Faculty of Engineering of the University of Porto

FEUP

Performance Measurement on Automotive Assembly Line

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Abstract

Performance measurement performs a major role in organizations management as the basis for decision-making and must be used for strategic planning, quality management, productivity improvement and benchmark among many other dimensions at all levels of an organization and across all sectors. Current challenge in the manufacturing engineering is based on the integration of product/process and factory concepts and the related information systems in order to synchronize product, process and factory life cycles in which tools for monitoring performance indicators are included.

This document focuses the development of a performance measurement system in the context of the participation of Volkswagen Autoeuropa, Lda in the Virtual Factory Framework (VFF), a Collaborative Research Project funded by the European Commission under the 7th Framework Programme. It is included and overview on performance measurement systems, the problem description, requirements identification and prototyping of part of the system using engineering recommended practices.

Acknowledgements

It is a pleasure to acknowledge all those who contributed for making this dissertation possible.

I would like to thank Prof. Dr. Américo Lopes de Azevedo for the supervision and support, Eng. António Norberto for the internship opportunity and all the colleagues in company who somehow collaborated.

I would also like to thank all my true friends and my family, especially to my father, who would certainly be happy with the conclusion of this stage.

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Chapter 1.

Introduction

1.1. Context and Objectives

This dissertation is done in the scope of the participation of the author in Virtual Factory Framework (VFF) (a Collaborative Research Project funded by the European Commission under the 7th Framework Programme) as a trainee in Volkswagen Autoeuropa, Lda, one of the 30 members of the consortium. The VFF project will provide a “holistic, extensible, scalable and standard” framework and deploy tools to support design, management, evaluation and reconfiguration during all the factory lifecycle. These tools will be implemented as functional decoupled modules operating with the same common space of abstract objects representing the factory.

Volkswagen Autoeuropa, Lda joined the VFF project as an industrial partner in order to provide the expertise in performance management in automotive industry and to validate the effectiveness and efficiency of the obtained results.

The main objectives of the author with this work are to study, understand and model the present methods and tools used in Volkswagen Autoeuropa, Lda for performance monitoring in order to identify the functional requirements for a module capable to deal with such constraints and to operate with the virtual factory collaborating with the other project partners in the development of a solution.

In this document it will be presented the complexity of the problem, the methodologies used by the author and the results obtained.

1.2. Methodology

During the development phase of this project, was adopted a methodology consisting in a sequence of steps in order to study a business process and improve it not only to achieve better performance in the execution of the process but also to allow the development of a new information system or improvement of an existing one in order to support those processes and oriented to them. The methodology was applied to the processes of calculation of the Key Performance Indicators (KPI) used in Volkswagen Autoeuropa.

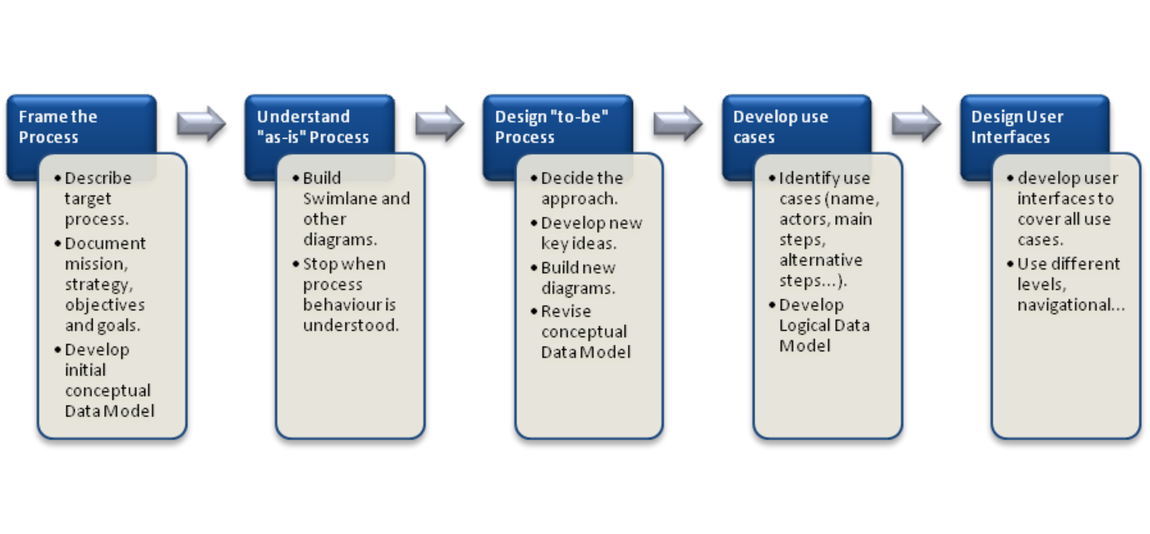

Figure 1 – Adopted Methodology

Step 1: Frame the Process

In this initial phase is very important to clarify some doubts that may persists from the start of the project and avoid the later appearance of problems and discussions.

Framing the process consist in identifying the set of processes that will be involved, establishing the scope and boundaries using an overall map, for example.

This must include, among others:

- review and document the strategy, mission and goals and align them with the organization culture, core competencies and management systems;
- perform an initial assessment;
- summarizing the vision and objectives of the different stakeholders.

Step 2: Understand the “as-is” Process

In this step the actual processes must be documented in a non-exhaustive way only to allow the key partners to understand the basic principles in cause.

It must consist of:

- mapping the current processes workflow to identify who does what, when and how;
- Develop draft swimlanes and other diagrams with different levels of detail for a better understanding;
- Identify major weaknesses of current processes and explicit improvements.
- This step is supposed to be consumed only the effort needed for the behavior is minimally understood.

Step3: Design the “to-be” process.

This step is divided in two stages: characterization and design.

Step 3.a) Characterization

The to-be process will be characterized by improving, re-designing and simply abandoning some of the issues of the previous processes.

During this phase must be:

- Idea generation and brainstorming and assessment;
- Definition of the key features of the to-be process;
- Conceptual revision and final ideas consolidation.

Step 3.b) Design

In this stage the sketch of the final solution begins to be defined by:

- Drawing the to-be workflow (in different levels of detail and in an iterative way);
- Identifying and analyzing individual use cases;

Step 4: Develop Use Case Scenarios

Identify use cases in terms of description, intervenient, boundaries, main steps and alternative steps.

This step makes the transition into systems requirements analysis by describing how the actors of a process interact with the system.

Step 5 Design User Interface

Each use case identified is reflected in user interface. This interface can be defined in different detail levels from descriptive design to implementation constraints.

Along with this methodology, the IEEE std 830-1998 Recommended practice for Software Requirements Specification was used as a basis for steps 3 and 4.

Chapter 2.

An Overview on Performance Measurement

"You can't manage what you can't measure" – Peter Drucker

The rapid increase in global competition brought by several aspects as technological changes and product variety proliferations had accentuated the importance of continuous improvement as a strategic and competitive requirement in many organizations. In order to improve the competitive advantage, performance measurement is imperative to control and improve company's business processes [1].

The definition of performance measurement is a broad topic. Some authors define it as a process of quantifying the efficiency and effectiveness of action [2], a metric used to quantify the efficiency and/or effectiveness of the action [3][4], a set of metrics used to quantify both the efficiency and effectiveness of actions [5], or the process of assessing and evaluating ways to effectively and efficiently utilize people, resources and technology within an organization [6]. In all these definitions, the concepts of quantifying, effectiveness and efficiency are included. Quantifying can be related to different types of measurement, evaluation or monitoring, effectiveness is related to the level of success meeting the requirements or planned goals and efficiency refers to the utilization of the different types of resources.

Organizations adopt performance measurement in their business for several reasons [7]: identify success; identify whether they are meeting customer requirements; helping them understand their processes; confirming what they knew and revealing what they didn't knew; identifying where problems exist and where improvement is needed; ensuring decisions are based on facts, not on suppositions, emotions or intuitions; and showing if planned improvements actually occurred.

