University of Twente

Faculty: Behavioural, Management and Social Sciences

Bachelor's Thesis

# Operational Control Tower

## For the after-sales service Supply Chain

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**Management Summary:**

The main objective of this thesis is to develop a demarcation for the Control Tower in the Service Supply Chain, and to compare the tools for Control Tower purposes, which are being employed by the Service Parts Organization of IBM, to it. Another intention of this paper is the identification of future research areas for the Work Package 3 of the ProSeLo Next research project.

In order to fulfil those objectives t four research questions are posed in this research, concerning the actual state of the Control Tower capabilities of IBM, and the overall capabilities, needed to effectively monitor the Service Supply Chain. Furthermore, is investigated what a Control Tower should be, thus which capabilities should it have, and how the tools at IBM fulfil those capabilities at the moment.

To answer what a Control Tower should be, and what is necessary to monitor the Service Supply Chain, an intensive study on the available literature has been conducted. In order to clarify what the actual tools at IBM are capable of, they have been investigated, and interviews with some of the users have been conducted.

An investigation of the tools, which are currently used for Control Tower purposes at IBM, has identified the capabilities of two tools, Entercoms and Servigistics. Entercoms is another company, whom IBM is in a partnership with, and who visualizes and analyzes Supply Chain data on a rather tactical level. Servigistics, is a software for which a license has been acquired and which is employed for the operational replenishment order handling. Hereby Servigistics is generating alerts, once an order deviates from prior established rules.

This paper continues with a literature based concept of the control tower. The chosen form for the concept is based on a five-layer approach and filled with other concepts from literature, in order to fit the service supply chain. Those five layers are:

- The Supply Chain Business Layer, which defines the processes, to control and monitor
- The Data Perception Layer, which perceives the actual Supply Chain data
- The Data Storage Layer, which stores the perceived data and orders it into data marts
- The Application Layer, which contains the capabilities to organize, analyze, and visualize the data
- The Manpower Layer, which contains the staff, taking the decisions

While all five layers are important to the working of the Control Tower, the application layer contains the most functionality. From literature and interviews the following definition of Control Tower has been devised: “A Control Tower is a centralized system, which enables the monitoring as well as the control of the Supply Chain.”.

The comparison of the current tools with the concept has shown that there are some areas, which could be enhanced. Those are: *Decision Support, Pattern Detection, Decision Evaluation, and Tracking and Tracing.* Except for *Tracking and Tracing*, which is located in the second layer, all fields are aspects of the Application Layer. *Tracking and Tracing* refers to the monitoring and recording of the physical location of service parts. *Decision Support* refers to the process of supporting supply chain decisions with accurate and timely data. *Pattern Detection* refers to the process of detecting meaningful patterns by monitoring events, with less impact. *Decisions Evaluation* is the assessment of earlier taken decisions and their impact on the supply chain.

In conclusion it can be seen that, although there are some areas of expansion, IBM is in possession of the necessary tools, for such purposes. Especially the cognitive platform Watson, which has learning capabilities could be interesting for Supply Chain applications. Future research should be directed at the *Application Layer* of the Control Tower (fourth layer), and should at first be focused on the application of IBM’s Watson, for the detection and clustering of root-causes, leading to a loss

in certain performance indicators. Other areas for future research have been identified in combination with a time in which IBM wishes to address them.

**Abbreviations:**

ABDS – Agent based Decision Support System

CT – Control Tower

DSS – Decision Support System

EO – Emergency Order

LT – Lead Time

MLO – Maintenance Logistics Organization

MO – Maintenance Organization

RCA – Root-Cause-Analysis

SPO – Service Parts Organization

SRU – Stock Replaceable Unit

# Contents

# 1. Introduction

Supply Chain Management is defined as: "[…] the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole." (J. T. Metzner, 2001). The coordination of the Supply Chain, which is a difficult task itself due to the immense number of businesses, included in it, has gained complexity with the progressing of globalization. The numbers of customers and suppliers, which need to be managed, have increased, and their geographic spread has become broader. Adding up to this are the increased customer expectations and demands, and, due to the increased spread and complexity, risks, which have to be managed. In order to cope with those and other challenges, a system, which gives improved insight in the supply chain processes, and allows to detect risks more quickly, is needed. For this purpose, the concept of the Control Tower has increasingly gained attention.

Many companies like SAP, Kinaxis, Viewlocity, and others, are offering supply chain control tower solutions, and there are many definitions available on what a Control Tower is, but although there is some consensus in those definitions, one common demarcation is missing. For this purpose, the company IBM, and within it the Service Part Organization (SPO), located in Amsterdam, has chosen to participate in the Research Project ProSeLo Next (Pro-active Service Logistics Next). The service supply chain, which is managed, and by that monitored, by this organization, deals with Spare Parts of the IBM logo and IBM non-logo (e.g. Lenovo) operations. The monitoring systems in place should aim to continuously give insight in the different processes and states and give early signals to the people responsible, in order to enable a system, which is highly responsive, flexible, and can react in a quick fashion in the case of unforeseen events.

In order to gain a high degree of insight in the Service Supply Chain processes, Supply Chain Control Towers could be used. The service supply chain of IBM is currently making use of different tools to pursue that goal. The main purpose of this research is to analyze what a Supply Chain Control Tower should be and in how far the systems at IBM already fulfil this. Gaps, which have been identified in this research, and the eventual propositions for solutions will be dealt with in further research. This research solely aims to give a clarification, and advice for future research. The structure of this thesis is as follows: Chapter 02 will elucidate the research design; Chapter 03 is dedicated to the Supply Chain of IBM, and the tools they use for Control Tower Purposes; Chapter 04 will explain the concept of a Control Tower, based on findings in the literature; Chapter 05 will compare the Concept with the tools, that are present at IBM; Chapter 06 contains the conclusions and further research questions.

## 2. Research Design

### 2.1. Research Objectives

As mentioned earlier, the main purpose of this research is to give a clarification of what a Supply Chain Control Tower is and how the tools, being used at IBM, fit this definition. In more detail thus this research will attempt to identify what is needed to monitor the service supply chain effectively, and what a Control Tower is.

Another objective, which ought to be fulfilled by means of this research is the Identification of needs for further research and delivery of starting points for such. As one starting point will serve the demarcation of what a Supply Chain Control Tower System in theory should and in how far those fulfil the needs of a Control Tower.

The questions, this research will be attempting to answer in order to fulfil the earlier mentioned objectives are the following:

- How does the Supply Chain at IBM look like and how do their tools work? (Q1)
- What is needed to effectively monitor and control the service supply chain processes? (Q2)
- What should a Supply Chain Control tower be? (Q3)
- In how far do the tools, used at IBM for Control Tower purposes, fulfil this definition? (Q4)

### 2.2. Research Design

The methodological perspective, which has been chosen to develop a theoretical model is the research cycle, introduced by Heerkens & van Winden (2012) as a formal approach to solving knowledge problems.

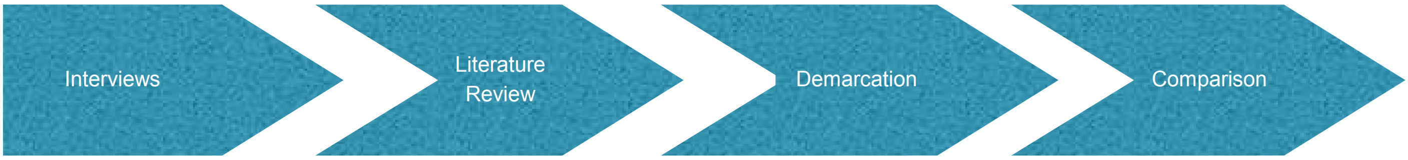


*Figure 1: Research Flowchart*

The flowchart diagram in Figure 1 gives the reader a general impression on how the research is intended to commence and proceed. Every step, being in the chart, will further on be discussed in more detail (see *Table 1: Research Design*). In this design the findings from one step are meant to enable the progression to the next one with the last step, giving an answer to the main question of this research. The nature of this research will be descriptive rather than prescriptive, which is in coherence with the problem statement and research questions. This research will be deep instead of broad. This comes from the fact that it concerns an explicit subject. Videlicet the usage and capabilities of Supply Chain Control Tower Tools.

| Question | Definition | Method |
|---|---|---|
| **1** | How does the Supply Chain at IBM look like and how do their tools work? | Semi-structured Interviews - The interviews will be conducted with personal of IBM, having contact with the software |
| **2** | What is needed to effectively monitor the service supply chain processes? | Literature Review - Criteria will be determined based on the consensus in the literature found |
| **3** | What should a Supply Chain Control tower be? | Demarcation - Will be based on the literature review and interviews |
| **4** | In how far do the tools, used at IBM for Control Tower purposes, fulfil this definition? | Comparison – Based on the demarcation of Q3 and the findings of Q1 |

*Table 1: Research Design*

# 3. IBM Supply Chain and Tools

This chapter will start by giving a description of the service supply chain of IBM in the EMEA region. After that the tools (Servigistics, Entercoms), which are used at IBM will be analyzed on their capabilities and functionality. The insufficiencies of both tools will be discussed in a later chapter (see *5 Comparison IBM tools and Control Tower Concept*).

The goal of this chapter is to answer the research question Q1: How does the Supply Chain at IBM look like and how do their tools work?

## 3.1. IBM Supply Chain

This research is conducted in order to define the concept of a Service Control Tower. Furthermore, it is intended to identify in how far the tools that are used at IBM do fit into the definition, coming from this research. In order to give the reader an impression of how the environment looks like in which the Service Control Tower operates, the Service Supply Chain of the Service Parts Organization (SPO) will be described in the following. The Reverse Logistics Process is highlighted in a follow up chapter (see *3.1.3 Reverse Logistics*), as it serves as a special source for spare parts, and has some specific characteristics, which demand attention by a control tower.

### 3.1.1. *Introduction*

The SPO is an organization within IBM, which is responsible for the where/when planning and unit cost management, the inventory planning, and the delivery control tower for the Spare Parts. Its supply chain consists of 331 suppliers and 489 locations, that need to be supplied and are spread around the globe. The annually purchase order lines are estimated at 286.000 orders, and the lead times vary from short ones up to nine months, with an average of 70 days. The SPO is operating in the field of after-sales services, which is defining for the supply chain characteristics. Almost all of the customer orders, placed at the SPO, are done according to corrective maintenance, which leads to a high fluctuation and uncertainty in the demand, which ought to be satisfied. It is also possible that planned demand occurs in the order system of IBM. This happens when a customer wants to order a certain amount of spare parts for one or the other reason. But due to the fact that those make a miniscule part of the total amount of customer orders, they will be neglected for this research.

The Service Parts, that are being moved in this supply chain, range from IBM products (Mainframes, Power Products, Storage), over previous IBM brands (Lenovo PC, Lenovo Server, Retail Storage Solution), to non-IBM spare parts, which are either IBM owned/consigned (Cisco, Juniper, etc.) or non-IBM owned/outsourced (e.g. Desktop products). For the parts that are non-IBM owned/outsourced, IBM is handling the planning only. One thing that is to note is that all of the parts are of electronic, rather than mechanical nature, which is important for the forecasting of future demand, as it will be seen later.

The main location for the EMEA (Europe, Middle East, Africa) region, is in Amsterdam. In order to cover the other regions, there are two more main locations, one in Singapore (Asia Pacific) and one in Mechanicsburg (The Americas).

