the Batch receives the same Batch Number.
- Batches containing small / thin / many Units (brackets, rods, etc.):

One Batch Number is transferred onto the entire Batch. This may be done, for example, by attaching a proper, tough and durable tag onto the Batch.  
One tag is allocated to the entire Batch as marking each individual unit would be time-consuming.

- Batch Numbers must be allocated using UPPERCASE and not lowercase lettering.

Step 7: After marking the Material Batch, the Warehouse Employee checks to ensure that the Batch Number has been attached or transferred correctly.

Step 8: To avoid confusion, the Warehouse Employee removes any other existing markings which may be present on the Material Batch. These are markings which may have been added by the Supplier during production.

Step 9: The Warehouse Employee immediately removes the temporary Batch Number documentation from the Batch and disposes of it.

#### *Raw Material Sample Marking*

A Raw Material Batch Sample must be marked whenever a Raw Material Batch must undergo additional testing. The samples must be identifiable only by their parent Batch Numbers. These steps must be followed to ensure proper marking of Raw Material Samples:

Step 1: The Metallurgist receives the order to test a particular Batch of Raw Material.

Step 2: The Metallurgist locates the Material Batch which must be tested and removes / takes the appropriate Samples.  
The Metallurgist may not remove or damage the physical Batch Number on the material in the process.

Step 3: The Metallurgist documents the Batch Number.

Step 4: The Metallurgist attaches the documented Batch Number onto the sample using a temporary adhesive such as masking tape.

Step 5: The Metallurgist transfers the sample to the testing facility.

Step 6: Using appropriate methods and tools, the Metallurgist permanently transfers the documented Batch Number onto the sample. The Batch Number must be allocated in UPPERCASE and not in lowercase.

Step 7: The Metallurgist removes the temporary documented Batch Number from the sample and performs all testing.

Step 8: Using the temporary documented Batch Number, the Metallurgist checks that the Batch Number on the sample is still intact and re-allocates the number if necessary.

#### *Manufactured Component Serial Number Marking*

A Manufactured Component Serial Number is a seven-character number used to uniquely identify a unit or piece which have been removed from the mother Batch or Piece. The Component Serial Number contains four letters and three numbers, such as "ACGT153" or "RSTY683". The first four characters are identical to the piece's mother Batch and link it to the mother Batch.

A Component Serial Number Marking must be allocated whenever a piece of Raw Material has been severed or removed from a Raw Material Batch. These steps must be followed to ensure proper marking and to avoid mistakes:

Step 1: The Production Foreman generates a Component Serial Number for the newly-severed or removed Material Piece.

Step 2: The Production Foreman immediately documents the Component Serial Number and hands a copy of it to the Artisan.

Step 3: The Artisan locates the Raw Material Piece or part and, using a temporary method, attaches the Serial Number documentation onto the piece or part.

- Step 4: The Artisan retrieves the tools and machines required for marking the Raw Material Piece.
- Step 5: The Artisan permanently marks the piece of Material correctly.  
The Component Serial Number must be allocated in UPPERCASE and not in lowercase.
- Step 6: The Artisan checks that the Component Serial Number has been transferred correctly.
- Step 7: The Artisan removes the Serial Documentation and disposes of it immediately.

#### *Procured Component*

A Serial Number for a procured component is a unique seven-character number which is used to identify an externally-procured component uniquely. An example of a Serial Number would be “ACGP395” or “RSTD294”.

A Procured Component must be marked whenever it has arrived at DLS and the Order Database has notified the Assembly Storage Foreman that traceability is a requirement for the particular component.

These steps must be followed to ensure proper marking of Procured Components:

- Step 1: The Assembly Storage Foreman documents the Serial Number and ensures that it has been documented correctly.
- Step 2: The Assembly Storage Foreman moves the documented Serial Number to the physical Component.
- Step 3: The Assembly Storage employee is ordered to transfer the documented Serial Number onto the Component.
- Step 4: The Assembly Storage employee takes the documented Serial Number and attaches it onto the related component using a temporary adhesive such as masking tape.
- Step 5: The Assembly Storage employee retrieves the applicable marking tools or machinery and brings it to the Component.
- Step 6: The component is permanently marked with the Serial Number.  
Serial Numbers must be allocated using UPPERCASE and not lowercase lettering.
- Step 7: After marking the Component, the Assembly Storage employee checks to ensure that the Serial Number has been attached or transferred correctly.
- Step 8: To avoid confusion, the Assembly Storage employee removes any other existing numbers or markings which may be on the Component. These are markings which may have been added by the supplier during production.
- Step 9: The Warehouse employee immediately removes the temporary Serial Number documentation from the Component and disposes of it.

#### *Product Serial Number*

A Product Serial Number is a six-character number used to uniquely identify an assembled product in its initial form. The Product Serial Number contains three letters and three numbers, such as “AGT153” or “RST683”.

A Product Serial Number Marking will be temporarily allocated immediately after the assembly of the product has started. The Product Serial Number will only be permanently allocated after the Product has undergone its final superficial modifications. These steps must be followed to ensure proper marking and to avoid mistakes:

- Step 1: The Assembly Employee perform the final surface modifications according to Technical Specifications.
- Step 2: The Assembly Employee ensures that none of the Component Serial Numbers present on any of the components have been removed in the process. If it is found that a Component Serial Number has been removed or damaged, it must be ratified immediately through aid of the Parent-Child structure within the Serialisation Information System.
- Step 3: The Assembly employee retrieves the necessary tools and machines required for marking the required component.