Performance measurement plays a major role in continuous improvement also. Modern quality control is based in the plan-do-check-act or similar methodologies where is truly important to measure and analyze performance to enhance the possibility to optimally utilize resources, provide feedback to stakeholders and evaluate the effects of improvement actions.

Current tools used for monitoring complex production systems are based in key performance indicators [8]. In order to adapt to the constantly changing market, today's factories have to be modular, scalable, flexible, open, agile, and knowledge based and so the techniques and tools to monitor its performance must be.

2.1. Objectives of performance measurement

Organizations must measure their performance majorly to determine the effectiveness and efficiency of the adopted strategy and operations and to address possible problems. The different reasons to measure up can be grouped as proposed in [9]:

- **Improvement:** by tracking performance, organizations can spot different types of problems or improvement opportunities.
- **Planning and forecasting**: performance measurement can be used to analyze the progress and trends leading to better prediction of the future scenarios which is the base for solid planning and budgeting.
- **Competition**: the comparison of performance between different organizations, as industry benchmarking, can help to identify the weaknesses and strengths.
- **Reward**: a performance-based incentive system can be the most fair way to promote excellence in work and lead to a better motivation of all employees.
- **Regulatory and Standards compliance**: some performance measures are obligatory to comply with some regulations (antipollution laws for example) and applicable standards.

2.2. Framework for designing a Performance System

Performance measurement systems can be examined at three different levels [2]:

- The individual performance measures;
- The set of selected measures;
- The system as an entity and its relation with the environment

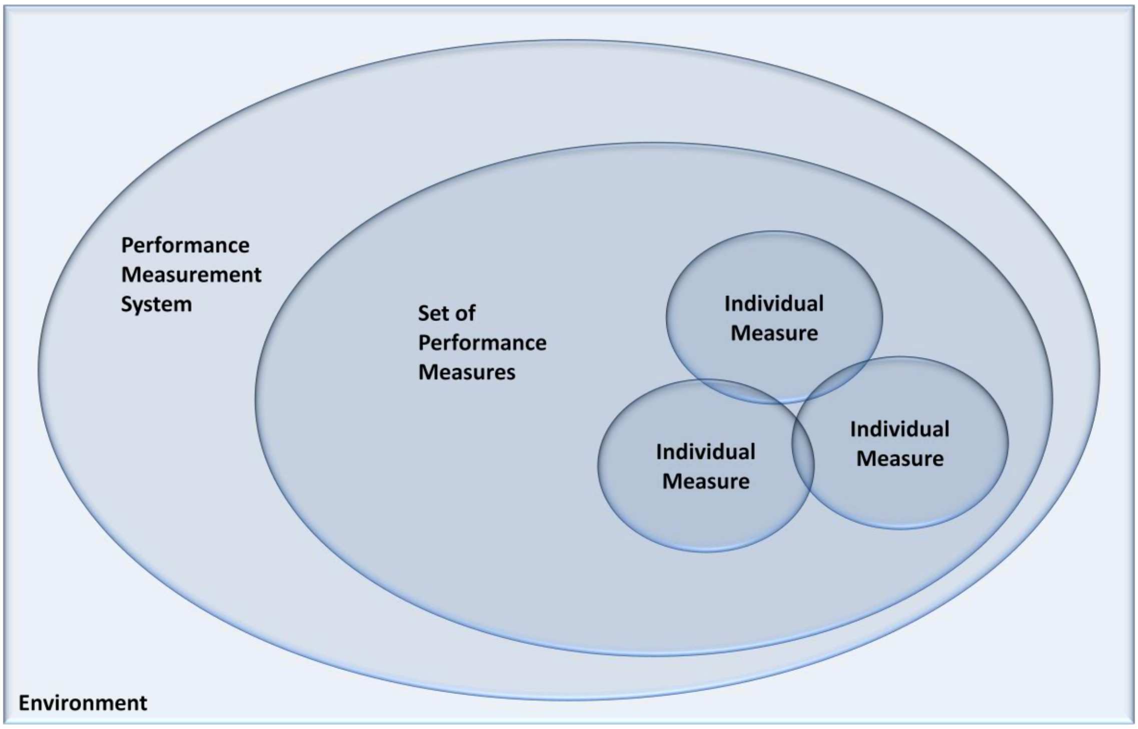

Figure 2 – Framework of Performance Measurement System design (adapted from [2])

2.2.1.Individual Measures

Each organization uses different individual performance measures depending on its key business activities and strategic context. Performance measures can be called different things. Some authors refer to them as metrics, measures, indicators and others. When a performance measure stands from the others for being of high importance to the business, it is often called as a Key Performance Indicator (KPI). A KPI is considered to be essential within a business and normally demands more attention than the rest of the metrics.

Table 1 – Examples of individual performance metrics (adapted from [9])

Business Activity	**Possible Performance Metrics**
Finance	Profit margin Revenues
Marketing	Market Share Customer profitability
Production	Number of units Produced in a time period Number of units shipped on time Machine changeover time
Sales	Percentage of customer visits that origins sales Percentage increase in sales Percentage of customers retained

Costumer Service	Number of complaints Service call response time
Purchasing	Vendors ability to provide goods on time Defect ratio on vendor's products
Quality	Defect ratio on a specific process Percentage of products with no defects
Human Resources	Absenteeism rates Workforce turnover

In order to choose the performance metrics or indicators that best fit an organization can be used some rules as Globerson states [10]:

- Performance criteria must be chosen from the company's objectives.
- Performance criteria must make possible the comparison of organizations that are in the same business.
- The purpose of each performance criterion must be clear.
- Data collection and methods of calculating the performance criterion must be clearly defined.
- Ratio based performance criteria are preferred to absolute numbers.
- Performance criteria should be under the control of the evaluated organizational unit.
- Performance criteria should be selected through discussions with the people involved (customers, employees, managers).
- Objective performance criteria are preferable to subjective ones.

Or, using the Maskell seven principles of performance measurement system design [11]:

- The measures should be directly related to the firm's manufacturing strategy.
- Non-financial measures should be adopted.
- It should be recognized that measures vary between locations ± one measure is not suitable for all departments or sites.
- It should be acknowledged that measures change as circumstances do.
- The measures should be simple and easy to use.
- The measures should provide fast feedback.
- The measures should be designed so that they stimulate continuous improvement rather than simply monitor.

Performance measures can also be categorized into the different hierarchical levels within an organization: strategic, tactical and operational, according to the type of decision it is meant to support. While for some of them it is clear the position in these levels, others are actually needed for more than one level. Moreover, must be a proper linkage between the different levels so all the organization is aiming for the same objectives. A performance measure on the strategic level can be broken down into specific measures in the tactical level and from the tactical level into the operational level [12].

Figure 3 - Business processes hierarchy

Strategic level

The decisions within the top level of an organization are strategic and have the effect in a time scale from months to several years. The measures at this level can help evaluating the decisions in the past and give guidance for future decisions.

Tactical Level

This level is the linkage between strategic and operational levels and address issues from both. Typically, measures at this level cover periods from weeks to a year and set boundaries for actual operations of the organization.

Operational Level

Measures at this level deal with operations and business process on a daily, weekly or monthly basis.

Other authors suggest a different hierarchical categorization in three aggregation levels as in Figure 4. At the base are the individual metrics, the most elementary possible, which are considered the building blocks. Individual metrics are aggregated into various metric sets. The metric sets regulate the individual’s activities in support of strategic objectives and are assigned by a strategic level to evaluate performance of a specific activity, process, area or function. At the top level are the metric clusters which aggregate both individual metric and metric sets linking them with the strategy and stakeholder values and prioritized strategy [13].

The performance measurement system is in this case responsible for maintaining alignment and coordination attempting to ensure consistency between higher levels and the individual measures. Measures need to be part of an integrated system that integrates the goals of everyone in the organization, such that everybody works together for the benefit of the organization as a whole [14].