### 3.1.2. *Supply Chain Architecture*

When it comes to the architecture of the supply chain, there are in principle two sides, whose connecting point is the SPO. On the one hand there is the supply side, on which IBM places parts orders

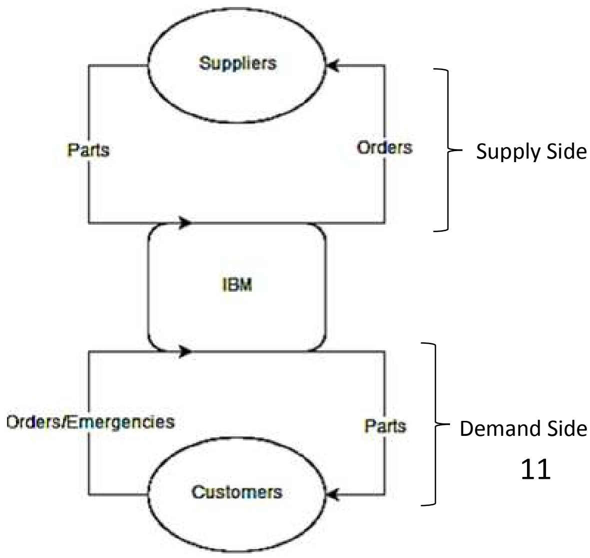


Figure 2: Basic Supply Chain

at the suppliers, and on the other hand there is the demand side, on which the customers create parts orders at IBM (see *Figure 2: Basic Supply Chain*). Both sides shall be discussed a bit further in the following. The description will be beginning with the supply side, going over to IBM's functions, and end with the demand side.

On the supply side there is a variety of suppliers in order to fulfil the demand that is dictated by the demand side. Supply sources can either be New Buy Vendors, Manufacturers, IBM owned Production Plants, or Repair Shops (see *3.1.3 Reverse Logistics*). For the sourcing and order management is the procurement division of IBM responsible. In order to be able to satisfy the Service Level Agreements with the customer, forecasts for the parts are made every four weeks. Those forecasts are based on the historic demand, and the accuracy of the forecast and the forecast is measured every week. More information on the forecasting methods will be available in the chapter on Servigistics Plan (see *3.2 Servigistics Plan*).

The inventory is primary, and for the biggest part, stocked in the Central Buffer. As the focus of this research is the EMEA region, the discussed Central Buffer is the one, which is located in Venlo, the Netherlands. On a local/regional level there are Local/Regional Stocking Hubs, which are carrying less inventory but are located closer to the customer. Even less inventory is stocked in the Same Day stores, which are located the closest to the customer and carry parts, that have a certain criticality, demanding same day delivery. The distribution of the stock and the identification of the needs is done by another IBM organization in Hungary, called Country Planning.

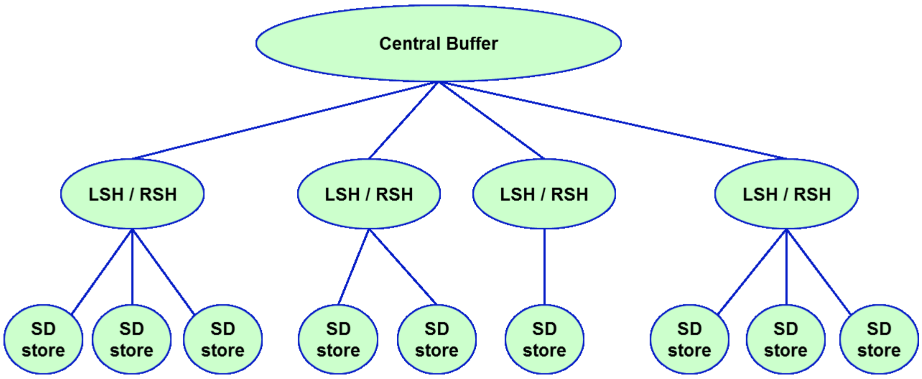


Figure 3: Stocking Options

If the stock at the local warehouses is not sufficient to fulfil an order, this order will appear as a review reason in Servigistics (see 3.2 *Servigistics Plan*), and it could be decided to make a direct delivery from the central buffer/vendor/manufacturer to the customer, in order to minimize costs. For each of the Stock Keeping Units and stock locations exists a Re-order level, Critical Stock Level, Keep on Stock Level, and Economic Replenishment Quantity. The distribution of the stock on the different stocking levels is internally outsourced by IBM, and handled by the so called Country Planning, which is located in Hungary.

On the demand there are the customers, who place orders/emergencies at IBM.  Orders are placed in order to keep the stock level of the different stocking locations on the preferred level, whereas emergency orders are placed when The orders are also referred to as emergencies, due to the fact that an order is placed whenever a part is broken and needs a replacement but the demand from the customer cannot be fulfilled from a stocking location. The demand can merely be planned in form of a forecast, as IBM handles electronic parts, whose breakdown does not occur in a deterministic way, and gives little condition based signals, unlike a mechanical part would do. The orders are placed at the local request management centres, which try to fulfil the demand, by using parts from the local/regional stock rooms or the central buffer. The physical delivery of parts is not done by IBM itself but by a third party logistics provider. The order has an urgency linked to it and the responsible department has to choose for a mode of transportation. Those can be by plane, taxi, or truck amongst others. Once the parts are delivered at the customer, there are three options for the installation of the parts in the machine, where they are needed. Parts are either installed by customer/field engineers, that work for IBM at the customer location, by a third party service provider, or in the case of easily replaceable parts, by the customer himself. The later could be hard drives for example.

The planning of how many parts need to be available at what time in the EMEA region is done by making use of the software Servigistics, which will be explained later.

#### 3.1.3. *Reverse Logistics*

The Reverse Logistics Process covers repairs and warranties. Whenever a customer returns a part, this part will be characterized as being in a certain condition, like for example *New, Equal to new, or defect*. This disposition is included in the planning process, as it allows the planner to draw on a broader variety of part types, in order to fulfil the customers' demand. This is, next to the environmental implication, important from a cost point of view, as New Buy is a more expensive option than repair/warranty in most cases.

The repairable parts are consecutively being transported to the repair depot, where they are stored until delivery to the repair shop/vendor. This function is also outsourced by IBM. The repair vendor does, as the manufacturers, have certain lead time agreements with IBM and works as such, in a similar fashion as a manufacturer. The lead times for a repair vendor can be higher and thus need to be planned with more attention. After being repaired the parts are being reintegrated in the forward logistics loop.

A problem, that can arise from the usage of such parts though, is the one of legal requirements. For some countries (e.g. Germany) it is not possible to distribute certain repaired parts. Furthermore, do some countries require a downgrade of the parts as repaired/used, due to the fact that they have been at a customer, although they have been returned with the disposition 'New'.

### 3.2. Servigistics Plan

In the following the software Servigistics Plan, which was formerly known as Xelus Plan, is explained. This software is being used for control and planning purposes and thus can be seen as a tool for a control tower. As such its functionality needs to be described in order to be able to compare it to the definition of a service control tower, which will arise from this research. It will be started by describing the working and functions of the software on a high level. After that a more detailed view on the features and information, conveyed, is given.

#### 3.2.1. *Introduction*

A license for Servigistics Plan was acquired by IBM, in order to use it as a planning system. The software was at the time of acquisition highly tailored to IBM's needs, and thus differs strongly from other versions of it. The company is using this system since the year 2004, which makes it 12 years old at the time of this research. The orders in the system are all placed according to lead time, and no short lead time orders are accepted by the system. This means that the lead times, with which the system works, are the contractual ones. Those can be altered by expediting them to an earlier shipment.

The system starts off with an interface, in which the queue of review reasons, that are assigned to the analyst, is displayed. Those review reasons are created whenever the order for a part falls out of the parameters (see *3.2.2.1 Parameters*), set for it. The most important review reasons and some of the parameters will be elucidated at a later point in this chapter (see *3.2.2.1 Parameters)*. Next to the handling of exceptions, is the system used for the planning of customer demand, by creating forecasts for future customer demand. It will be seen in the part on the Review Reasons, that some of the Review Reasons are linked to the goodness and fit of the used forecasting methods and parameters.

All orders, that are made, and fall within the boundaries of the parameters, are automatically processed by the system and need no review of an analyst. In this Servigistics could be seen as a hands-off system, in which the user is alerted, once an order falls outside of the parameters.

### 3.2.2. *Features of Servigistics*

#### *3.2.2.1. Parameters*

The parameters are guiding the flow of customer orders through the system. They can be seen as characteristics of an order, which are expected by the system, and if those expectations are not met the order will appear as a Review Reason. The data on the parameters and the orders comes from IBM's ERP system, where most of the data is stored.

The parameters can be divided in planning- and system parameters. The planning parameters are dependent on the material class of the item, and thus can vary per part. The material class is dependent on the dollar value and demand over time of the item, and indicated by an ABC code. As suggested by the name do the planning parameters guide the parts planning process, and are for this purpose further subdivided into three categories, being: Forecast, Safety Stock, and Order Review. In the following a planning parameter from each of those subareas shall be discussed.

> The area 'Forecast' contains the parameters that have been set for the forecasting for this specific item. An example is the 'Moving Average Period'. This is the number of historical demand periods, being considered when using the Moving Average forecasting method. A higher number would smooth the forecast more strongly but also cause the forecast to be less reactive to the actual demand.
>
> The area 'Safety Stock' contains all of the parameters that are required for the determination of the safety stock. An example is the 'Safety Stock Strategy, which is indicating the method, being used for the Safety Stock calculations. An example for such a strategy is 'Probability of Not Stocking Out', where the: "Safety stock is set to a level that is likely to prevent a stock-out from occurring during the normal replenishment interval (the time between order placement and order receipt). The value is calculated using a formula for finding the safety stock k factor." (Servigistics User Manual).
>
> The area 'Order Review' contains all parameters, which are required for the definition of a 'should be' situation. An example of a parameter in 'Order Review' is the 'Excess POS Inside Lead Time'. This is a number, specifying the number of periods of supply to be used when calculating the Excess Point inside of the Lead Time. The Excess Point is the stock level at which order reductions are suggested. Those parameters are needed for the system to generate order recommendations, in order to balance the inventory and the forecast.

The system parameters do on the other hand contribute more to the software architecture and are by that less interesting for the operational capabilities of Servigistics.

*Table 2: Review Reason Description*

#### 3.2.2.2. Review Reasons

The review reasons (from now on RR) can best be described as alarms, which are created whenever an event in the processes of the SPO occurs, that falls outside one or several parameters. The RR are described with the following attributes:

| Attribute | Description |
|---|---|
| **Priority** | Position in the list of all RR, the highest being 01. This value ranges from 1 – 80. |
| **ID** | Unique Identifier for the RR, in form of *Rxx.* |
| **Name** | Abbreviated Name for the RR. |
| **Description** | Full name of the RR, implying the underlying business condition. |
| **Disable days** | Once an RR has been triggered, it cannot be triggered for some a period of time (0 – 30 days). For example if RRxx has been triggered and has 20 disable day, it cannot occur in the next 20 days. |

For the sake of brevity, it has been decided to only include a selection of all the RR's, in order to paint a clearer picture of what is meant, when talking of RR's.

The RR with priority 01 is R2, which is called 'Forced Worksheet". This means that the Forced Worksheet flag is on. The forced worksheet indicates, that the system may not automatically process this part.

Priority 02 is given to the R4, which is called 'Backorder Quantity'. This indicates that the back-order quantity for this period for the item at hand, is more than zero. This RR does also appear whenever an alternative part, for the part, is affected by the back-order condition.

R45 has the priority 31 and is called 'Transship instead of New Buy'. This RR is shown to a planner, when the system recommends to make use of transshipment rather than buying a new part, to fulfil an order.