Step 4: The Assembly employee permanently marks the component with the Product Serial Number which is already temporarily attached onto the Product. The Product Serial Number must be allocated in UPPERCASE and not in lowercase.

Step 5: The Assembly employee checks that the Product Serial Number has been transferred correctly.

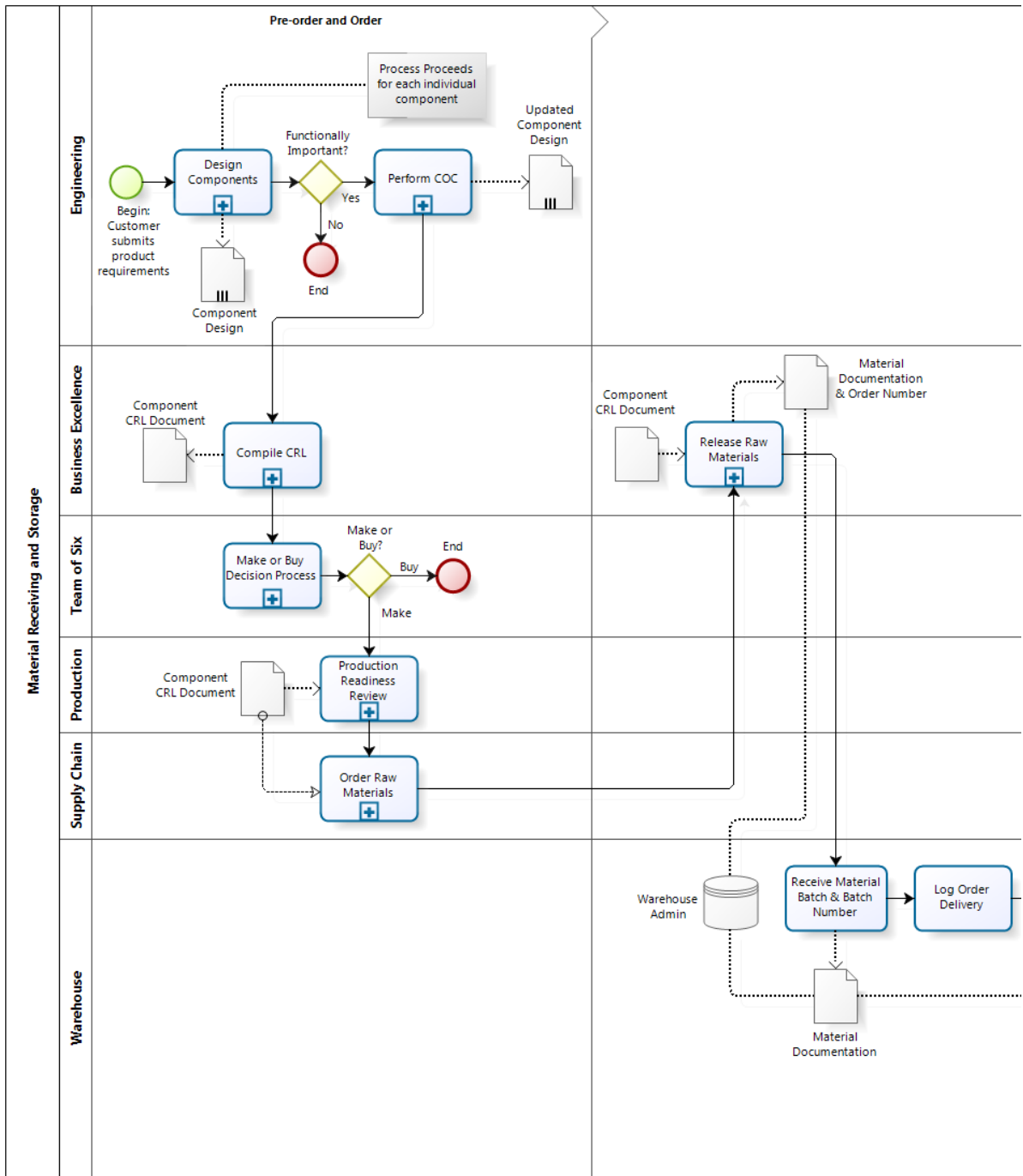
Step 6: The Artisan removes the Serial Documentation and disposes of it immediately.

## 10. FINAL BUSINESS PROCESSES

The final processes and procedures presented in sections eight and nine were mapped using BPMN. This was done to create a more visual overview of all the new processes and to make it easier for the in-house Business Process Improvement Specialist (at DLS) to view the new processes at a glance. It was also done as Sowell (2009) advises that the final business processes are presented in the form of BPMN diagrams, rather than IDEFO models.

Recall that the Initial “As-Is” BPM Model was divided into Manufacturing, Procurement and Assembly sections. However, the new “To-Be” BPM Model was divided into Material Receiving, Component Receiving, Component Manufacturing and Product Assembly sections, with subsections for certain testing sub processes. This was done as the detail contained within the Proposed Model was too cumbersome to be clearly presented in a limited number of sections.