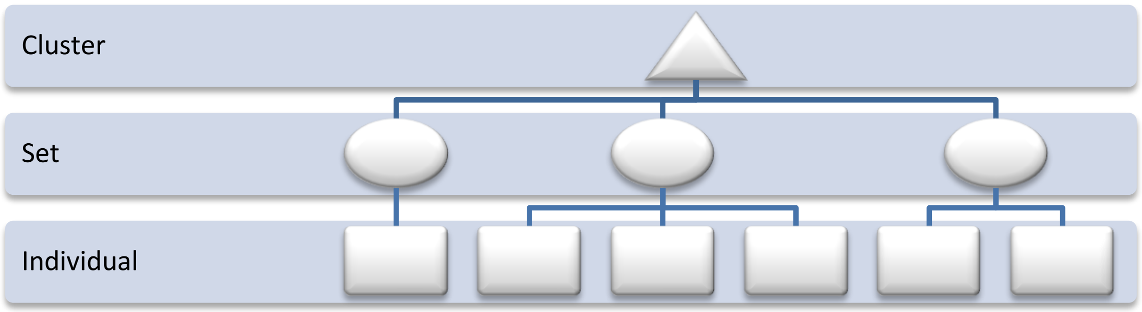

Figure 4 - Levels of Performance Measures (by aggregation level)

2.2.2. Performance Measurement System as an Entity

Once the individual measures are identified, they are then constituted as a performance measurement system. Most companies have such type of systems even if not formally defined.

Over the years several conceptual frameworks have been developed in order to aid the design of performance measurement systems. The main existing models can be referred to five typologies [15]:

1. "Strictly hierarchical", characterized by cost and non-cost performance on different levels of aggregation, till they ultimately become economic financial.
2. "Balanced Scorecard", where several separate performances, corresponding to diverse perspectives (financial, customer, etc) are considered independently.
3. "Frustum", where there is a synthesis of low level measures into more aggregated indicators, but without the scope of translating non-cost performance into financial performance.
4. Those that distinguish between internal and external performances.
5. Those that are related to the value chain.

Further, the models can be distinguished for being vertical (or hierarchical), balanced (or "*tableau*") and horizontal (or by process) as in Figure 5.

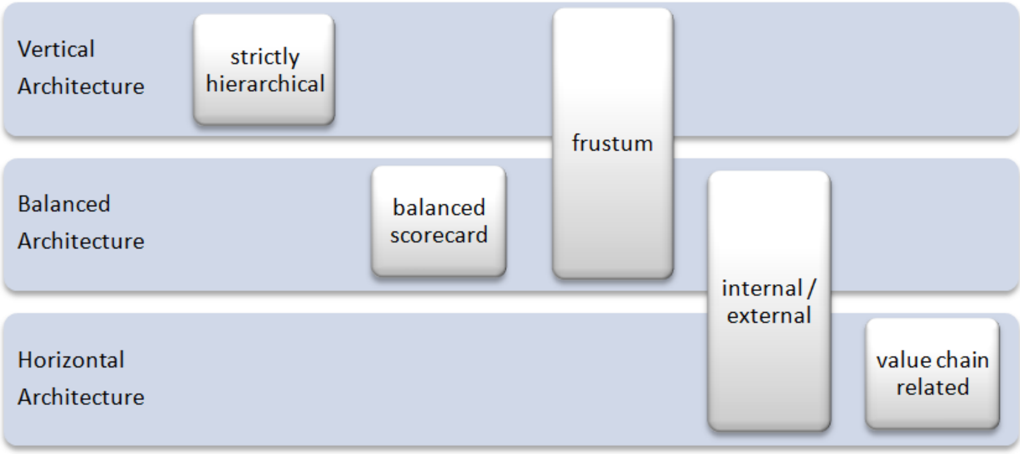

Figure 5 – Classification of Performance Measurement Systems [15]

2.2.2.1. Some conceptual frameworks

The Balanced Scorecard

The Balanced Scorecard is one of the most well known conceptual frameworks. It proposes that organizations should use a balanced set of measures to allow top management to take a quick but comprehensive view of the actual state of the business concerning four proposed perspectives: the Financial perspective, the Customer perspective, the Internal Business Process perspective and the Learning and Growth perspective as in Figure 6. These perspectives provide answers to four fundamental questions:

- How do we look to our shareholders? (financial perspective)
- What must we excel at? (internal business perspective)
- How do our customers see us? (customer perspective)
- How can we continue to improve and create value? (innovation and learning perspective)

However, these perspectives are not to be taken as definite. Kaplan and Norton state that they can be replaced or supplemented by different perspectives (environmental perspective, supplier perspective, etc).

The financial measures give the result of taken actions. The other non-financial and more operational performance measures are considered as drivers for future financial performance.

Balanced Scorecard must not be considered as a replacement for other performance measurement and control systems in an organization; it is a complement that should direct the attention of managers and employees to factors where high performance levels are expected [16].

This Framework has been adapted by many organizations with success. The unsuccessful implementations where mainly caused by a selection of inappropriate or excessive measures, inefficient implementation by the management, delay in feedback or excess of emphasis on financial measures. It has also been pointed out that there is no concrete evidence that Balanced Scorecard leads to improved performance or to answer if the chosen strategy is the right one for the business [17]. Thus, it is intended to be used as a monitoring and controlling tool rather than an improvement tool. It is a valuable framework suggesting important areas in which performance measures might be useful but provides little guidance on how the measures can be identified, introduced and used to manage the business.

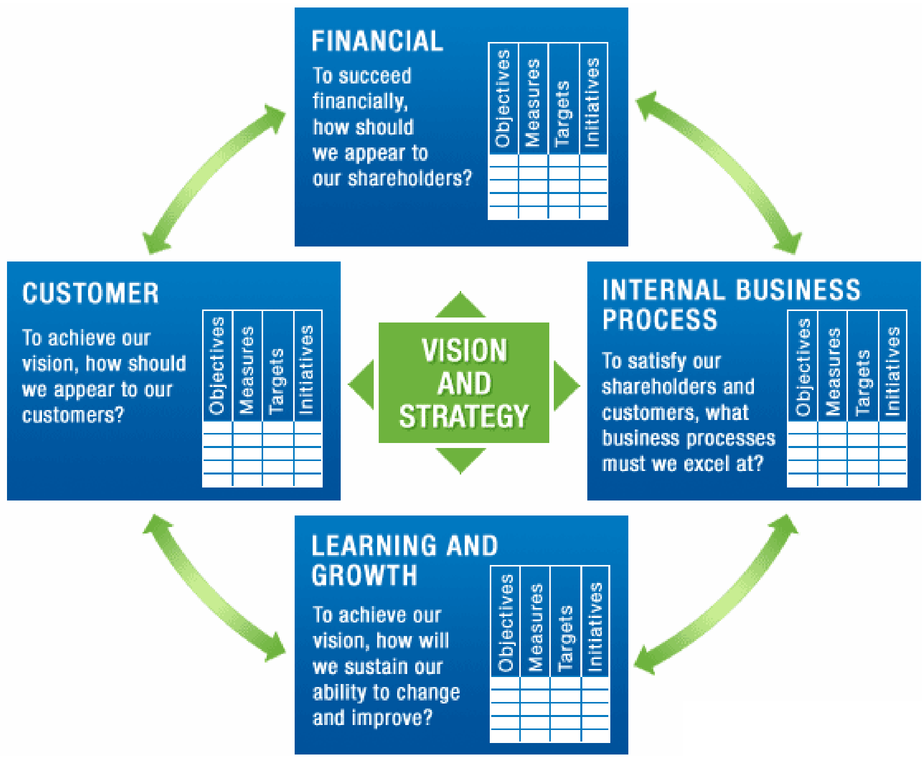

Figure 6 – The Balanced Scorecard Perspectives

The Performance Pyramid

The Performance Pyramid is an example in how the link between the performance measures at the different hierarchical levels in the company can be established so that each function and department strives towards the same goals.