R19 has the priority 17 and is called 'Order on Sum Code 2 Part'. This RR is triggered when a new buy order or a return process order contains one part with the sum code 2, indicating that it is an obsolete part.

R78 has the priority 29 and is called 'Order Requires Legal Entity Approval'. This RR is triggered when an order is marked as "waiting for legal approval". Think here for instance of import or export requirements.

#### 3.2.2.3. Primary features of Servigistics Plan

The primary features of Servigistics Plan are as follows:

- Planner Worksheet
- Planning Tables
- Reports

- Special Analysis

Other features of the software do have a more of an administrative function and do as such not directly contribute to the operational capabilities.

The ‘Reports’ feature enables the user to generate a variety of reports on different fields. Those field cover *Parts Management Reports, Management Reports, Order Reports, Audit Trail Reports, Configurable Reporting*, which enables the user to generate a report, tailored to his/her business needs. The reports can be used in the following for tactical and strategic decisions on, for example, the architecture of the supply chain or the operations.

#### *3.2.2.4. Planning Tables*

In the following is a list of the tables that contain the necessary data for the planner worksheet.

| TABLE | DESCRIPTION |
|---|---|
| **ABC Codes** | Used to clarify and rank items based on their dollar values of demand over time. |
| **Leading Indicators** | Shows the indicators for forecasting in order to account for known conditions like machine population, seasonal demand, or the part-life. |
| **Location** | Contains information on the hierarchy of the of the distribution areas. |
| **Parameters** | Set of planning parameters, which are assigned to the item. This is based on the material class of same item. |
| **Products** | Contains the product specific information on the item. |

Table 3: Table Description

#### *3.2.2.5. Special Analysis*

For the purpose of special analysis’ Servigistics Plan offers two types of analysis. The first is Excess Analysis, which helps to manage the inventory by identifying and recommending the disposal of excess inventory.

The second is Exchange Curve Analysis, which is a modelling tool to test various planning strategies (see *3.2.2.1 Parameters*) for inventory investment and service levels. The different strategies for are as follows:

- Probability of Not Stocking Out (1): Safety stock is set to a level that is likely to prevent a stock-out from occurring during the normal replenishment interval (the time between order placement and order receipt). The value is calculated using a formula for finding the safety stock k factor.
- Piece Part Fill Rate (2): Safety stock is set to a desired service level (fill rate) in pieces based on an item's forecast error history. Fill rate is the percentage of demand that is immediately satisfied.
- Periods of Supply (3): Safety stock is set to a desired number of periods of supply, based on an item's average forecast over the next year.

- Stock-Out Occurrences (4): Safety stock is set to tolerate a given number of stock-out occurrences per year. It differs from Strategy 1 by explicitly considering the number of cycles per year for an item.
- Percentage of Lead Time Demand (5): Safety stock is set to a percentage of lead time demand.

By testing those strategies an analyzer has the capability to keep costs low, while holding up the necessary service level.

#### *3.2.2.6. Planner Worksheet*

The Planner Worksheet is the 'heart' of SERVIGISTICS PLAN. According to the system itself the main function of the planner worksheet is to bring together demand and supply over time, by bringing together the forecast and demand decisions. Within the Planner Worksheet the user can see the Item Data Window, which gives descriptive information on an inventory item. Under the Item Data Window are more specific data windows, in forms of tabs, which are concerned with different aspects of the item.

The tabs cover the *Forecast, Field Data, Inventory levels, Plan Level, Quick Plan, Returns (Repair/Warranty), Surplus and Excess, and Graphs*. In the Graphs some of the other aspects are visually represented. They furthermore display the historic development of the Forecast (*Figure 5: Forecast Graph*), Orders, Repairs, and Warranties over time.

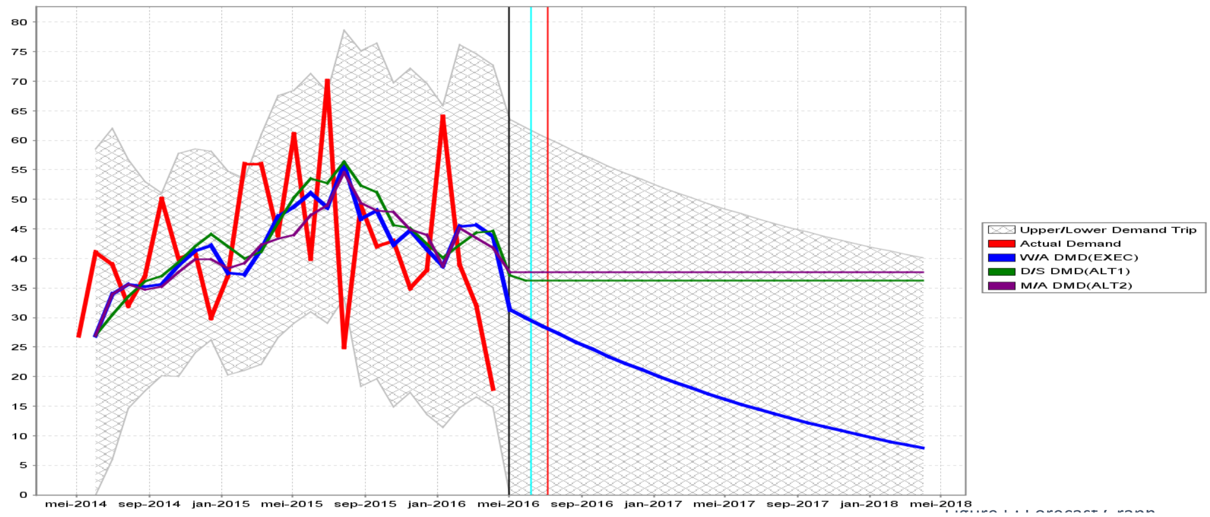


Figure 4: Forecast Graph

The forecast, as displayed in *Figure 5: Forecast Graph*, can be seen as an example of how the forecast for future demand looks like. One important feature to notice, is that there are three forms of forecast for the demand, that have been chosen for the Item. Those three are depicted by the blue, green and purple line in the picture. The forecasts are deterministic in nature and do not account for randomness. Furthermore, is the lifecycle forecast included in the forecast, which explains the declining executive forecast and the overall development of the forecasting curves. The planner can use this forecast to see how much demand is expected to occur and thus how many parts should be ordered in order to fulfil the Service Level Agreement. The forecasts are made every month based on the historic demand, and are being checked every week in form of review reasons (see *3.2.2.2 Review Reasons*).

The shaded region (Upper/Lower Demand Trip) symbolizes the tolerable limits for forecasting errors. When they are exceeded a review reason is triggered.

Next to the Graphs the tabs hold a tremendous amount of information, which can help the analyzer in the analysis and solving process for the review reason. The information, which can be found there is containing the following:

- Demand (Future/Historic) per type (warranty/repair/new buy) per month
  - Calculated Forecast
  - Manual Forecast
  - Can be viewed for each location
  - Historic demand can be split into the sources, from which the demand occurred (customers/lower stocking locations)
- The stock levels per location per month
- The inventory levels per type (warranty/repair/new buy) per month
- The number of requirements for order analysis
- The Policy Safety Stock per month
- The returns (repair/warranty) per month
  - Total expected returns
  - On hand returns
  - Work in process returns
- The surplus stock per type (Internal Demand/Excess/Global Asset Recovery Service) per month

The level of detail, in which the data is represented, is on single parts level with the possibility to specify it for every location the part is held at or needs to be delivered to. By that it is possible for the user to have a well-structured view on the information for every part. The user can see where the parts are being stocked and how much is stocked there. Furthermore, one can see which types (repair/warranty/new) of parts are when available in order to fulfil demand. The same information is available on the demand side, namely from where which part of the demand occurs.

### 3.2.3. *Capabilities in Summary*

In conclusion, is Servigistics a software for the operational handling and detection of customer order exceptions. The main functionality, that is added by Servigistics is its capability to process the orders, that do fall within the boundaries of the pre-set parameters, and filter the ones, that do fall outside of those. It creates review reasons whenever this case occurs and makes those available to the analyzer, being responsible for the concerned part. Furthermore, does the software aggregate and organize a variety of data on the status of the inventory, the forecasted demand, and the status of the arriving parts, which source they may come from. The level of detail, that is applied in Servigistics goes to every part, at any location they might be at, over the development of time, which is being measured in months.

Next to the handling of order exceptions, does Servigistics allow its user to create a broad variety of reports, which can be studied in order to determine underlying problems and trends. The data, which the software has available, comes from IBM itself and future demand and incoming parts from repair/warranty, vendors, or manufactures are present as statistical functions, based on historic events. There is no actual data, from within the vendors or repair-shops available to IBM.

## 3.3. Entercoms

In the following the Control Tower tool by Entercoms is discussed. For the sake of brevity, the tool will be called Entercoms from now on. Together with Servigistics, Entercoms serves as a Control Tower tool at the SPO of IBM and thus needs detailed analysis for later comparison with the definition of a Control Tower, arising from this research. The following chapter will start with an explanation of what Entercoms is, and continue by elucidating the features in a more detailed form.

### 3.3.1. *Introduction*

Entercoms is a managed services company with focus on supply chains in the aftermarket, whom IBM is in a partnership with, and whose main purpose is to analyze and organize the data, which is sent to them by IBM, in order to give a better insight into the order fulfilment trends. This partnership has been entered, as Entercoms has tools with tremendous analytical capabilities and the expertise to use those tools. By that IBM has outsourced the analysis and, rather importantly, the visualization of their data. Within the software the suppliers' as well as IBM's own performance is being analyzed and visualized.

The solution, that is presented to IBM is called "Control Tower". It could be described as an information hub with retro perspective, analytical capabilities, that are on a more tactical level than Servigistics. There is no direct software feedback loop to Servigistics, and the information created by the aggregation and analysis of the data is only being processed by the staff, working with Entercoms. As highlighted before is visualization of data and information, which is carried by it, an important feature, especially as the further processing of the data is not automatically processed. It allows the users to quickly understand a broader picture and make use of that knowledge.

Due to the fact that Entercoms and IBM have just recently started to work together the information, available to and on the EMEA region is rather limited. The analytical fields at the time of this research are: *Supplier View, Geographic Parts Availability Level (PAL), Root-Cause, Emergency order Recovery, and Chain Change and Visibility*. Not all of those fields are yet able to give information on every region, but the information available in them, will be discussed in the following.

### 3.3.2. *Supplier View*

Essentially the Supplier View is a high level view on the performance of the different suppliers. The supplier view is moreover divided over three sub-areas, called: *Supplier View, Alerts and Details and Order Details*, whereas *Order Details* contains the data, which is send from IBM to Entercoms for analysis and represented in the other two areas.

SUPPLIER VIEW enables its user to see the purchase order value, order count, and the percentage of early/on-time/too late order arrivals, per Suppliers or Parts (see *Figure 6: Details By Suppliers*). Furthermore, one has the choice to filter the information by parts, suppliers, order types, receiving locations.