It should be stressed that the new “To-Be” BPM Model must be interpreted in conjunction with the Traceability Procedures which were presented in section nine. The “To-Be” BPM Model is only a framework for the execution of the presented Procedures. Following only the “To-Be” BPM Model without the support of the Procedures will not ensure proper traceability or product realisation.



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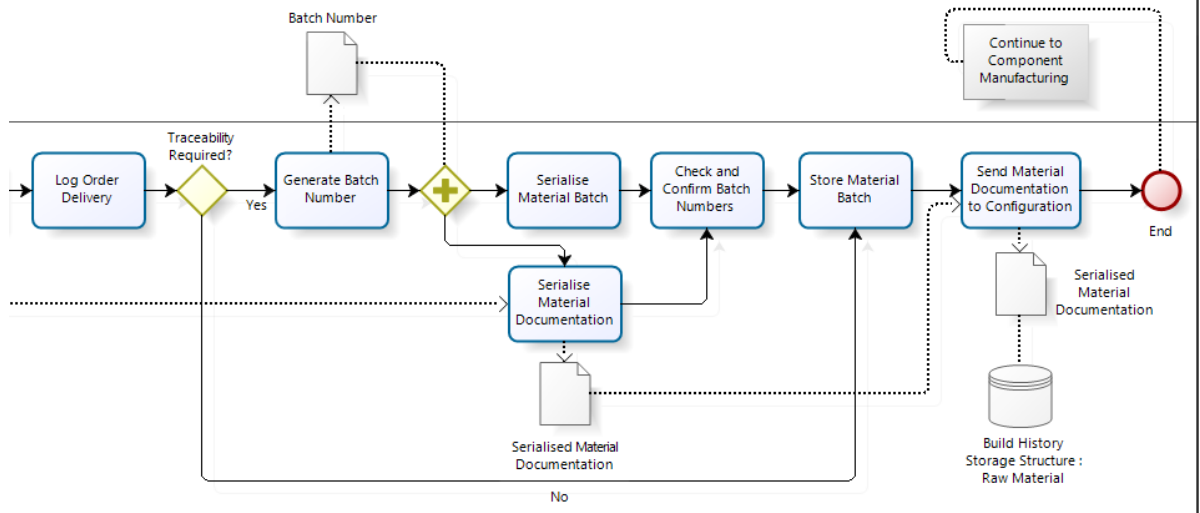