This framework divides the organization into four different levels. It starts at the top of the pyramid with the company's vision, designed to set a strategic course. The second level, business units, compromises the organization's key results, objectives and measures defined in both market and financial terms in two ways: reaching short-term targets of cash flow and profitability and achieving long-term goals of growth and market position. Business operating system is the bridge between top-level and operational measures (e.g. customer satisfaction, flexibility, productivity) and includes the core processes of the business. Finally, four key performance measures (e.g. quality, delivery, cycle time and waste) are used at departments and workcenters on a daily basis [18].

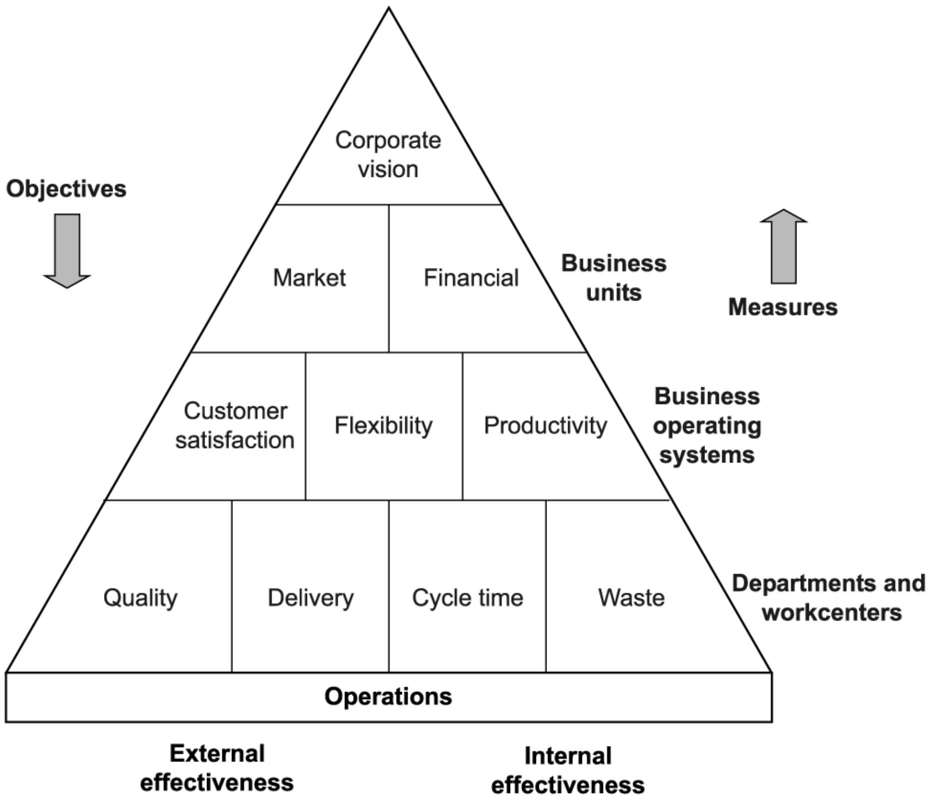

Figure 7 – The Performance Pyramid [19]

The Performance Measurement Matrix

The Performance Measurement Matrix is similar to the balanced scorecard as it seeks to integrate different classes of business performances – financial and non-financial, internal and external. However it is not as extensive as the Balanced Scorecard as it does not make explicit the links between the different dimensions [20].

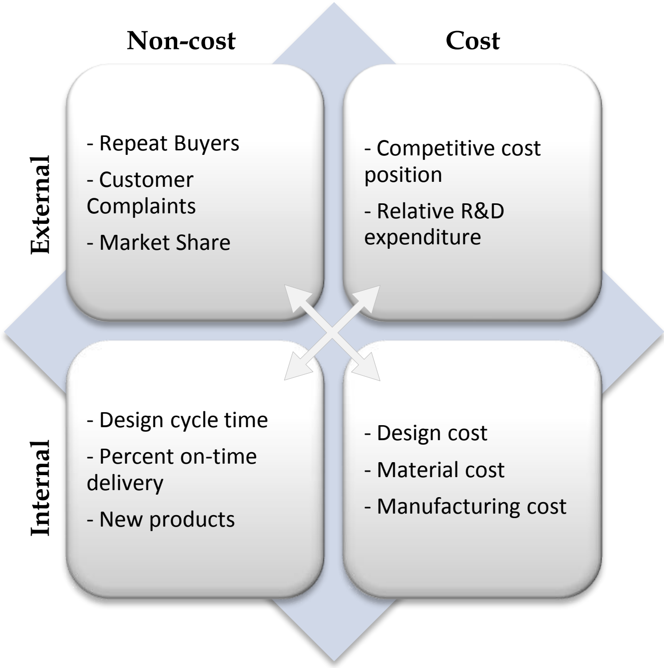

Figure 8 - The Performance Measurement Matrix [20]

Results and determinants Framework

This framework is based on the premise that there are two basic types of performance measures on organizations; those related to results (competitiveness, financial results) and those focused on the determinants of the results (quality, flexibility, resource utilization and innovation. This distinction highlights the fact that the obtained results are a function of past business performance regarding specific determinants [21].

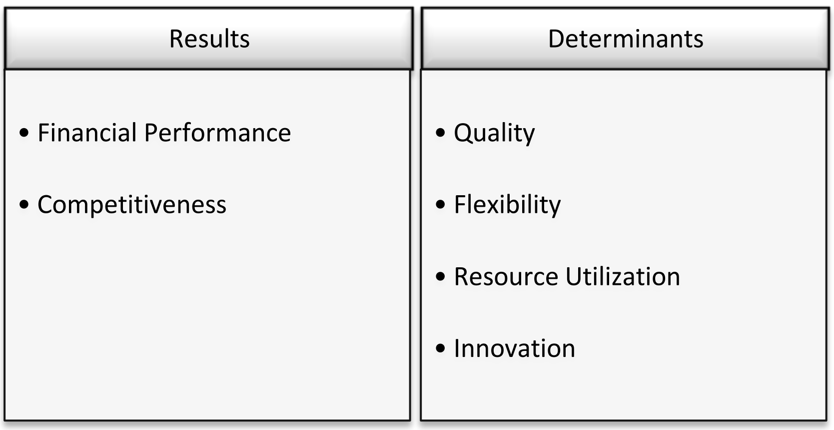

Figure 9 - Results and Determinants Framework [22]

2.2.3. Performance Measurement System Operating Environment

Development and implementation of a performance measurement system must consider the interaction with a wider environment. This environment is composed by two fundamental dimensions. First is the organization, the internal environmental. The second is the market where the organization competes, the external environmental.

Internal Environment

A performance measurement system is seen as part of a wider system, which includes goal settings and feedback. This wider system would match with business strategy [23]. Performance measurement systems must be consistent with organization's culture and a positive culture actually facilitates its implementation. One of the problems that may arise is conflicts between different parts in the functional structure mainly because of inappropriate reward systems.

External Environment

In the external environment are two distinct elements: customers and competitors.

While customers are mainly concerned with measures related to quality, the focus on competitors must comprise all types of measures. Benchmarking is often used for this purpose. One relevant system design suggested [24] consists of a closed loop that combines periodic benchmarking with ongoing monitoring and management as in Figure 10.