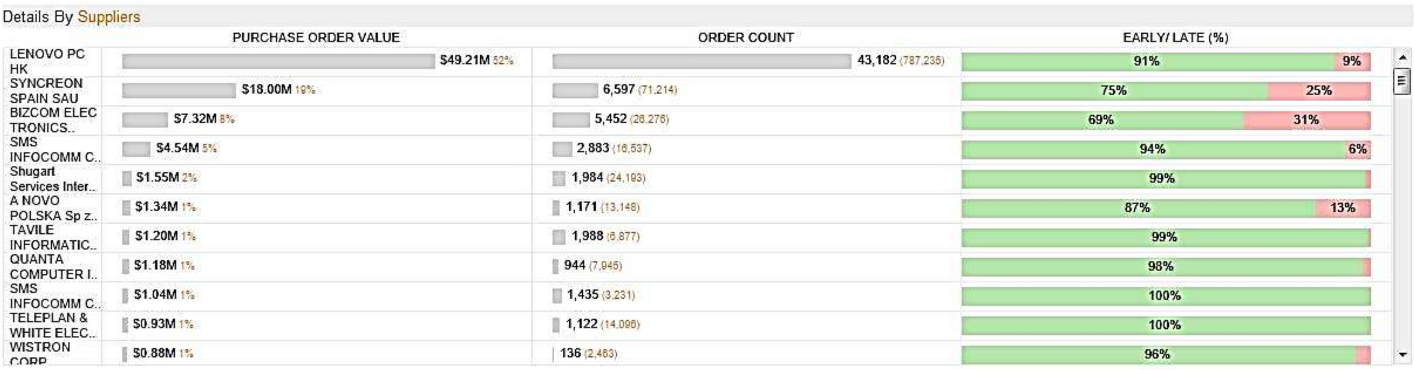


Figure 6: Details By Suppliers

Next to this supplier specific data, Entercoms gives its user trend lines on the early, too late and on-time development of all orders, in form of a line chart, and a scatter plot, which plots the orders on the x-axis, according to the Order Quantity and on the y-axis, according to the observed lead time. Entercoms also gives a chart, showing the lead time variability trend over time, by displaying a boxplot of the avg. observed lead time of the orders.

ALERTS AND DETAILS could be seen as a higher view on "Supplier View". It gives charts on the distribution of alerts by supplier or by commodity. An alert is created whenever the actual LT variates from the contractual one. The actual LT is recorded at the moment of order fulfilment. With this it gives the user an insight on how different suppliers stick to the agreed LT, and might help with eventual Supplier evaluation or the planning process.

### 3.3.3. *Geographic PAL Root-Cause*

The Geographic PAL Root-Cause analysis window is focused on IBM itself. It gives information on where and when the Product Availability Level metric was not on target, and what the reasons therefore are. The PAL "*is a key measurement used by the EMEA Parts Logistics community to indicate in how many cases a parts request on a stock location is fulfilled (expressed in a %). Each time a part requested by the Customer Engineer is not available, is recorded as a loss. (Example: 10 losses out of 100 requests in a month equals to a PAL of 90% in that month)*" (*EMEA Work Instruction: For Logistic Planning Analyst*). By that this window acts as an identifier of problems and, still on a rather high level, the reasons. An example for such a reason is the "No Source", indicating that no supply source was available for certain parts.

FULFILMENT TREND. This area of Entercoms shows the user a graphical interpretation of the development of the PAL in percentage over time and per location. By means of color code indication the user can see when and where the target was reached and in which cases it was not. The user can see the weekly PAL per location for the last 12 weeks. Furthermore, it enables its user to see the distribution of the most important root-causes that lead to a loss in PAL. Next to the pie chart, a stapled bar chart indicates the trend in different root-causes over time (last half year).

In DETAILED ROOT CAUSE the data, used for the creation of the graphs can be seen in tabular form.

### 3.3.4. *Emergency order recovery*

The subarea EMERGENCY ORDER RECOVERY shows the amount and age of emergency orders. An Emergency Order is issued by a customer when a machine is broken and if the order cannot be fulfilled from a local storage point. The display of the emergency orders is either as number or percentage of all emergency orders (EO's) per region. Other graphs depict the EOs by function, product family, customer, or part number, and distribute the Eos over three statuses. The three statuses are: not available, past due, and future due. Next to that the user can also see the amount of recovered EO's at different points in time.

The subarea DETAILS shows the EO recovery at part level and the recovery date changes, which are: *First occurrence, no change, pull in, and push out*. Here *pull-in* is shown whenever a supplier was able to improve the shipping date. *Push-out* is shown when a supplier had to delay the shipping date of an order.

### 3.3.5. *Chain Change Impact and Visibility*

This window allows the user to see gives the user information on the parts that are experiencing a change of supplier or from prime part to alternative part. Next to the amount of parts, that experienced a change, the user can see the impact that change had on the overall PAL. The total number of parts, subjected to a change, can also be seen per week. The impact the change had in the development of time can be viewed as well. This gives indication for some of the PAL misses that have been identified in another window (see *3.3.3 Geographic PAL Root-Cause*).

CHAIN CHANGE IMPACT shows the user of Entercoms the total number of parts, which are affected by changes in the chain. A *change* could be a change of supplier, or a change from a prime part to an alternative one. Of those the number of parts, which are actually subject to change are displayed, as well as those that are subject to a source change. Furthermore, the user is able to see the different forms of impact and the amount of parts affected by them. Next to that Entercoms suggests, for which parts which action should be taken, and shows in another chart, for which parts a New Buy source is available. It also enables the user to see, what the impact on the PAL is, and how the impact on the inventory for certain parts will be.

DETAILS shows in more detail, per part, what the impact of a change is, by comparing the situation before and after the change. The comparison is done per part and includes the part itself, the alternative parts, and its successors. One of those factors is for example EBL at LT, which stands for Projected Ending Backlog after one Lead Time period. In this example you can see that the chain change resulted in an increasing Backlog, which is rising every four weeks, in a constant manner. This could indicate that despite existing demand, there might be no supplying source.

CHAIN CHANGE AND COMPARISON shows per part, which of its supporting and supported parts

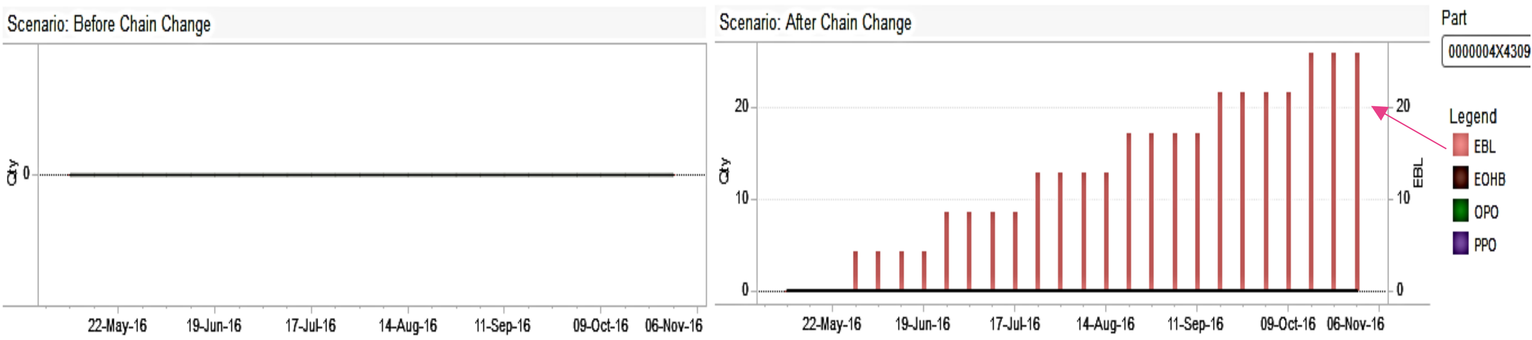


Figure 7: Details After Before

were procurable and which were not. It also shows how those supporting and supported parts, were affected by the change.

The CUMULATIVE IMPACT VISIBILITY is in principle a representation of the 'CHAIN CHANGE IMPACT' window, in the development of time. It gives an indication of the inventory- and PAL exposure and shows, which parts were negatively or positively affected.

The displayed Data can be filtered by *Week, Impact, Status, Action Proposed, and Part Number*.

### 3.3.6. *Capabilities in Summary*

By analyzing and visualizing Entercoms adds value in form of visibility. It gives the user insight in underlying trends for the Suppliers as well as IBM itself. Historical information that IBM has available, is transferred to Entercoms, where it is analyzed. By that IBM is outsourcing a part of its analytical tasks, which saves time and the need for extra staff with analytical expertise. The solution itself is on a more tactical level than Servigistics as it does not contribute to the daily handling of orders. Entercoms might give insight in bottlenecks at IBM, which are leading to a consistent underperformance. At this point the solution is rather limited though, as it leads to the visualization and analysis of data, which is after that not automatically transformed into alerts. The further procession of the data is done manually.

# 4. Control Tower

For the definition of a Service Control Tower the five layer model by Ji Shou-Wen (2013) has been chosen. Although the Five-layer concept is not specifically developed for the After-Sales Supply Chain, the overall framework is of such form, that it can be adjusted for the after-sales supply chain by enriching it with aspects of other concepts. This concept has been chosen as it has the potential to include the relevant aspects of other definitions, which is not given for any of the other definitions. Furthermore, does this framework facilitate the later evaluation of existing control tower solutions, and explains the connection of the different Control Tower aspects. By choosing this concept the research at hand will not only provide a demarcation of what a Control Tower should be but moreover give indications and suggestions for the creation of a Control Tower. The framework will consist of: The Supply Chain Business Layer, Data Perception Layer, Data Storage Layer, Application Layer, and the Manpower Layer. The goal of this chapter is to answer research questions Q2 and Q3:

- What is needed to effectively monitor and control the service supply chain processes? (Q2)
- What should a Supply Chain Control tower be? (Q3)

## 4.1. Supply Chain Business Layer

The Supply Chain Business Layer forms the bedrock for the Control Tower. It contains all processes that need to be performed in the after sales supply chain. Driessen et al. (2010) suggest a framework, containing eight processes that ought to be performed by a Maintenance Logistics Organization (MLO). In their article they claim that this framework is fit to be the starting point for spare parts management and control systems. Within those processes are different decisions that need to be taken, and which are levelled into strategic, tactical, and operational. Furthermore, it is to be noted that there are various feedback loops in between the processes.

To have an amount of information, sufficient to guarantee an adequate level of control, it is important to record the outcomes of all those decisions. As this research is concerned with the framework for an operational service control tower, the focus in higher layers will be directed towards the operational processes and decisions. Yet it is to be noted that the outcomes from strategic and tactical decisions ought to be incorporated in the information data base of the Supply Chain Business Layer to create the environment for operational decisions and are thus important to be recorded in the Control Tower.

Rustenburg (2016) has already done a selection of the operational processes for service control tower purposes and is therefore being considered for this research. In his paper on Shared Service Centers, he uses a PCOI model (Processes, Control, Organization, and Information). In the Processes-part, he employs the operational processes: Assortment, Forecasting, Inventory Planning, and Deployment, from the framework of Driessen et al. (2010). The eight processes, as identified by Driessen et al. are depicted in *Figure 8: Processes and Feedback Loops*. More information on those processes is available in the appendix (see *p. 36 Operational Processes*).