Figure 44: BPM “To-Be” Material Receiving

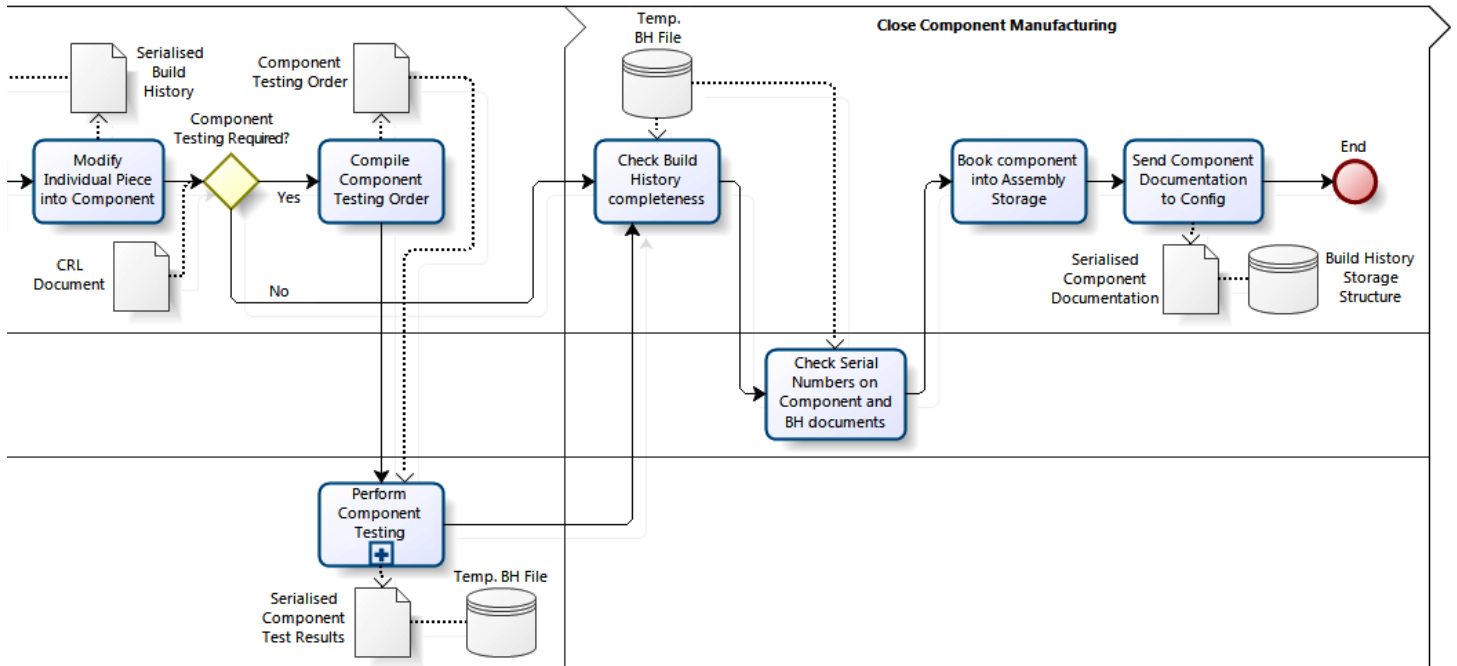
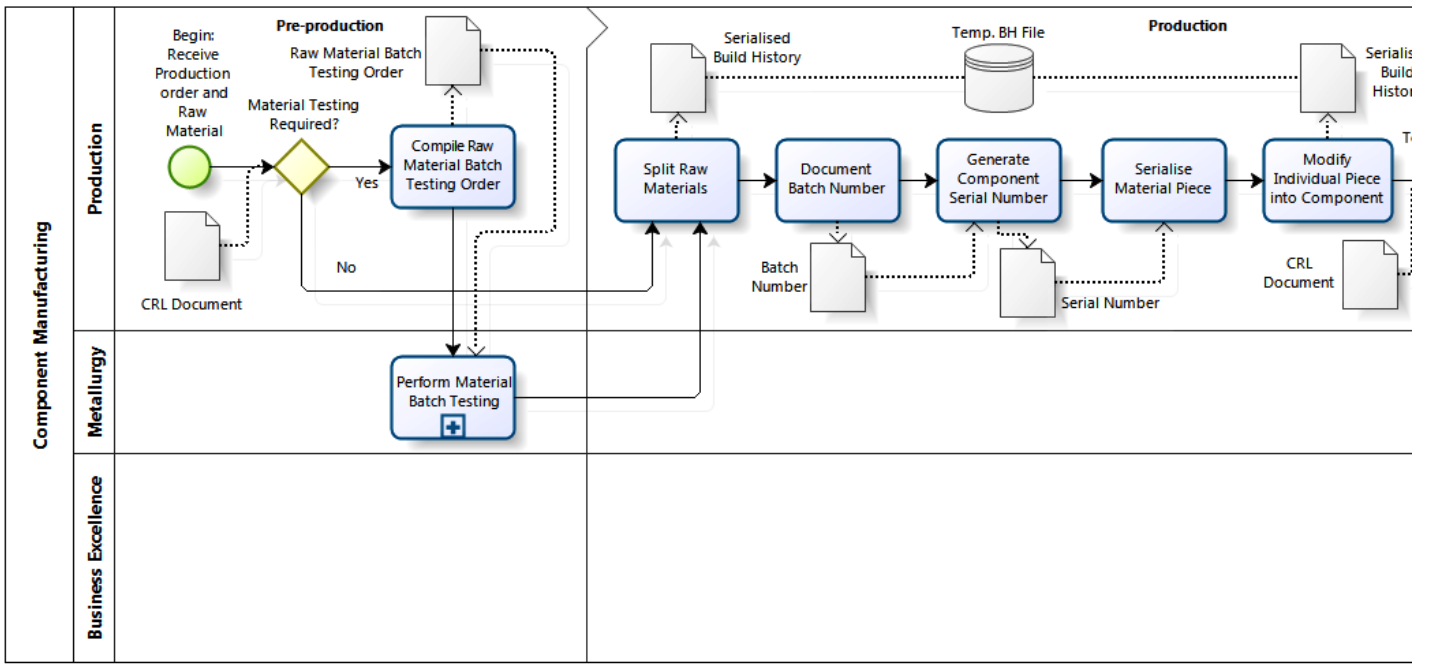