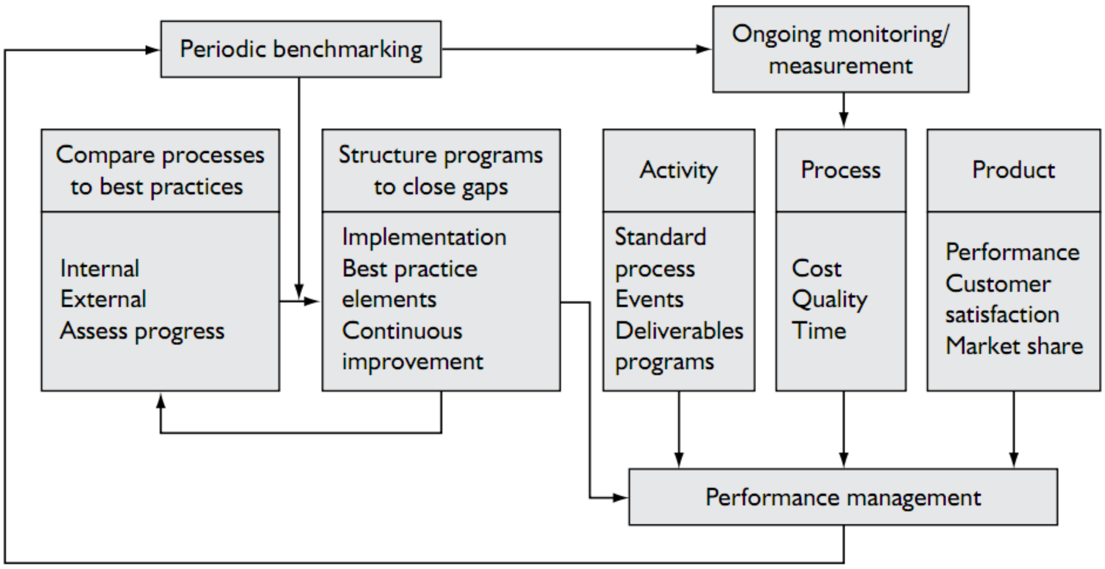

Figure 10 - Closed loop performance management (adapted from [24])

2.3. Performance Measurement in Automotive Industry – The Harbour Report

The Harbour Report is a comprehensive global automotive manufacturing performance analysis published annually. It includes key statistical information, labour and equipment productivity performance, capacity utilization, sourcing, financial data and much more. It is recognized globally as a tool for assessing automotive manufacturing and currently most automotive manufacturers provide voluntarily the required data.

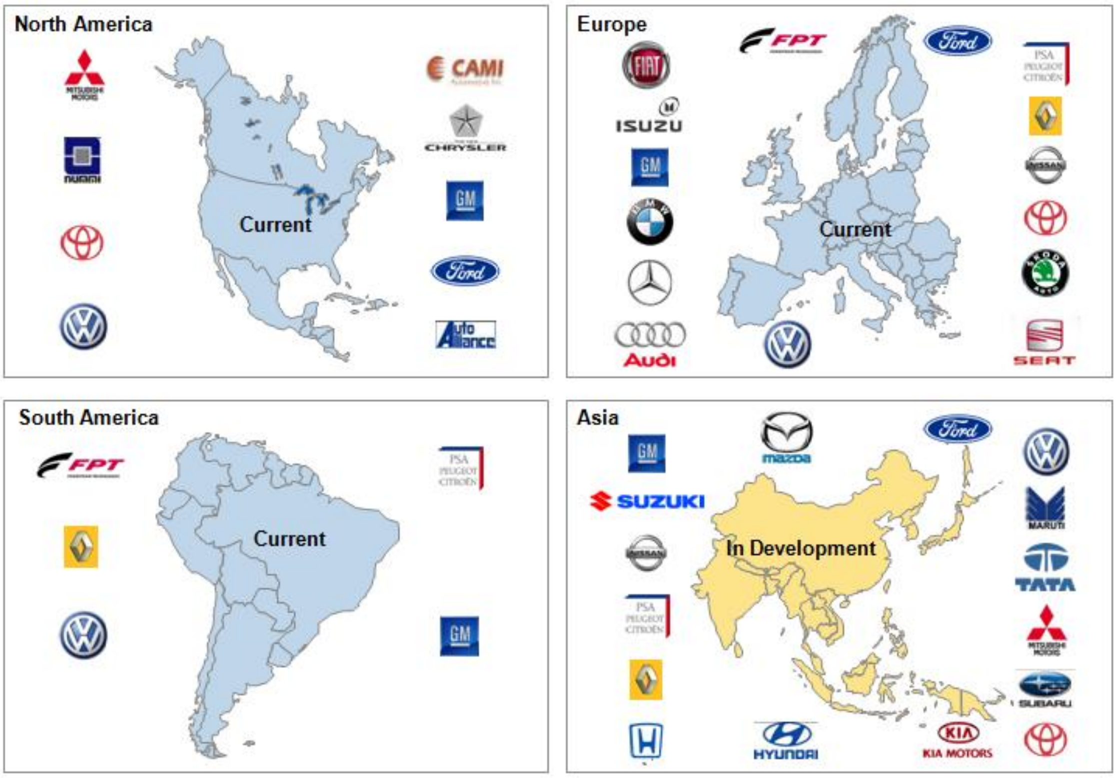

Figure 11 – The Harbour Report Global Participants

The data in The Harbour Report includes, for each facility, plant capacity, annual production, number of platforms manufactured, model types and variations, etc. With the collected data, are obtained core metrics, which are the basis for benchmarking, and other metrics to aid the identification of sources of performance gaps.

The core metrics are:

- Hours per Vehicle (HPV),
- Capacity utilization and
- Press line metrics.

Other metrics are (among other):

- For Assembly plants:

  - Number of welds,
  - Part delivery method,
  - Amount of sealer.
- For Stamping facilities:
  - Press technology,
  - Material utilization.
- For Powertrain plants:
  - Hours per Engine,
  - Machining content,
  - Equipment type,
  - Vehicle applications,
  - Design.
- Common to all types:
  - Sourcing,
  - Plant size,
  - Level of Automation,
  - Number of stations,
  - Lead time,
  - Plant services,
  - Logistics work content,
  - Absenteeism and overtime,
  - Part numbers.

The harbor Report considers five distinct plant types: stamping plants, vehicle assembly pants, engine plants, manual transmission plants and automatic transmission plants. Vehicle assembly plants are divided in three functional areas: Body Shop, Paint Shop and Final Assembly. Engine, manual transmission and automatic transmission plants, are measured separately but with the same constraints and are divided in two functional areas: Machining and Assembly. The customer-client relation between plant types and its functional areas are standardized as in Figure 12.

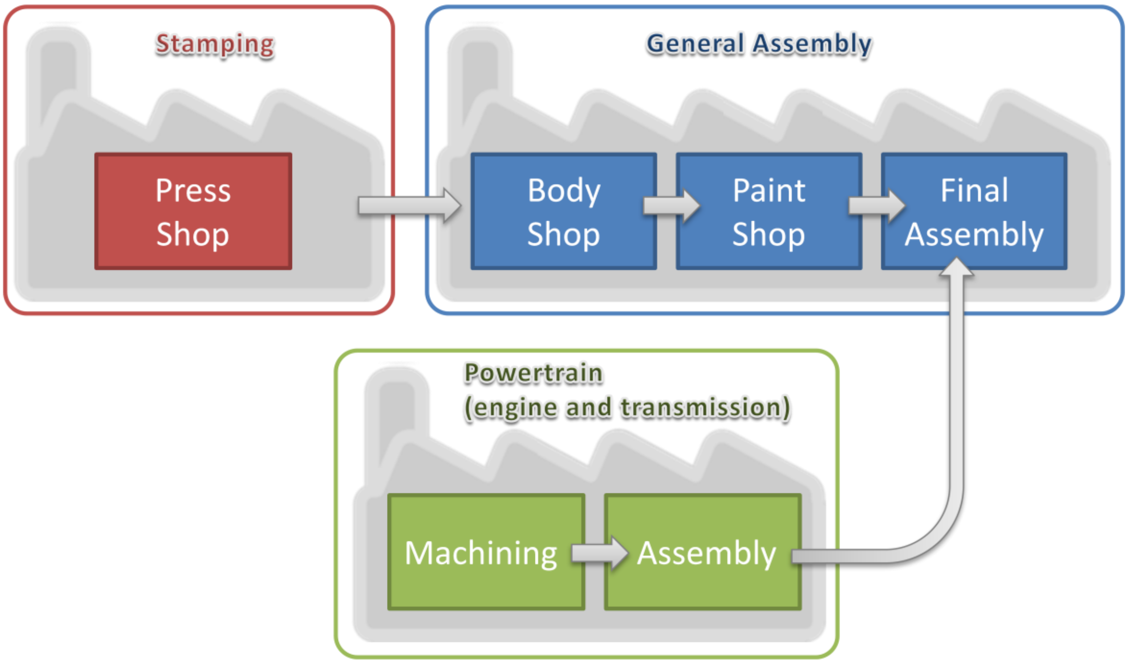

Figure 12 –Harbour Report plant types and functional areas

The output is comparable benchmarking data for comparable products to drive the right decisions. Companies use these analyses to benchmark performance, develop strategies, and improve operations.