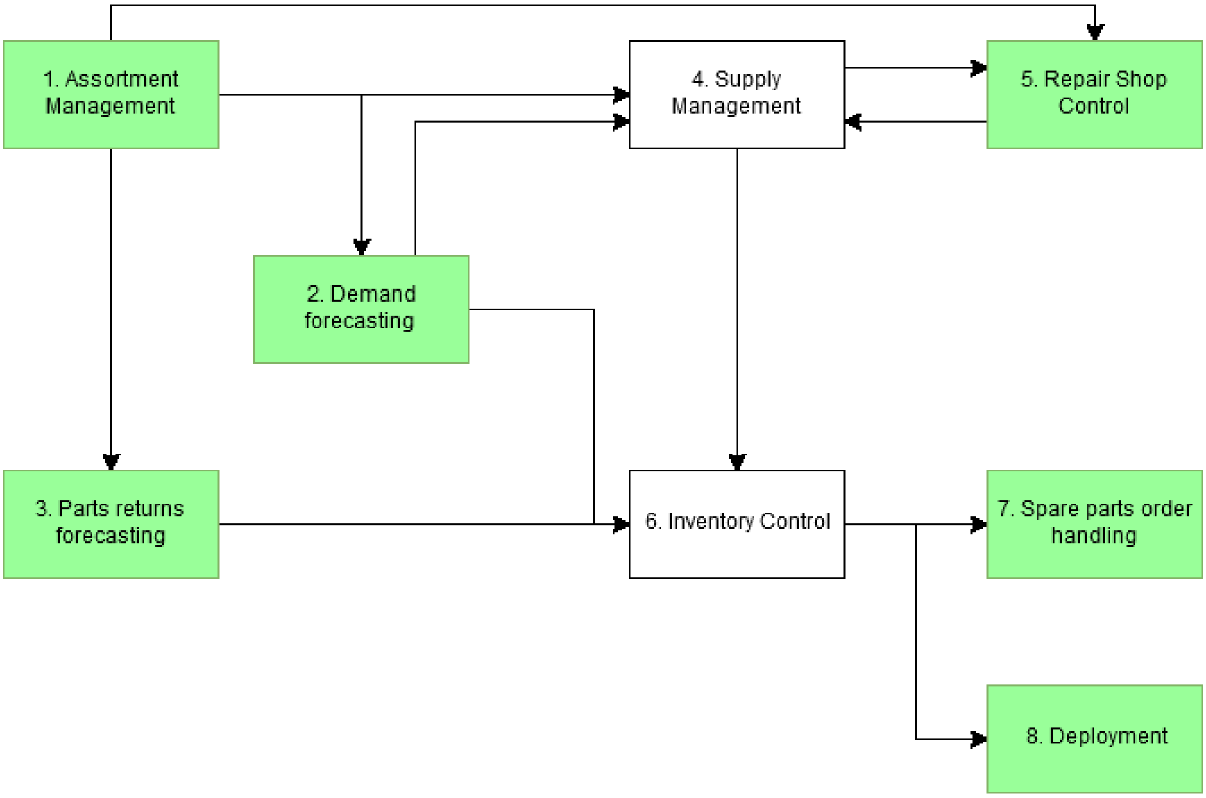


*Figure 8: Processes and Feedback Loops*

## 4.2. Data Perception Layer

The data, that is produced daily in the business layer has to come to the data storage point in some way. Those ways are being discussed in the Data Perception Layer. As the information, that ought to be gathered in this layer comes from various sources, which have been defined in the previous layer (see *4.1 Supply Chain Business Layer*), there are different modes for the perception of information, varying per source.

Here it has to be differentiated in between two different business models for the Control Tower. The first would be a Control Tower, managed by one organization, which is part of the Supply Chain (Ji Shou-Wen, 2013). Further on this model is called Model A. The second model is a Control Tower, which is handled as a service by a legal entity with no own interest in the Supply Chain. This could be a fourth party logistics provider (4PL) for instance (T. de Kok, 2015). The second model is called Model B for this research. The specifics of this distinction, will be elucidated further on, but it is necessary to mention it already, as it has direct implications on the mode of information gathering. There are some features, though, that both models share. If in the following the business model is thus not mentioned, the described features are shared by both models.

For Model A the sources of information can be differentiated into the following:

- internal process data/information
- external process data/information (harder to obtain)
- logistic data/information (SCEM, tracking and tracing)

For Model B, the *internal process data/information* source is not existent, because it concerns a legal entity, which is not performing any supply chain operations, and rather acts as a service provider. A difference of those the sources, has to be made as the amount of information that is receivable from each, varies. Furthermore, is the level of difficulty to obtain the necessary data/information from different sources, dependent on the willingness to share and the ability to gather data/information. The data/information on the internal processes is, in case of a well working internal data perception structure, rather complete. The data/information on logistical processes, is the data/information on the movement of spare parts in between the internal and external processes.

In the following, the modes of information perception for each of the different sources shall be discussed in more detail.

### 4.2.1. *Internal Processes*

The internal processes, that have been introduced earlier, do generate a vast amount of accessible data. As earlier mentioned the Internal Processes do only play a role for Model A. All decisions, that are being taken in those processes need to be registered in the Data Perception Layer. Usually those decisions are being recorded by an Enterprise Resource Planning (ERP) system, independent of the IT system with which the decision has been taken, and stored in a database.

### 4.2.2. *External Processes*

For Model A, the external processes are those, which are internally performed by other members of the supply chain, for example vendors, manufacturers, repair shops, and others. Logistic Service Providers, will be discussed separately. For Model B, all processes, which are internally performed by members of the Supply Chain, are external processes. In the following will this chapter be divided into subsections, which cover each of the models.

#### *4.2.2.1. Model A*

There are several constraints, that are imposed on the data gathering from other companies, but the main obstacle to sharing data on operational activities seems to be the lack of trust towards other players in the supply chain (Ruijgrok, 2010). Other barriers can be in form of incompatible systems, lack of perceived benefits from sharing, high level of bureaucracy, a lack of internal data gathering, and others (P. Gour, 2013). Another aspect that might block collaboration is that the insight of other companies in the own processes also reveals errors that have been made. Furthermore, can the definition of various concepts vary in between organizations, which can lead to miscommunication. The overcoming of those barriers is crucial for an effective data perception. Data sharing, is thus very much dependent on the willingness to share internal data/information with the controlling party. If it is taken into consideration that real trust is hard to establish or measure, it is advised to create different contracts, concerning the amount and frequency of shared data/information. Here it appears to wise to establish long-term contracts, in order to establish a long-term relationship, which has been seen to lead to more trust and thus an overall better performance (D. Prajogo, 2012).

A common technique for the automated Business-to-Business (B2B) communication is the standardized Electronic Data Interchange, which has been accepted within different industries, and is listed as a Best Practice in the eleventh version of the Supply Chain Operations Reference (SCOR) Model.

#### *4.2.2.2. Model B*

In this model, the main constraint of Model A, namely the mistrust, is being alleviated. Since the information is not concentrated in one member of the supply chain, but rather in another company ‘besides’ it, the perceived benefits for all members of the Supply Chain are higher than in Model A. This might ease the development of agreements on the amount and frequency of sharing information. Hillergersberg (2015) suggest the usage of a web-technology based B2B integration, in order to enable companies with less developed ICT structures to be integrated in the overall ICT framework. As in this model the Control Tower is a company above the supply chain, we suggest that a web-based data input system is made available to the members of the supply chain in order to gather data from the various sources. This resolves the problem of universality as the method of data transfer is given by the Control Tower provider. It has to be assured though that the security during the transfer is given. For some systems it might be necessary though, to create a middleware software that is 'translating' the information from the original system, into the one of the Control Tower, in order to automate the process.

#### 4.2.3. *Logistics Information*

The distinction between Model A and Model B, made in the external process information, is not necessary for the logistics information, as we refer to the transportation and warehouse management, which is not part of the MLO or the other supply chain members in the previous section, but executed by a third party-party logistics provider (3PL) (M. Berglund, 1999). Thus both models can gather information in the same way. Transportation refers to any movement of goods from member of the supply chain to another, and warehousing to the picking up allocating of spare parts within a warehouse. But a distinction in between different perception modes can be made here. Videlicet in Supply Chain Event Management (SCEM), and Tracing & Tracking of physical parts. According to the ISO: "Traceability is the ability to trace the history, application or location of an entity by means of recorded identification. ISO relates traceability to the origin of materials and parts, the product processing history and the distribution and location of the product after delivery. According to ISO, traceability includes the set of interrelated resources and activities which transform inputs into outputs" (Dorp, 2002). For this research an entity refers to a spare part, that is being delivered. For SCEM the spare parts go through a pre-defined chain of events, which are marked as complete, once they have been passed. The chain starts with the picking up of a spare part in the warehouse and ends when the customer holds the spare part. Whenever an event has not been marked as complete at the time it should have been marked so, it indicates that a delay might occur. The choice for a mode of monitoring is made by the 3PL, but Baumgraß et al. (2015) suggest that tracking & tracing be included in a transportation control tower. We conclude that it might be the superior method, in terms of control. The transfer of data from the 3PL to the Control Tower should be done by giving the 3PL the possibility to directly upload the information into the control tower.

### 4.3. Data Storage Layer

This layer is further split into two parts: the supply chain data storage part and the supply chain data control part. The data, that is coming from the Supply Chain Business Layer and is transmitted through the Data Perception Layer, is being stored in the storage part, which from here on serves as an information basis for the information control part. The control part can consecutively feedback updated control information into the storage (Ji Shou-Wen, 2013).

#### 4.3.1. *Supply Chain Data Storage*

The exponential growth of data volume from many data streams (Demchenko Y., 2012), creates the need for a modular storage structure that can be expanded, whenever needed. Furthermore, have Wang and Alexander (2015) identified the need for a neutral data repository, which aggregates, organizes and makes the data available, from and to the different members of the supply chain. The need for such a data repository arises, when many organizations within the supply chain share their data, because trust is as, earlier mentioned, a barrier to information/data sharing in the supply chain. It can be seen again that Model B, might alleviate this barrier. The usage of cloud-based based technology is being endorsed by Chandra and Hillergersberg (2015), who state that a cloud based operator provides the ICT infrastructure, platform and software as a service through the internet, which does not need an initial investment but is highly scalable, easy accessible and reduces the business risk. Furthermore, it easily allows the integration of new companies into the control tower. The authors also state that a concept similar to Model A (see 4.2.2.1 Model A) is less likely to be able to operate an integrated Control Tower, than a concept similar to Model B (see 4.2.2.2 Model B). It is still suggested for Model A to make use of cloud technology in order to have the benefits of the scalability and enhanced accessibility.

### 4.3.2. *Supply Chain Data control*

Due to fact that data is coming from various sources, there might be redundancies in the data. This is also referred to as noisy or dirty data. Especially the data, coming from RFID sources has been identified to be noisy (Zhang, 2014). Thus in order to decrease the total amount of data, coursed by redundancies the system in place has to be able to identify those and feedback information on redundancies into the storage part, where they are being deleted. By that the data is becoming more structured and smaller in the total amount. Those redundancies could be resolved by a Data Convertor as suggested by Yan et al. (2012), whose functionality not only includes the cleaning of data, but also source data quality checks and a feedback loop into the Control Tower database in order to achieve an organization in it. Furthermore, is the data being organized in Data Marts in order for the applications in the following layer to be able to access the data, without having to filter through a vast amount of data.

## 4.4. Application Layer

The application layer does contain the applications, that generate the biggest part of the Control Tower's functionality for monitoring and controlling the Supply Chain. While the earlier layers are crucial to the establishment of a basis for analysis and the data availability, this layer contains the power to filter, analyze, and visualize the data. By that it leads to the creation of information and gives the user insight in the operational supply chain processes.

The capabilities that could be included in an operational Control Tower are:

- Overview over Supply Chain Metrics, with possibility to drilldown the information
- (Real-time) alerts based on prior established business rules
- What-if analysis for the predictive impact analysis of decisions
- Root-Cause analysis of a loss in a certain metric and trend development
- Trend identification
- Top down distribution of alerts and decision support

The selection of those features is based on various sources from the literature and discussions with practitioners. In the following, each of those features will be explained in more detail.