Figure 45: BPM “To-Be” Component Manufacturing

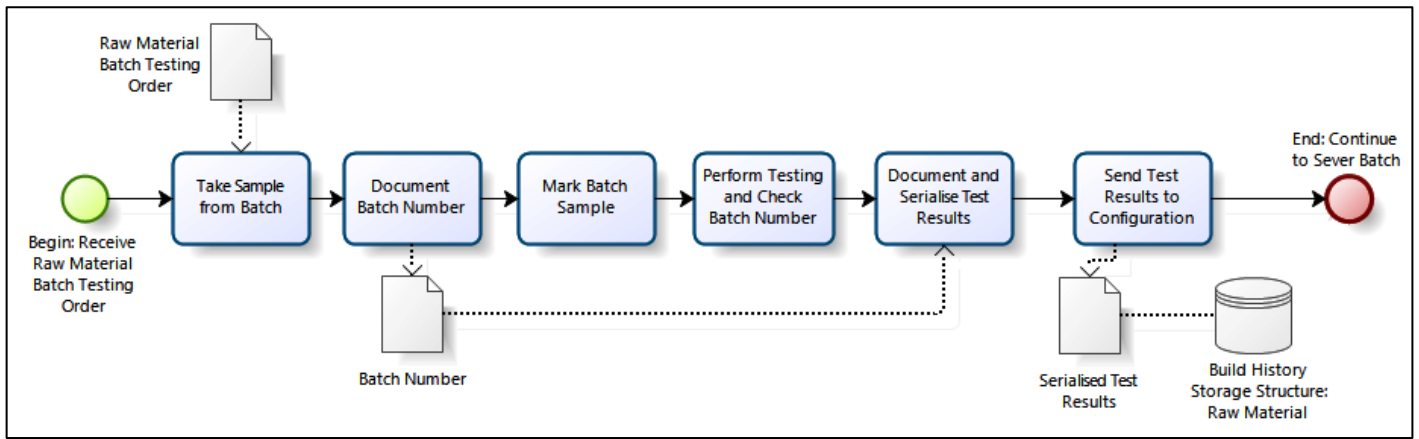


Figure 46: BPM "To-Be" Component Manufacturing - Material Testing Sub process