In Figure 13 is an example of a HPV analysis for two consecutive years side-by-side for some manufacturers' assembly plants.

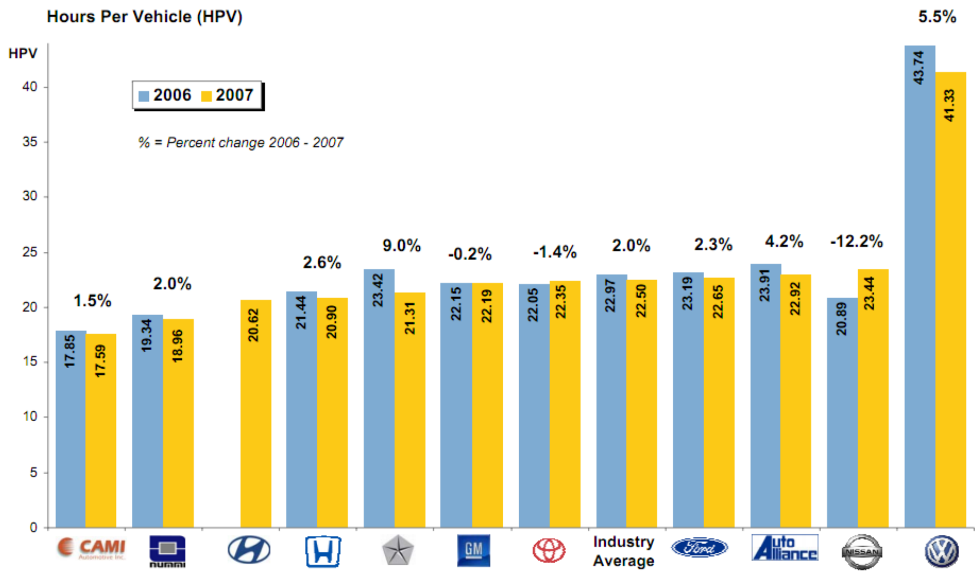

Figure 13 – HPV comparison for some companies' assembly plants

Figure 14 presents the evolution of the KPI Hours Per Engine between 2003 and 2007 for powertrain plants.

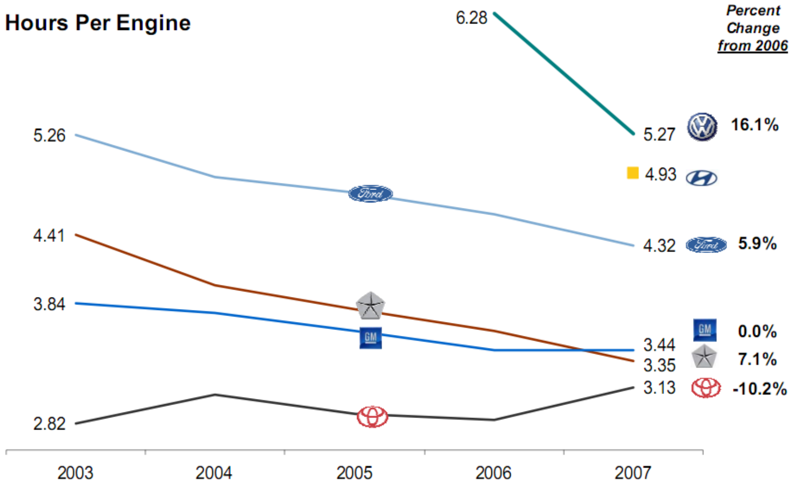

Figure 14 – Hours per Engine evolution for some companies' powertrain plants

Chapter 3.

Case Study

3.1. The Virtual Factory Framework (VFF)

The Virtual Factory Framework (VFF) is a collaborative Research Project funded by the European Commission under the 7th Framework Programme. The consortium is formed by 30 partners (academic institutions, software developers, industry). The importance of the framework is recognized mainly by the impact on industry if the defined goals are achieved.

3.1.1.The VFF Concept

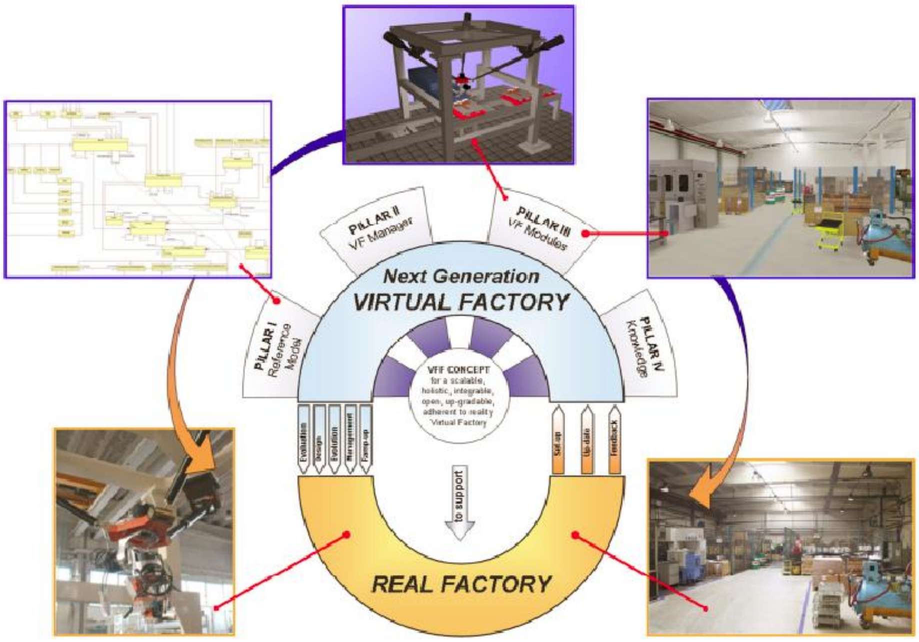

Figure 15 - VFF Concept

The VFF project aims the development of a new conceptual framework based on three Key Pillars:

PILLAR 1: Reference Model

The Reference Model for factory planning is based on two key concepts: the “factory as a product” and the “non-linear non-deterministic planning methodology”. The Reference Model establish a coherent standard extensible data-model at the base of the common representation of Factory Objects

PILLAR 2: VF manager

The VF manager handles the common space of abstract objects, representing the Factory. This representation is based on the standard data model defined in Pillar I

PILLAR 3: VF modules

The VF modules are the Decoupled Functional Modules that implement the various tools and services for the Factory design, evolution, evaluation, management … They all operate on the same Common Space of Abstract Object, defined in Pillar II. This structure allows plug and play of existing and new modules.

PILLAR 4: Knowledge

Integration of Knowledge as engine for the VFF CONCEPT. To model a wider range of complex systems and support greater comprehension of modeled the phenomenon.

These four pillars collaborate with each other and are constantly synchronized with the real factory in order to implement the desired holistic, modular, open and scalable Virtual Factory. The implementation of the VFF on real production systems is meant to achieve real measurable goals which are:

-Time for factory design, re-configuration, re-engineering: -50%.The implementation of the new reference model for factory planning, integrated with formalized multi-competence knowledge deriving from past and current planning processes, allows to shorten the time required for new processes.

-Ramp-up time: -30%

Quick, efficient and adherent to reality modeling speeds up analysis, synthesis and diagnosis, allowing an accurate but rapid prediction and optimizations of production processes during the pre-production stage though preserving the reliability of information gathered during production ramp-up and its value-adding usability in the later stages.

-Capability Index Cp: >=2.0

The effectual virtual representation of all the production phases and of their mutual interrelation enables the intelligent selection of parameters affecting critical product characteristics and the improvement of production parameters, resulting in a reduction of process normal variation and of the overall amount of defective products answering to increasingly stringent design specification requirements.