### 4.4.1. *Supply Chain Metrics*

The applications, that are analyzing the data, should have the capability to measure the metrics, which have been chosen as performance indicators by the management. Furthermore, it is important to track the development of the measurements over time. Those metrics are created on a fairly high level and give indication on the overall performance of the Supply Chain. Due to its own Database, the Control Tower should be able to drill down the information, that is aggregated into performance measurements, to an operational level. By that it enables the user to gain insight in the composition of the metric. Furthermore, should the Control Tower have the possibility to apply various filters on the information displayed, in order to achieve a tailored view on the performance measurement (IBM Supply Chain Control Tower - Overview).

The metrics, that are displayed, could be divided into:

- Internal
    - Control
    - Process
- External
    - Supply
    - Demand

The control metrics are those that are giving an indication on how the actions, taken in order to deal with alerts did impact the overall performance. The process metrics are those that measure the current working of the internal processes (see *4.1 Supply Chain Business Layer*). The segmentation of those metrics is based on the different supply chain risk sources, as identified by Christopher and Peek (2004). The choice for specific metrics can vary per company, and falls beyond the scope of this research.

For Model B[1] (see *4.2.2.2 Model B*) it would be possible, due to the enhanced amount of information, to have more sophisticated metrics on the end-to-end supply chain processes. Model A[2] (see *4.2.2.1 Model A*) has to rely on the Data, that is available to it through means of observation, or the willingness of other supply chain members to share internal information.

### 4.4.2. *Alerts*

Alerts are given by the Control Tower, whenever an event is detected, that might have a negative impact on the performance. As mentioned earlier, it is important to note that the alerts for Model A and Model B differ in timeliness and accuracy. For Model B it might be possible to generate alerts, based on actual and accurate data from one supply chain member, in a pro-active fashion. This would also enable operational risk management as defined by Rajamani et al. (2006). Take for example a manufacturer, who might have for whatever reasons problems to fulfil a parts order. If the Control Tower has the possibility to detect this problem, it could inform the ordering party about the upcoming bottleneck, enabling this party to deal with the issue in a timely fashion. By actions such as these, events might be identified before affecting a service level. For Model A such actions might not be possible, as explained earlier. For both models though, it is necessary to pro-actively identify potential supply chain risks. Here supply chain risk means: "[…] the damage - assessed by its probability of occurrence - that is caused by an event within a company, within its supply chain or its environment affecting the business processes of at least one company in the supply chain negatively" (W. Kersten, 2008).

An established logic for the creation of alerts is the definition of business rules, which, when not fulfilled, trigger an alert. For the first establishment of such business rules it is essential to integrate people with domain knowledge in the process of rule establishment. Essentially those business rules, create critical definitions for a "*Should be*" state. Critical in this sense means that those rules have to be followed for certain performance targets, to be reached. Furthermore, they act as a filter for the vast amount of events that are occurring in the supply chain. It would be uneconomic to check all of those events manually, so the majority, if the business rules are met, are being processed automatically, so that only a selection requires attention.

Venkateswaran et al. (2016) claim that the current alert mechanisms are limited by their static nature. To improve the quality of alert generation, they suggest to base the business rules for alert

[1] Model B = Control Tower is managed by service provider, besides the supply chain
[2] Model A = Control Tower is managed by a Supply Chain member

generation, on historic values. Furthermore, they suggest to include temporarily varying behavior into the model. By that, they argue, unnecessary alerts can be avoided.

Next to the detection of unwishful events, the discovery of patterns, that might lead to undesirable business results plays an important role. Complex Event Monitoring (CEP) is an application, which can help to proactively predict high level events by analyzing a set of, seemingly unrelated, low-level factors. Those high level events are of such nature, that they will have an impact on business decisions.

### 4.4.3. *Decision Support*

By integrating and analyzing the data, that is produced daily in the supply chain, it is possible for the Control Tower to give the operating staff support for decision making, whenever needed and based on (near) real-time data. But next to the data, which is available, there are uncertainties, arising from Supply Chain parties, of whom less information is accessible. In order to integrate this uncertainty in the decision making process, and analyze the impact of possible decisions, a so called Decision Support System is needed. A decision support system is "[…] *a general term for any computer application that enhances a person or group's ability to make decisions.* […] *Five more specific Decision Support System types include: communications-driven DSS, data-driven DSS, document-driven DSS, knowledge-driven DSS, and model-driven DSS*" (Power, 2008) More information on the decision analysis for decision support is available in the Appendix (see p. 38 Decision Support).

One example of a DSS is the Agent Based Decision Support System (ABDS), in which a system of agents is modelled to simulate real-world events. Agents in this case are modelled entities, which are interacting, and acting to maximize their 'own benefits', and act as a simulated version of other supply chain members. The system does, next to the agents, contain some performance indicators, in order to evaluate simulated decisions (P. Hilletofth, 2012)

Next to ABDS, there are other approaches to decision support systems like system dynamics, discrete event simulation, or hybrid models.

### 4.4.4. *Root-Cause Analysis*

Root-Cause analysis (RCA) is aimed at identifying the underlying courses of existing problems in order to launch a counteraction (J. J. Rooney, 2004). The need for such analysis arises from the fact that not all eventualities in the supply chain can be predicted, due to the ever-changing environment, it is operating in. While the immediate identification of a problems symptom, and the treatment of same, are important for the working of the supply chain, the treatment of the root-cause, is of utmost importance. RCA has in itself more tactical than operational implications, as it can help to identify problems, that lead to a constant underperformance. One method for identifying the Root-Causes is by making use of a Bayesian Network (A. Alaeddini, 2011). A Bayesian Network is a statistical model, which is representing statistical variables and their interdependencies. After a problem has been identified, the Bayesian Network can give an indication, which cause is most likely linked to this problem, and according to the authors, this method provides a real-time identification of one or multiple failure causes, and has the potential to improve itself by learning from mistakes.

Another method for the identification of root-causes is the Cause Effect Diagram (CED). For this method the potential causes for symptoms are identified and depicted in a graph. After that they are aggregated in different categories. For the service industry those are the four s: Suppliers, Systems, Surroundings, and Skills. Other methods are for example the five-why method, according to which a root-cause can be identified after asking the question "why" five times, and Apollo Root-Cause Analysis, which is similar to a tree analysis, but analyses two causes, an action and a condition (S. A. Sarkar, 2012).

#### 4.4.5. *Distribution of alerts and decision support*

As the Control Tower is located "besides" the supply chain, and aggregates and analyses all of the operational processes, there is a need for feedback to the supply chain members, which are responsible for the execution of potential solutions. Top-down does in this case thus refer to the distribution of alerts and potential solutions to the acting supply chain members. This is necessary, as the control tower itself does not have the executive capability itself, but rather serves as an organ for failure detection and optimization, by creating enhanced visibility. Furthermore, it adds another layer of control to the process, by integrating the people, who have the specific domain knowledge, into the decisions process.

#### 4.4.6. *Evaluation*

Next to the Supply Chain metrics, the Control Tower should include a self-controlling mechanism, which keeps track of the Control Tower decisions and activities. By recording all of the decisions, that have been taken and distributed by the Control Tower, it becomes possible to create and maintain some metrics, that evaluate the impact of the activities. If it can be seen that there is a consistent underperformance in some areas of the Control Tower, a root-cause analysis should be conducted, in order to identify areas of improvement. Take for example a solution, that has been suggested by the Control Tower. If the impact of this solution has been seen to be unwishful, it could be investigated if the settings of the Decision Support System need to corrected. Overall speaking, the evaluation of the Control Tower's own performance would lead to a self-optimizing system, which in turn would deliver enhanced Supply Chain Visibility. Once an area of improvement has been identified, a feedback loop to the settings of the application needs to be started, in order to realise an improvement in performance. Take the Decision Support System for example. If for example an ABDS is employed to aid in decision making, it could be decided to upgrade the parameters of the agents, according to new insight.

### 4.5. Manpower Layer

The highest layer of the Control Tower, contains the staff, that is responsible for utilizing the functionality, delivered by the other layers. In this layer the supply chain monitoring and decision making takes place. This layer's decisions are being supported by the functionality and information aggregation of the previous layers. Supply Chain visibility is being delivered to the operating staff by the applications. CapGemini has defined the delivery of visibility as "measuring and controlling the effectiveness of the overall supply chain in four key areas" (G. Bhosle, 2011). Those four key areas are:

- Agility
- Resilience
- Reliability
- Responsiveness

Agility is defined as the capability to change aspects of the supply chain, according to arising needs, with little or no unwanted impact. Resilience is the ability to withstand unexpected events with minimal negative impact. Reliability refers to the capacity to meet external commitments, while staying effective. Responsiveness is defined as the ability to gather information and adapt to changes in the environment. Agility and responsiveness could be seen as located on a tactical level, while resilience and reliability are on a more operational, day-to-day level. Thus the decision making on an operational level includes among other inventory tracking, and exception management. Another functionality, which is delivered by the Manpower Layer, is the capability to serve as an information contact point for people, who work on the execution of operational tasks. Whenever those people encounter a problem, the operating staff in this layer can help by analyzing the centralized data, and giving insight to them.

Although it might be possible to automise some of the functionality, delivered by the manpower layer, human interaction might still be necessary for some fields. Take for instance legal requirements, that are linked to the import and export of parts.

## 4.6. Summary

To effectively monitor it is necessary to gather data as quickly as possible (near real-time) from all operational supply chain processes. The data has to be accumulated in a centralized system, in order to be analyzed, and scanned for unwishful events, that might have a negative impact on the supply chain performance. Moreover, it is important to identify the root-causes of those events, in order to identify potential points of improvement. For the control of the supply chain it is necessary to make use of the information, gained through the monitoring, and transform it into knowledge. The people working with an appropriate system should be able to dispatch decisions on eventual actions, to the people, who are responsible for the enactment of those decisions.

A Control Tower is a centralized system, which enables the monitoring as well as the control of the Supply Chain. A system means a collection of elements, that together and by interacting with each other fulfil a purpose. The parts are in this case: Software Systems, People, and Data. The purpose is the monitoring and control of a Supply Chain. The Control Tower can do this by integrating the data, coming from various points of the Supply Chain, which is consecutively analyzed and presented to the users of the Control Tower. Those people can make use of the knowledge, they gain through the process, by reacting on unwishful events. The Control Tower does not only provide reactive capabilities, but rather allows the proactive identification of potential risks.

# 5. Comparison IBM tools and Control Tower Concept

This chapter will address the functionality, which is achieved by Entercoms and Servigistics, and evaluate it in comparison with the Control Tower Concept, that has been introduced in Chapter *4*

*Control* Tower. By that it aims to answer research question Q4: In how far do the tools, used at IBM for Control Tower purposes, fulfil this definition?

The Control Tower begins by creating a data base, serving as a base for the analytical applications, running on top of it. For this purpose, the supply chain decisions, that lead to the design of the chain and the operational decisions, which are taken on a daily basis, are included in the aggregated and organized, in real-time. The richness and accuracy of data, is at this point depending on the model, chosen for the CT (Model A or Model B). On top of the data base do sit the applications, that are responsible for the analysis and processing of the data. The main areas of functionality, delivered by those applications, are: Supply Chain Measurements, Alerts (Exception detection), Decision Support, Root-Cause-Analysis, Feedback to Executive Functions, Self-Evaluation. In the highest level of the Control Tower resides the staff, which is operating the CT, and responsible for the final decision making process and maintenance of the Control Tower.