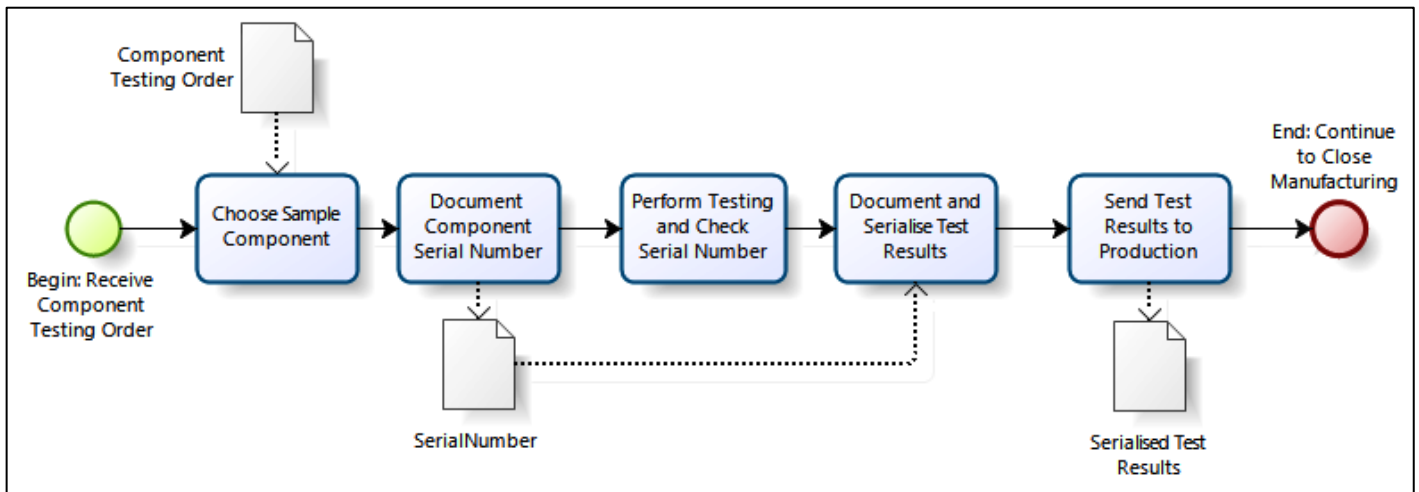


Figure 47: BPM "To-Be" Component Manufacturing - Component Testing Sub process



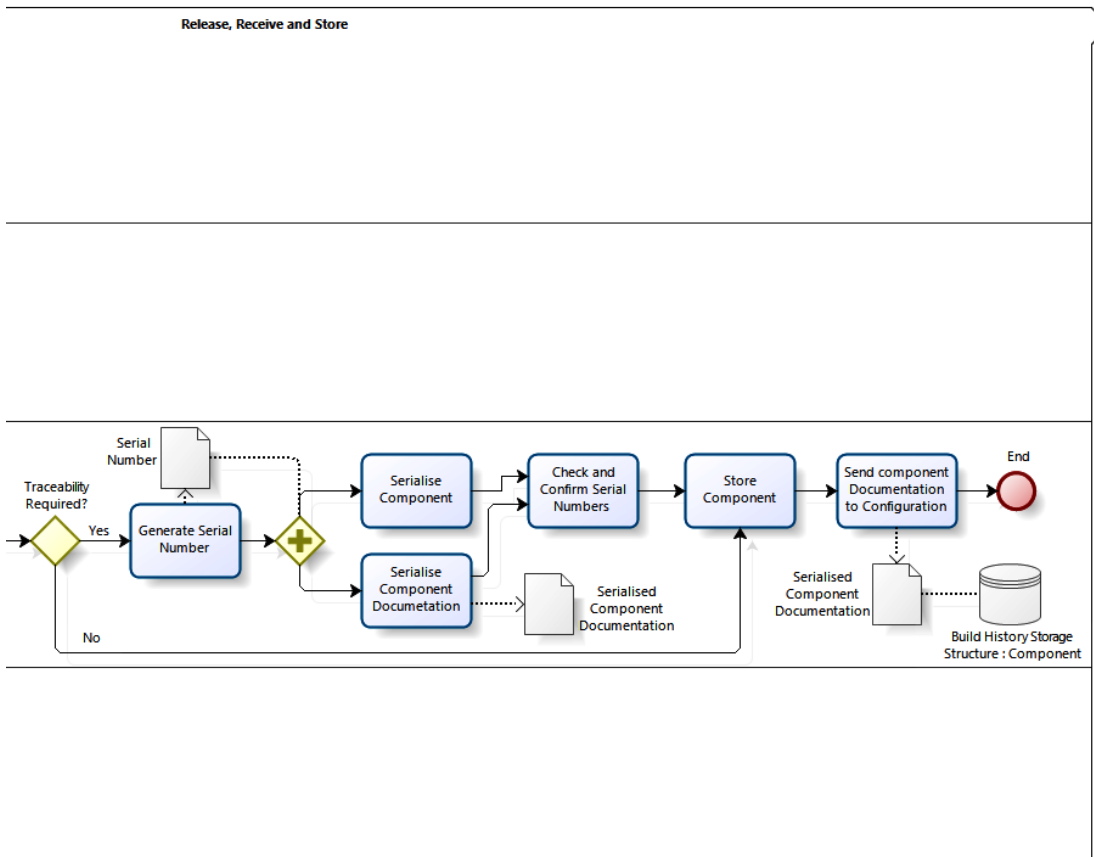
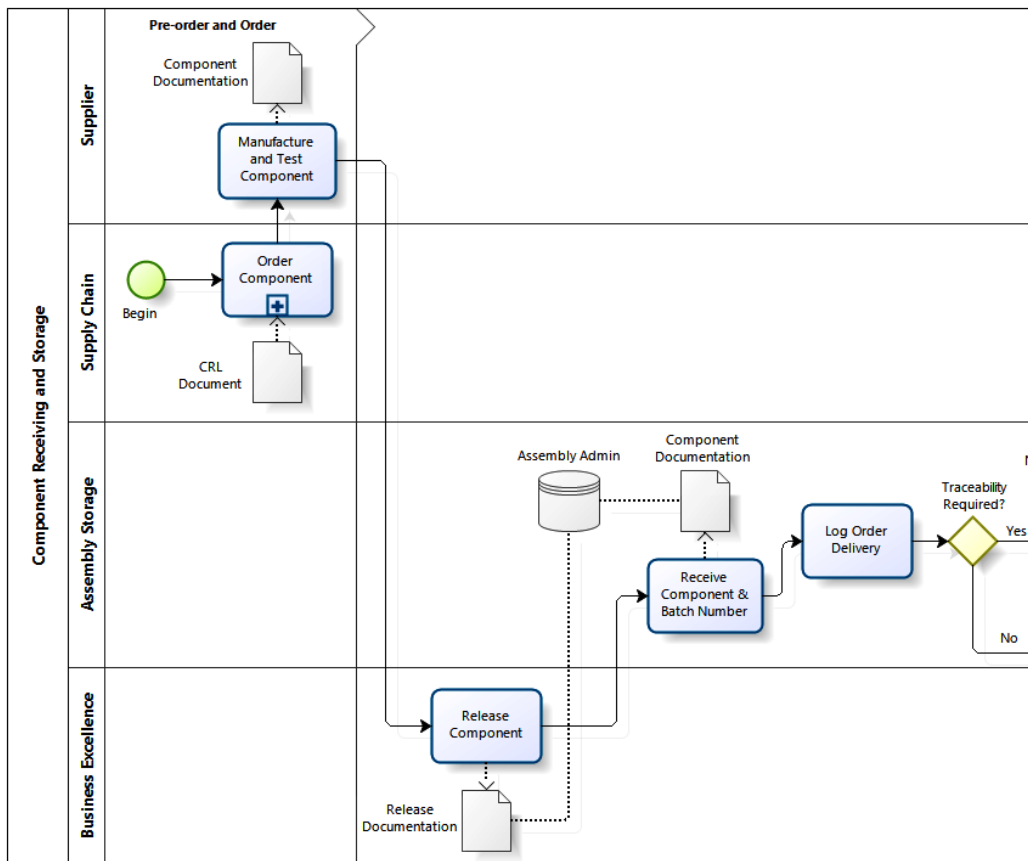