-Democratization:

The project provides a ground-breaking framework for a new VF but also democratize its usage thanks to new open technologies, thus providing basis for decision making to all levels and functions, allowing for quick yet substantiated decisions to be made where they unfold full potential. The VFF will open access to Virtual Representation technologies to larger group of enterprises, including SMEs.

In Figure 16 are presented the concepts and objectives that are meant to be achieved both in the development of each Pillar and in the implementation on real production systems.

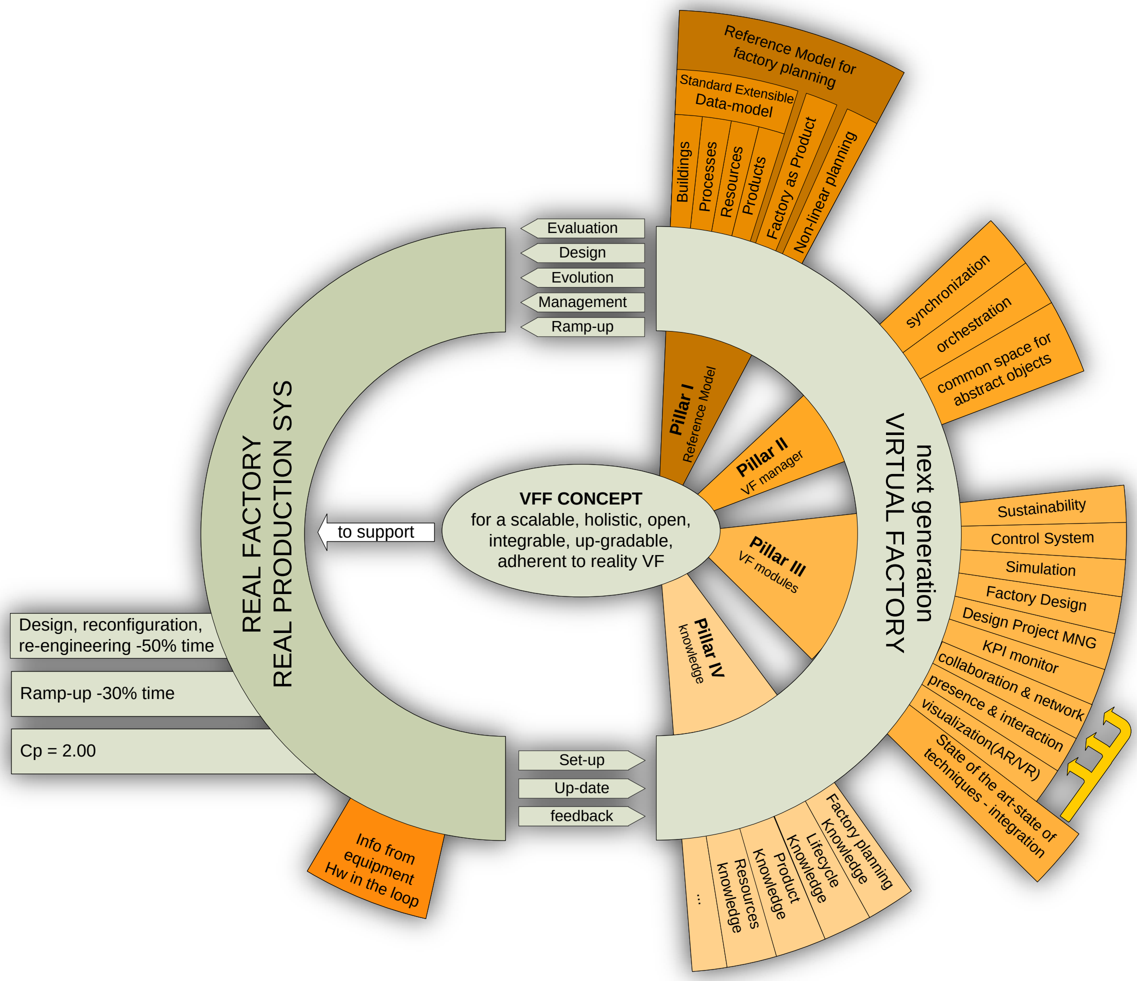

Figure 16 - VFF Framework

3.1.1.1. Pillar 2 – VF Manager

VF manager will act as a center for communication supporting all the input/output operations between the different implemented modules and the data model. The data model will be implemented as a versioned file system with appropriate characteristics. The knowledge manager is responsible for knowledge representation applying the ontology of the knowledge repository. The data model will be implemented by a versioned file system and will be handled inside the VF Manager with the IEP (Interface Exchanging Platform)

Some requirements have been identified for the Data Model:

- Use existing Standards: if exists any standard for any kind of data used, these standards must be used.
- Data Consistency and Glossary: in order to avoid redundancy and allow consistency, each file of the data model must be clearly identified and addressable.
  - Data Safety: must be adopted a solution based in data replication and backups that allows recovery from hardware failures or others.
  - Versioning: this is a central feature of the VF Framework. A dedicated application (e.g. Subversion) will be used with this purpose.
  - Granularity: to allow locking some parts of data to avoid that a module blocks all the other ones in a cooperative process.
  - Extensibility: besides being as complete as possible since the beginning, data model must support future improvements. The initial design of the data model architecture must allow adding new data structures compatible as much as possible with previous ones.

3.1.1.2. Pillar 3 – VF Modules

The foreseen Functional Modules to be added to the framework can be of different nature. Some of them will be existing commercial applications connected with the VF Manager by adaptation modules, while some others can even be implemented from scratch.

There are two main types of modules in the VFF:

- Client Modules - deployed on a remote workstation and with no specific requirement about operating system, programming languages or hardware.
- VF Manager Plug-in Modules - implemented as a server application. The VF Manager exposes a plug-in interface (Tomcat) that allows integrating plug-in modules.

About the deployment approach, the modules can be:

- Pure client – an application running on a remote workstation and connected to the VF Manager trough exposed Web Services
- Pure Server – an application running on the server with the purpose of exposing functionalities not included in VF Manager. Those functionalities can then be used by other modules.
- Client-Server – an application composed by a part running in VF Manager Server and connected to its remote clients in an unrestricted way, possibly, by a proprietary protocol.
- Client adapters for existing applications – modules able to exchange (import/export) data between existing applications and VF Manager.

3.1.2. Volkswagen Autoeuropa role in VFF

As stated before, Volkswagen Autoeuropa joined the VFF project as an industrial partner in order to collaborate with its know-how in performance monitoring and management in automotive industry. For this reason was allocated in the Ramp-up and Monitoring Scenario. This scenario addresses to issues related to monitoring the operations of real factories (during ramp-up also) and the interaction between the real and virtual factories.