The analysis of the tool, employed at IBM for Control Tower purposes, shows that the capabilities of those are as follows:

- Exception Management capabilities, by creating alerts
- Metrics and Measurements over time (Supplier, Own performance)
- Root-Cause Analysis (Tactical)

There are yet some aspects, which are missing in comparison with the Control Tower concept. The first aspect is the Decision Support, which should be included in the Control Tower. Although it could be argued, that the forecasts, which are delivered by Servigistics, might act in such a way, they do merely act in a static way. Moreover, are they of deterministic nature and rely on historic demand values. They do thus not give any indication of the impact of certain decision, and do not account for the uncertainty and interrelations in the behavior of different supply chain parties. A simulation based system, that gives indication on how certain metrics might be affected by a decision, could be valuable. Those metrics could for instance be the three points (Inventory, Cost, Service) of the triangle of business dynamics, which is implicitly used by IBM Service Logistic.

Servigistics has the capability to identify exceptions and can give recommendations on for example transshipments instead of New Buy, but those features are rather reactive than proactive. For the Control Tower those features should be proactive though, in order to identify exceptions before they become a problem. Here it could be helpful to identify patterns of symptoms, instead of just events, that fall outside of certain parameters. Due to the fact, that the Control Tower gathers data from various points of the supply chain and aggregates it in a centralized depository, it could understand the interconnections of seemingly unconnected events, and create information.

Another aspect, which is closely linked to the decision support, is the self-evaluation of the software. Servigistics contains some RRs, which are triggered when the forecast deviates from the actual demand, but there is no evaluation of the actions taken by a planner. A system, which aims at the evaluation of the impact of operational decisions, might help to improve the future decision making, by giving insight in the effects of previous decisions. Furthermore, does the evaluation aspect refer to the evaluation of the Control Tower's performance. As Entercoms does not give any forecasts, there is no need for such evaluations. Servigistics, on the other hand does give such forecasts, which are checked by the system. Nonetheless, there are no evaluations on the change of forecast settings, and how well the new settings predict demand, compared to the old ones.

A third aspect of the Control Tower, that is not being utilized by the SPO, is the one of real-time order tracking and tracing. Due to the fact, that IBM has outsourced the transportation and warehousing to a 3PL, they have but little influence on this. This aspect has been introduced in the second layer of the Control Tower (see *4.2 Data Perception Layer*), and enables it to base decisions more accurate shipping/arrival dates. Furthermore, can this help with the creation of alerts, by identifying for example potential stock outs, more quickly and accurate.

Although Root-Cause Analysis is done by Entercoms, it can be seen that it is rather tactical than operational. Moreover, does Entercoms not have direct access to the database of IBM, which makes it slower in response. As Entercoms is another company, IBM does not have the possibility to run RCA themselves on operational problems, that have been identified. Thus RCA becomes a point, which is partially fulfilled by the tools, that are employed by IBM.

Despite the fact, that some aspects of the Application Layer are not included in the SPO yet, IBM has the tools available, which might fulfil this purpose. Since 2009 ILOG, a company who is specialized in the business rule management, visualization, and optimization, belongs to IBM. One of their offerings is the Decision Optimization Center, which has decision supporting qualities. It makes it possible to access necessary information and perform what-if analysis, in order to test eventual solutions. But IBM has another system, called Watson. It is a technology platform, which utilizes different techniques like machine learning, in order to analyze vast amounts of data, and gain insight into it. Hereby unstructured data is also included. Watson has the potential to identify seemingly unrelated patterns, and to give, based on that, an advice for actions to be taken. Moreover, is Watson a learning system, which has the capability to improve, based on prior mistakes.

## 6. Conclusion and further research

### 6.1. Conclusion

The investigation of the two systems in place at IBM at the moment has shown that Servigistics is a system for the operational order and exception handling. Entercoms is a system, used to visualize and organize data. There are some aspects, that could be enhanced for Control Tower purposes. Those are: *Decision Support, Pattern Detection, Decision Evaluation, and Tracking and Tracing.* Except for *Tracking and Tracing*.

After conducting a review on the available Control Tower literature, a comparison between the different definitions, delivered there, has been made. It could be seen that the definitions share some common ground but deviate in some aspects. The chosen five-layer approach makes the Control Tower concept scalable and fit to be applied to different supply chains. Furthermore, does it give an indication on how to start creating a Control Tower. The framework of Ji Shou-Wen (2013) has been taken as a shell, and was enriched by other research, in order to fit it for the after-sales supply chain. The resulting concept could be visualized like in *Figure 9: Control Tower Concept*. This concept could be used as a common understanding of the Control Tower in further research within the WP3 of the ProSeLo Next project.

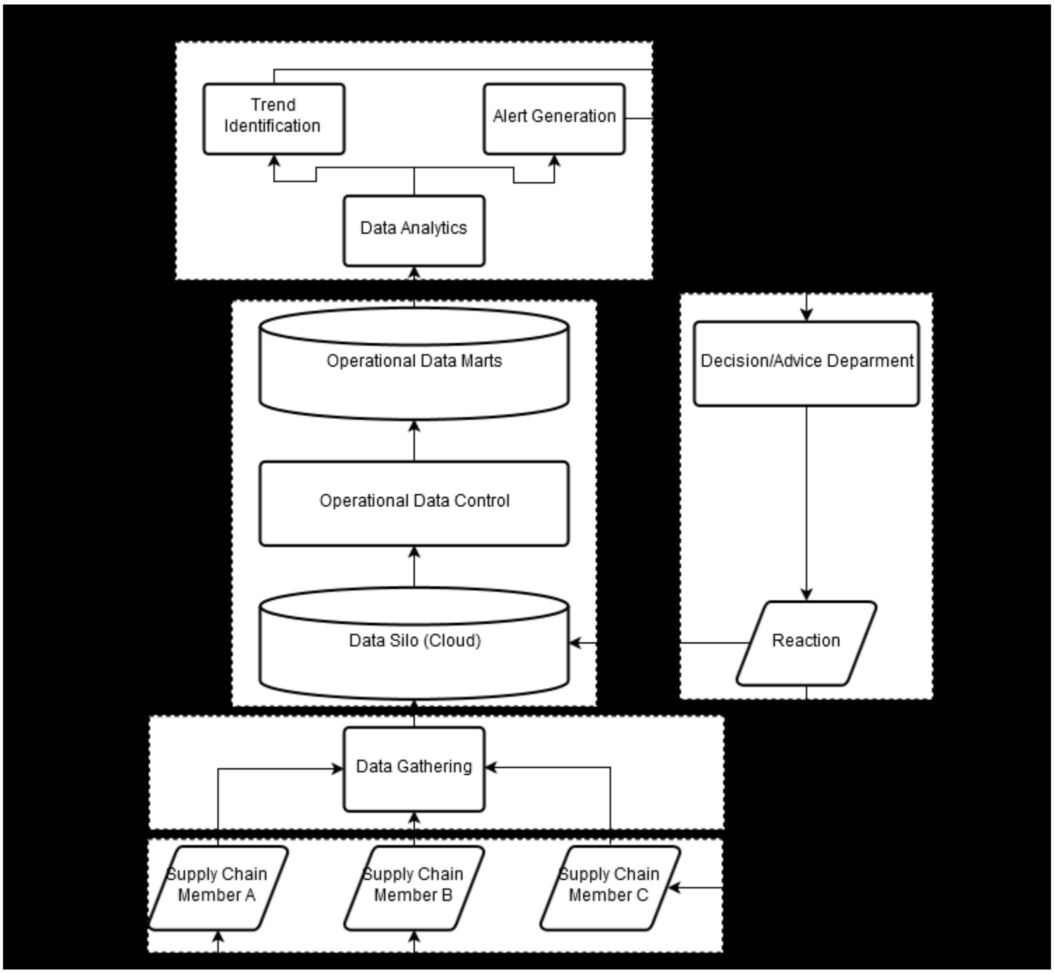


*Figure 9: Control Tower Concept*

The research at hand has some limitations though. The methods and models, presented in the different layers, are not necessarily best fit for practical usage, due to the fact, that the biggest part of the Control Tower concept is based on the literature, and serves the purpose of creating a common understanding of what is meant, when talking about the concept. The practical implementation and creation of a Control Tower needs to be addressed in future research. A contact with PTC (the company, owning Servigistics) could also have been established, in order to verify the observations, that have been made by the researcher. It has been decided to not do that, because the version of the software, available to IBM, was highly tailored to their needs. Moreover, was the software 12 years in use, at the point of research, making it unlikely to receive detailed information on the systems capabilities from the producer, especially as PTC has acquired Servigistics themselves. A third limitation to this research is that, due to the limited time, it was only possible to cover a certain part of the literature. It could be possible that insights from other research, which has not been regarded in this research, might lead to new insights in the definition of a Service Control Tower.

## 6.2. Future Research

This research has the potential to pose as a starting point for further research on the field of Control Towers in general, as well as for IBM. Further research has yet to be done, in order to deepen the understanding of the different layers. Here the focus should be directed at the Application Layer and the Manpower Layer. The Supply Chain Business Layer is dependent on the company, which wishes to establish a Control Tower, and the Information Data Storage Layer is strongly focused on data storage technology. Moreover, does the biggest part of the Control Tower functionality arise from the Application Layer. For the ProSeLo Next research project the main focus should thus lie on the capabilities of the Application Layer.

In the following table (see *Table 4: IBM's status versus the Control Tower Application Layer capabilities*) you will be see the potential areas of expansion, and which of those IBM wishes to research in the WP3. This table could also be applied to the other companies, taking part in this work package, in order to identify potential Control Tower research areas.

| Control Tower capabilities | Available | Wish to research | Time |
|---|---|---|---|
| **Display of measurements with historic tracking and drill down functionality** | YES | - | - |
| **Reactive creation of alerts** | YES | - | - |
| **Proactive creation of alerts (Pattern Detection)** | NO | YES | Year 2 |
| **Model-driven decision support (what-if analysis)** | NO | YES | Year 3 |
| **Root-Cause analysis** | On high level, not automatic | YES | Year 1 |
| **Distribution of alerts and decision support** | YES | - | - |
| **Evaluation of decisions and Control Tower** | NO | YES | Year 2 |

*Table 4: IBM's status versus the Control Tower Application Layer capabilities*

The first area of research, which IBM would like to pursue, is the application of Watson for root-cause analysis. It could be started by analyzing a single loss in a performance indicator. Consecutively it could be examined how Watson can a set of losses and determine the major contributors to them, which can be resolved by IBM.

# Appendix

## 1. Operational Processes

### *1.1 Assortment Management*

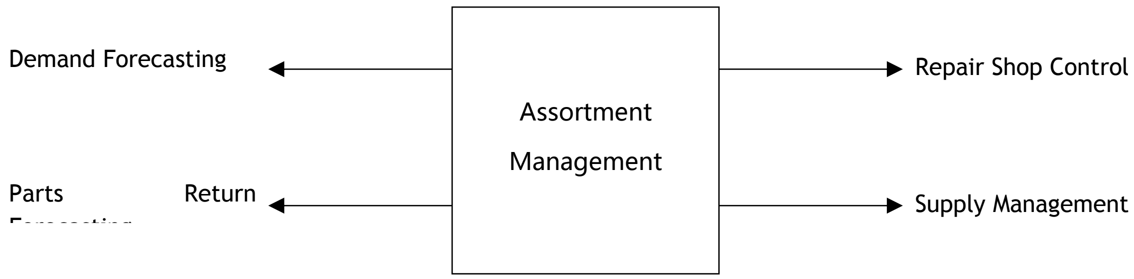


*Figure 10: Assorment Management*

The first task is Assortment Management, which is concerned with the question whether to include a spare part in the assortment and maintain information on it. While the inclusion of parts is done on a Strategic or Tactical Level, the data that is gathered on the part is operational. The information, which is referred to here is over the: Criticality, Redundancy, Specificity, Position in Configuration, Commonality, Substitution, Shelf life, and Reparability of parts. The ones that are most likely to be checked on operational basis will be explained in the following. Criticality refers to the degree of importance of the part in the overall configuration of a machine. Other criteria for the criticality of a part might be dependent on the Service Agreements, and costs inclined, when a machine breakdown occurs. The position in the configuration refers to the other parts in a machine that are linked to the part and might be affected by a part's failure. Commonality refers to parts, that can be used in different systems. The knowledge on this has an impact on the stocking location and the deployment of parts orders, depending on the different service agreements. Furthermore, does this information serve as input for the forecasting.