Figure 48: BPM “To-Be” Component Receiving

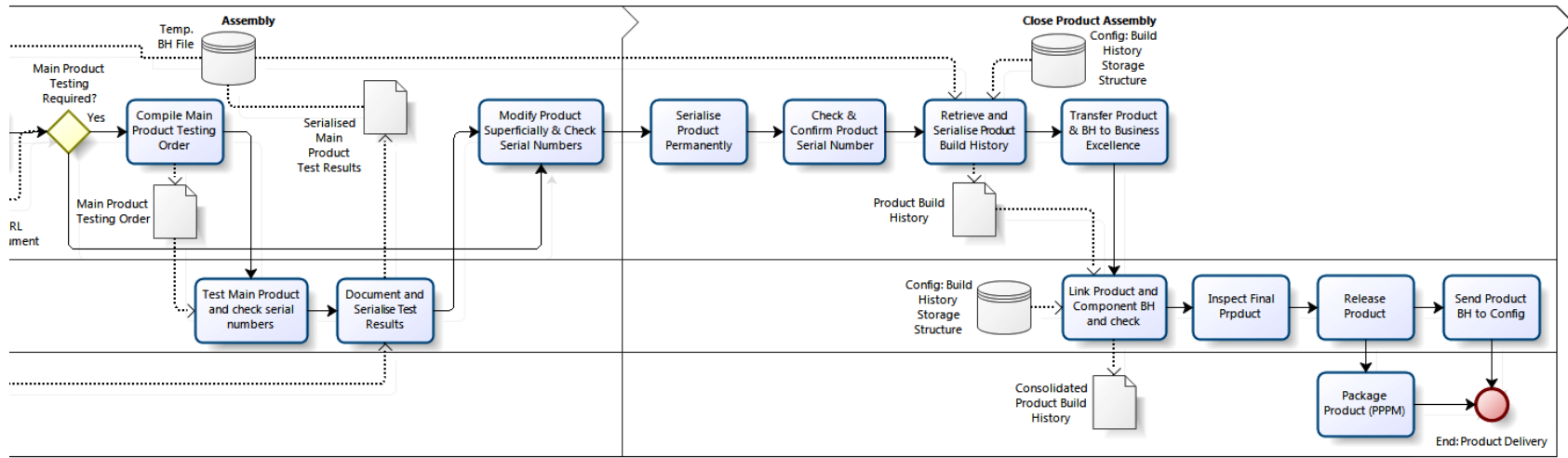
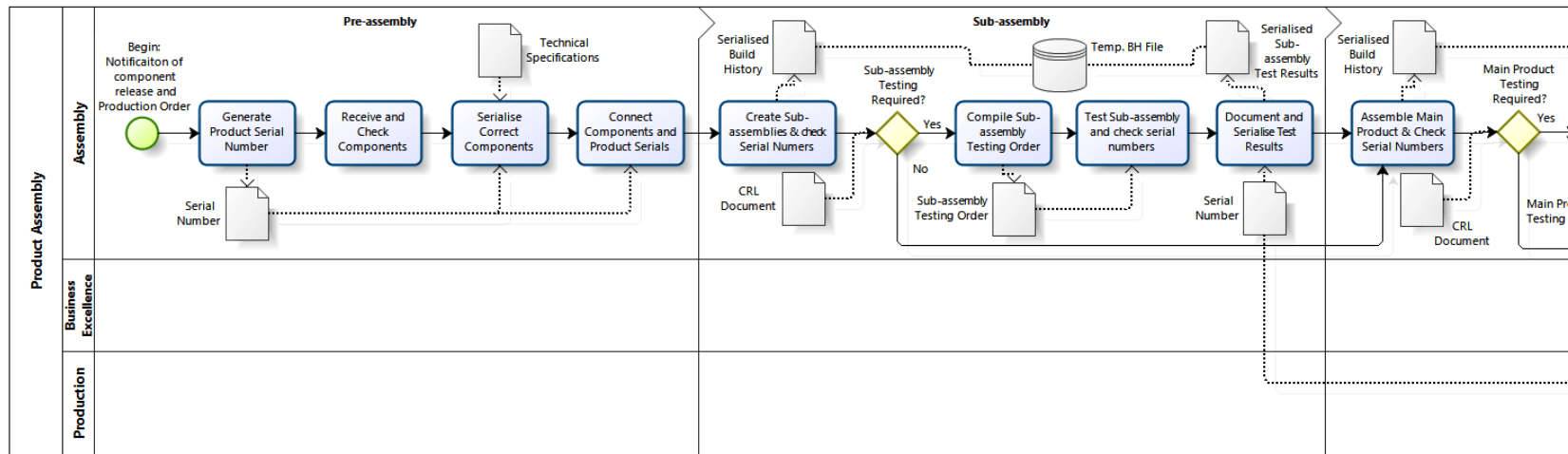


Figure 49: BPM “To-Be” Product Assembly

## **11. IMPLEMENTATION ROADMAP**

To aid in the successful and full-scale implementation of the new Traceability Solution which has been created in the preceding sections, an Implementation Roadmap was constructed. Implementing change within a company environment is usually a difficult task faced with resistance and many obstacles. An Implementation Roadmap is thus vital for the proper execution of change.

Throughout the implementation of the Traceability Solution, continual verification must take place. The inevitable implementation stages will be now be discussed.

### **11.1. TRACEABILITY SOLUTION INTRODUCTION**

To prepare the workforce of the imminent change, the existence and the basic principles of the Traceability Solution must be presented to the key stakeholders. With this, the Traceability Solution shall be released into the company.

Initially, all processes, procedures and the Serialisation Information System shall be implemented in a Pilot Phase. Employees should then be encouraged to provide feedback on the various solutions and this feedback should then be used to make adjustments accordingly.

### **11.2. SERIALISATION INFORMATION SYSTEM**

The implementation of the Serialisation Information System shall include the implementation of the Serialisation Numbering System and the Build History Storage Structure. The following actions must be taken to ensure the correct and effective establishment of the Serialisation Information System.