### *1.2 Forecasting*

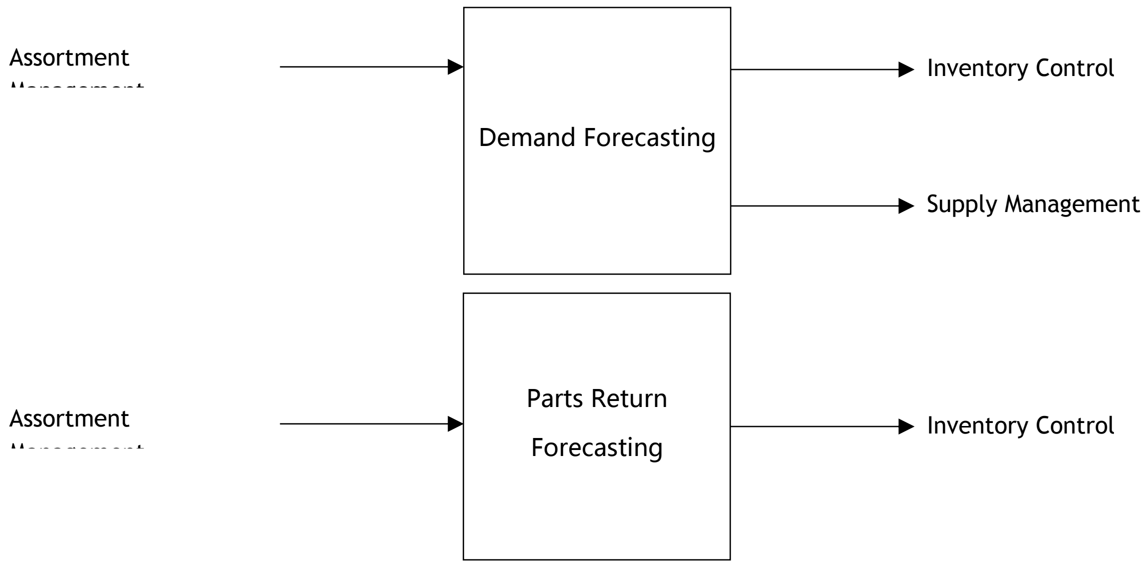


*Figure 11: Forecasting*

Forecasting is concerned with the estimations of customer demand, as well as the returning parts from the customer. The parts, that come back from the customer, are returned due to a defect. As the defective part can sometimes not be pinpointed, a variety of parts, that are not effective are returned as well. As a consequence, the stock level of the parts, being returned but not defective rises. Such increases need to be forecasted, in order to prevent excessive stock levels.

The operational part of this process, concerns the cleaning of data and the execution of forecasting decisions, which have been taken on a higher level. This means that the actual forecasts for all parts, be it for Customer Demand or Parts Return, need to be recorded for later analysis.

### 1.3 Repair Shop Control

In the spare parts supply chain, the repair shop works similar to a manufacturer in other supply

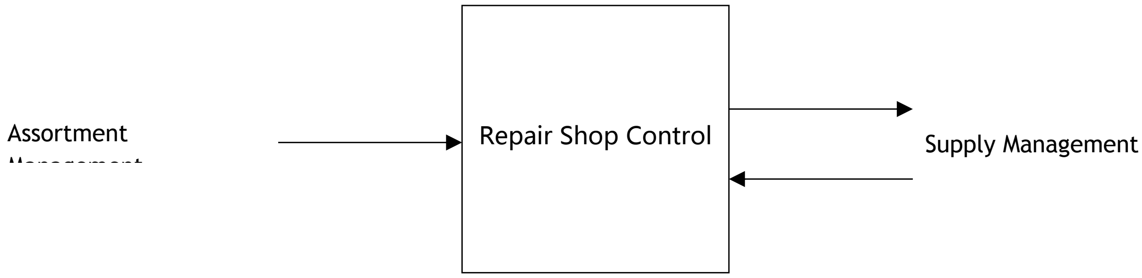


*Figure 12: Repair Shop Control*

chains. There are agreements made on the lead time of repair, as well as on the load imposed on the repair shop, so that the contractual lead times can be achieved.

For the internal repair shop, the capacity of resources, that are assigned to the repair shop, does have an impact on the costs of the repair as well as the repair time, and needs to be determined as well. The decision on the capacity spans around the staff to hire, the number of shifts, the number of SRU's to stock, and the number of tools to acquire. Those decisions can be based on the expected repair workload and the variability accompanying it. The costs that follow out of this decision, paired with the lead time, can be used to reconsider the repair or new-buy decision on an operational basis.

Another operational decision is the scheduling of the repair jobs. As the agreed planned lead time of the repair shop is known, planners can schedule the repair jobs in such a fashion that the capacity of the repair shop is not overloaded and the due dates can be achieved, so that repaired parts are available when needed. Constraints for this might be a maximum amount of repair jobs that can be assigned and certain batch sizes of repair orders, so that the set-up cost time and costs in the repair shop are reduced.

### 1.4 Spare Parts Order Handling

The orders, which are coming from several Maintenance Organizations (MOs[3]) are being placed at

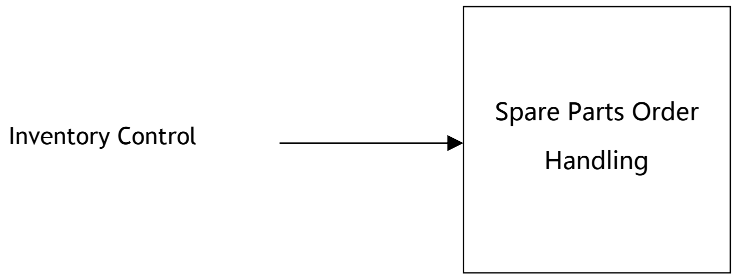


*Figure 13: Spare Parts Order Handling*

the MLO, which is consecutively responsible for handling those orders. The steps that ought to be undertaken in that process are:

[3] An MO is a department at the customer organisation, which is responsible for the maintenance.

- Accept, adjust or reject the order (1)
- Release of Spare Parts on the order (2)
- Handling of return orders (3)

The acceptance, adjustment, or rejection of orders can be based on agreements on order quantities, order priority levels, and order lead times, having been set in advance, which help in the quicker recognition of unrealistic or unusual orders. This can also be seen at IBM, where the orders are automatically processed by Servigistics, whenever they fall within the boundaries of earlier determined parameters. For those orders the MLO can decide to adjust or reject them, and a feedback loop to the MOs needs to be triggered to inform about the MLO's decision. This can help the MO to adjust their own planning. As the checking of orders leads to higher operational costs, the MLO has to make the trade-off in between those costs and the costs of holding unnecessary inventory. Next to the order quantities and lead times, it needs to be investigated if the part is requested for the first time. The demand forecasting information for that part can then be determined in consultation with the MO. The prioritization of orders is rather important, although not being easy, when the stock available is not sufficient to fulfil demand. Unfortunately, there is no optimal solution for this problem in general. After the release of a work order, the return process begins, where the MLO issues a return order for the failed parts at the MO, with an agreed hand-in-time. The spare part order is seen as fulfilled, once all requested parts are at the MO.

### 1.5 Deployment

Deployment refers to the replenishment of spare parts inventories. For this process preconditions

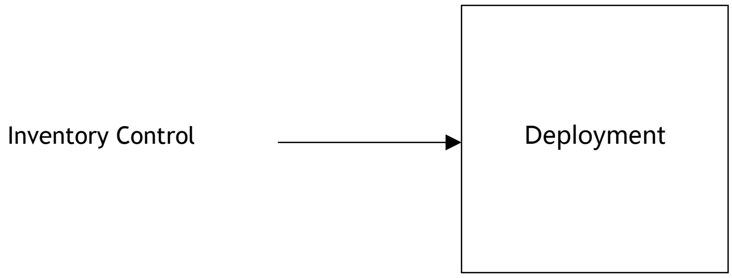


*Figure 14: Deployment*

have to be set. Those preconditions are partly set by the inventory control process, in form of replenishment policies. The deviation from those policies, based on new (daily) information is part of the deployment process. This new information is furthermore being used in a feedback loop to the tactical decisions, in order to reconsider the demand, forecast or supply lead times, leading to exceptional orders. By that the deployment function is acting as an exception detector and manager and has direct implications on the Control Tower. Preconditions should also be set on whether the deployment function is included in the overall process for a certain spare parts order, or rather not. Moreover, is deployment responsible for the management of procurement and repair orders. It should procure/repair parts with the correct quantity and priority, check if the quality of those parts is sufficient, and monitor the supply lead times. Here the deployment's order can deviate from the one set by inventory control as well, based on newly obtained information.

## 2. Decision Support

The decision support system, that could be implemented at IBM, should be a model-driven DSS, as this kind of system allows the analysis of different solutions, on their impact (Power 2008). But in order to aid in the decision making, the decision situation has to be identified and formalized first. Keeney (1982) calls this process Decision Analysis. The methodology of this process follows in four steps.

The *first step* concerns the structuring of the decision problem, which means that possible alternatives have to be identified and that the objectives for solutions have to be specified. In the case of IBM, the software Servigistics identifies a decision problem in form of Review Reasons (RR). The objective here is the resolution of an RR, and possible alternatives are the possible ways to resolve an RR. A point, that could be researched in this context, is if the detection of RRs, as it is done today, is an adequate method for creating alerts. It could be investigated if a system like *Watson*, which enables the detection of patterns for the proactive identification of unwishful events, is better fit for Control Tower purposes.

The *second step* concerns the impact assessment of possible alternatives. As it is not possible to eradicate all uncertainties, concerning the prediction of impacts, it is necessary to include stochastic variables to account for uncertainty. The impact could be quantified by indicating a change for certain Key Performance Indicators. For IBM it could be the three points of their business dynamics triangle (Cost, Inventory, Service), which is implicitly being used. An aspect of the impact, that should not be overseen, is that more than one criterion has to be analyzed. A fitting method for the impact analysis could be simulations in order to perform what-if analysis, and pair the occurrence of an event, resulting from a decision with a probability, indicating the likelihood of the event. In this second step could a model-driven decision support system greatly benefit the Control Tower at IBM. To the best knowledge of the researcher, IBM does not have such a system in the Service Supply Chain at the moment.

The *third step* is concerned with the determination of the preferences of the decision maker. If a case occurs, in which no decision has an effect on all impacted performance indicators, but different decisions impact different indicators, it has to be determined where the preference lies, in order to weight the different options. If the business dynamics triangle was chosen as a performance indicator, weights could be distributed over the three points. As this research concerns the operational Control Tower, and the preference of the decision makers should be aligned, it could be considered to include the weights in the decision support system. Furthermore, does this ensure consistency in future decisions.

The *fourth step* is concerned with the comparison of the different alternatives. The previous points should have resulted in the presentation of information about the risks and impact of the evaluated decisions, which makes it relatively simple to compare them, and draw a conclusion on the choice. In order to facilitate the decision comparing, it might be favorable to test several potential solutions at the same time and present the attractiveness of each solution.

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