1. Handover of the logical system design (Presented in Chapter 6)
2. Translation of the logical system design into full system specifications
3. Technical development of the Serialisation Information System
4. Initial Testing of the Serialisation Information System
5. Further Technical development
6. Final Testing of the Serialisation Information System
7. Integration of the Serialisation Information System with all applicable In-house Systems and testing
8. Introduction of the Serialisation Information System to relevant employees and stakeholders
9. Preliminary Training of Employees
10. Pilot Implementation of the Serialisation Information System
11. Final Training of Employees

### **11.3. PROCESS AND PROCEDURE INTRODUCTION**

The various traceability processes and procedures must be introduced to the respective employees and the relevance of these processes and procedures must be explained to them. Furthermore, a step-by-step explanation on how the processes and procedures should be implemented should be given to the employees. If any employees are illiterate or struggle to understand any of the principles, special care must be taken to give a clear explanation to these individuals.

### **11.4. PROCEDURE TRAINING**

All affected employees must be instructed properly as to how the new procedures should be followed. After training, employees must be able to follow the procedures correctly at all times and understand what is expected of them.

### **11.5. FINAL IMPLEMENTATION AND CONTINUAL IMPROVEMENT**

After employees have provided feedback on the various solutions and this feedback has been used to make adjustments accordingly, all segments forming part of the final Traceability Solution must be implemented on a final basis. The improvement of the solution may however never end as continual improvement of any system or process is vital to its permanent success.

## **12. TECHNOLOGICAL “WAY FORWARD”**

After all of the refinements have been made and all employees have become comfortable with the solution, the possibility of incorporating technological improvements with regards to the permanent physical marking of components or products must be considered. Currently, serial and batch numbers are manually punched onto components or products and this technique is very time consuming and filled with much room for error. With

the implementation of proper processes and procedures, there will be an opportunity for advancement in technology.

Many readily available technologies for permanently marking hard surfaces were investigated and the application environments, advantages, disadvantages and core characteristics of these options were weighed against one another. The details regarding the options which were found to be the most promising will now be discussed shortly.

### **12.1 DATA MATRIX BARCODES**

Data Matrix barcoding is a barcoding technique used in a wide range of applications - from the electronics industry to the defence industry. It is a more advanced version than the original barcode consisting of simple vertical lines. Data Matrix barcodes are more durable than the original barcodes and more information can be stored within a Data Matrix barcode.

Although Data Matrix Barcoding is not a physical marking technique, it should be considered as a possible future replacement of the physical serial numbers engraved into components and products. Instead of physically marking a component or product with a serial number, the Data Matrix barcode can be added onto it, resulting in a much larger amount of information being stored onto and carried with a product.

If this method is thoroughly incorporated within a stable Serialisation Information System, it will remove the possibility of marking errors which currently exist within the production function and it will increase the overall efficiency of all Traceability-related operations. Overall, the use of Data Matrix barcodes should be strongly considered for future improvement of production operations at DLS.

### **12.2 ELECTROCHEMICAL MARKING**

Electrochemical Marking is a physical marking technique offering a wide range of advantages. This technique offers the unique property that it can be used to mark extremely hard surfaces such as armour plating, while still being fully compatible with the Data Matrix Barcoding technique. Furthermore, it requires a low capital investment and unlike most other techniques, it is suitable for low volume production (such as the production volume present at DLS). (Pryor Marking Technology, 2012) Due to these advantages, the Electrochemical Marking method was found to be an attractive future possibility. It will be especially advantageous if it is incorporated with the Data Matrix Barcoding method.

### **12.3 METAL TAGGING**

Metal Tagging is a very popular technique where a durable metal identification tag is attached onto a product or component instead of marking the actual surface of the component. This technique is very popular in the defence industry and it is even utilised by the defence force of the United States of America. This technique provides a wide range of advantages. It is compatible with Data Matrix Barcoding and the metal plates used for identification is extremely durable. It has a high heat resistance level and it is completely waterproof. (Infosight, 2012) With the advantages of this method apparent, the Metal Tagging technique should be taken into consideration when investigating future technological improvements with regards to traceability.

## **13. CONCLUSION**

To create a Traceability Solution, the traceability related problems occurring at DLS were documented and investigated. From this, a Traceability Policy was created to govern the activities of all relevant employees at DLS. Furthermore, a new Serialisation Numbering System was created and a Serialisation Information System was designed. To support the accumulation of Build History Documentation, a Build History Storage Structure was also designed. From these elements, a set of new processes was created. Supporting procedures for these processes were then compiled so as to ensure the correct implementation thereof. Finally, a set of guidelines for the future implementation of the solution was set out and recommendations regarding the improvement of technology usage were made.

If the various components forming part of the Traceability Solution work together, the problems and potential problems which exist within the company will be eradicated. The implementation of the solutions will not require a large economic investment and, other than the retraining of employees, will not be a complex endeavour. As the solutions have been created specifically for the company with continuous verification throughout all phases, the implementation of the project will be technically realisable on all levels.

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15. APPENDICES A - E: OFFICIAL DLS POLICY AND PROCEDURE DELIVERABLES
- 15.1. APPENDIX A: DLS TRACEABILITY POLICY DOCUMENT
- 15.2. APPENDIX B: DLS RAW MATERIAL RECEIVING PROCEDURE DOCUMENT
- 15.3. APPENDIX C: DLS COMPONENT MANUFACTURING PROCEDURE DOCUMENTS
- 15.4. APPENDIX D: DLS COMPONENT RECEIVING PROCEDURE DOCUMENT
- 15.5. APPENDIX E: DLS MARKING PROCEDURE DOCUMENT