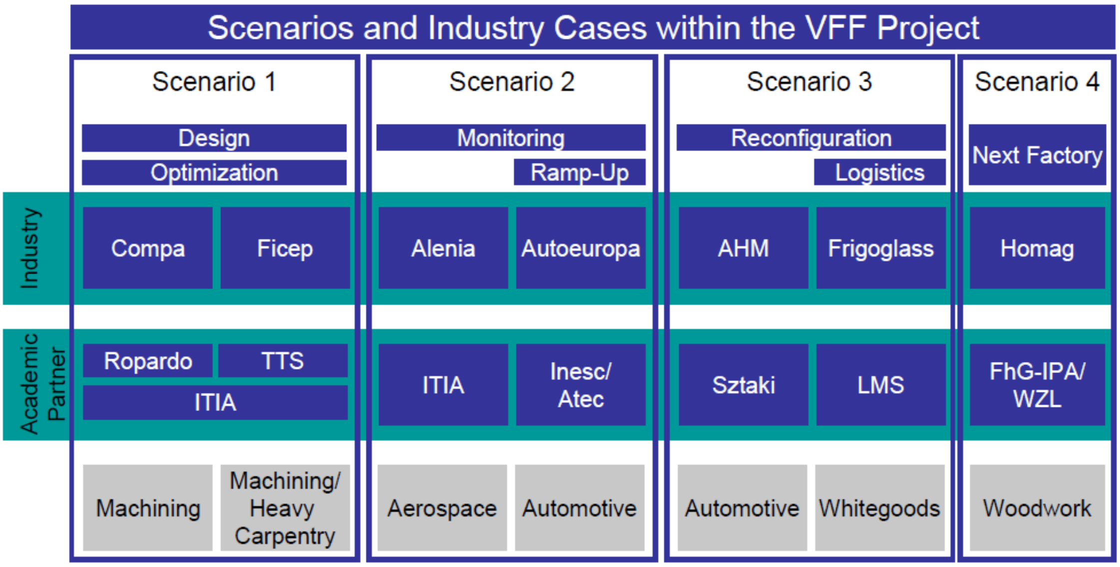

Figure 17 - Allocations of Project Partners to the Scenarios

In the scope of the VFF approach, the needed VF modules can be grouped into several categories as: visualization modules for viewing the characteristics of the factory and support the activities carried out by other modules, KPI (Key Performance Indicator) modules, Discrete Event Simulation modules to evaluate the performance of the factory, presence and ergonomics modules, kinematic simulation modules, control modules for the emulation of the production systems, factory design modules to support the design of the factory layout and systems or others.

Volkswagen Autoeuropa is particularly committed with the KPI Module for automotive Industry.

3.2. Volkswagen Autoeuropa

Volkswagen Autoeuropa, Lda is one of the vehicle manufacturing plants of the Volkswagen Group. It is the largest foreign investment project ever done in Portugal and is located in Palmela. Characterized for being a competitive factory in the automobile sector, Volkswagen Autoeuropa presents itself as a flexible company capable of facing the future challenges following the latest quality and environmental standards. Since its inauguration, Volkswagen Autoeuropa has been the target of several investment agreements aiming the settlement of new production infrastructures, equipment modernization and the training of the employees in order to turn the production lines and methods each time more efficient and increase the competences of its employees. The models produced are Volkswagen Sharan, Volkswagen Eos, Volkswagen Scirocco and Seat Alhambra. Volkswagen Autoeuropa's philosophy of continuous improvement has been placing it as one of the companies of the Volkswagen group in the leading edge in several performance indicators.

3.2.1.Mission and Vision

Mission

VW Autoeuropa strives for excellence in the manufacture of high quality cars in Portugal, and is perfectly aware of the fact that success, in an ever increasingly competitive market, depends on this philosophy.

Vision

“Autoeuropa - the most attractive Volkswagen plant in Europe.”
Producing cars with highest quality and productivity based on flexible infrastructures and skilled human resources.

3.2.2.Volkswagen Production System

Volkswagen Production System describes the basics, principles and rules according to which the production processes at Volkswagen Group production sites must be conceived, performed and continuously redeveloped.

The final objective is to create a company oriented towards value creation and with completely synchronized supply chains geared towards short lead times, small inventories and continuous improvement. It is based on clear standards and is focused on people.

The Volkswagen Production System consists of a variety of basics and the four principles columns “Cycle”, “Flow”, “Pull” and “Perfection” as in Figure 18.

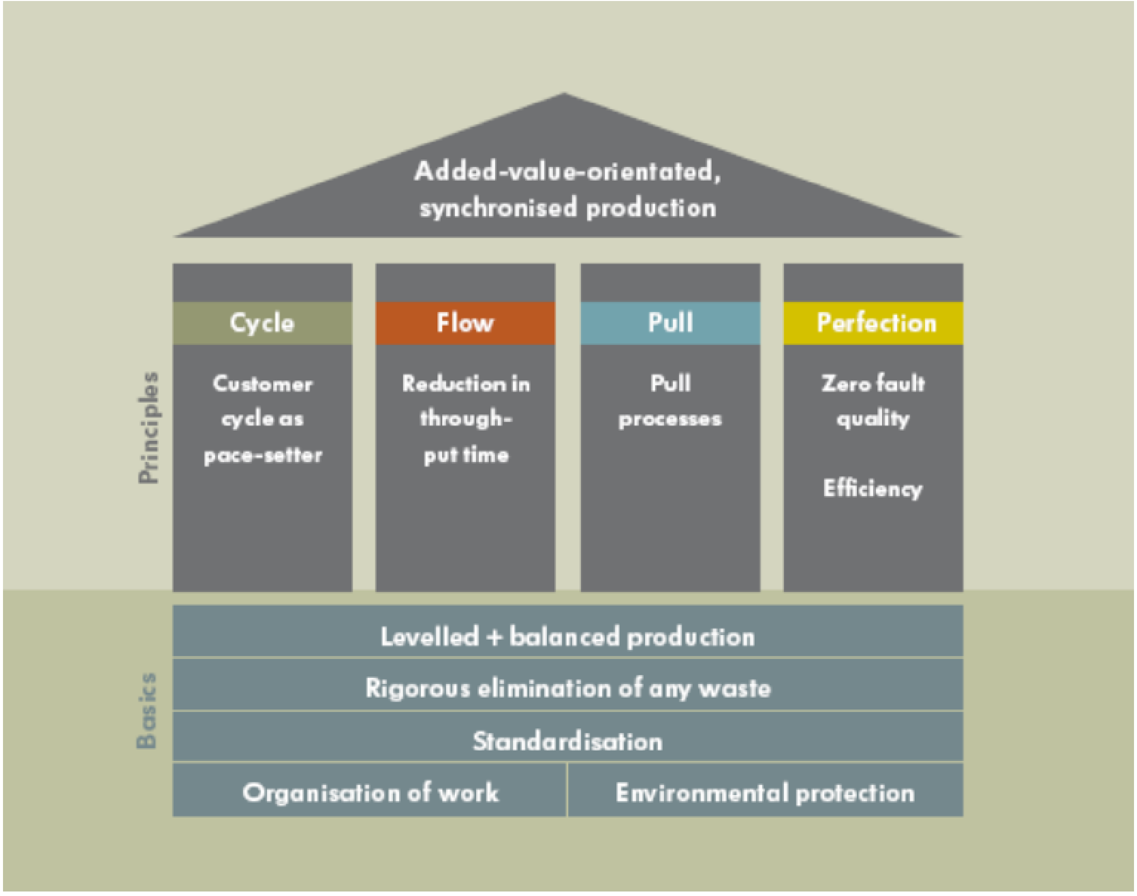

Figure 18 - Volkswagen Production System

3.2.3. The Production Process

The production process is divided in four major sequential macro-processes corresponding to four distinct production areas (Figure 19) which has been improved and adapted along time in order to allow new car models and with the newest technologies available.

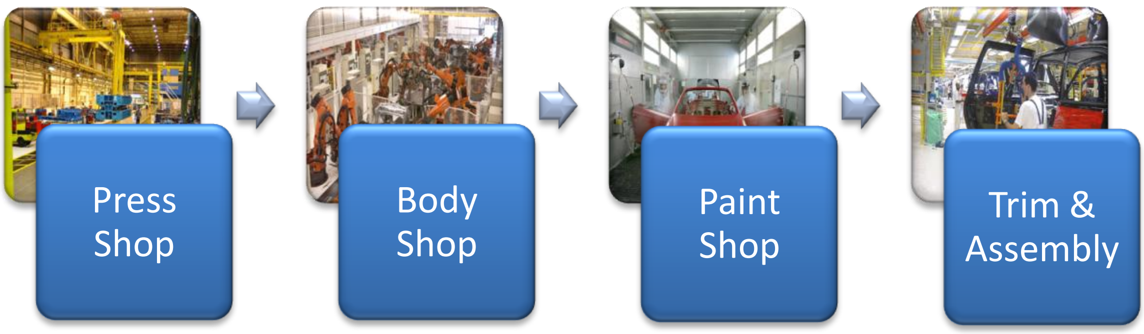

Figure 19 - Production Areas

These areas are displaced in the plant layout as in Figure 20.

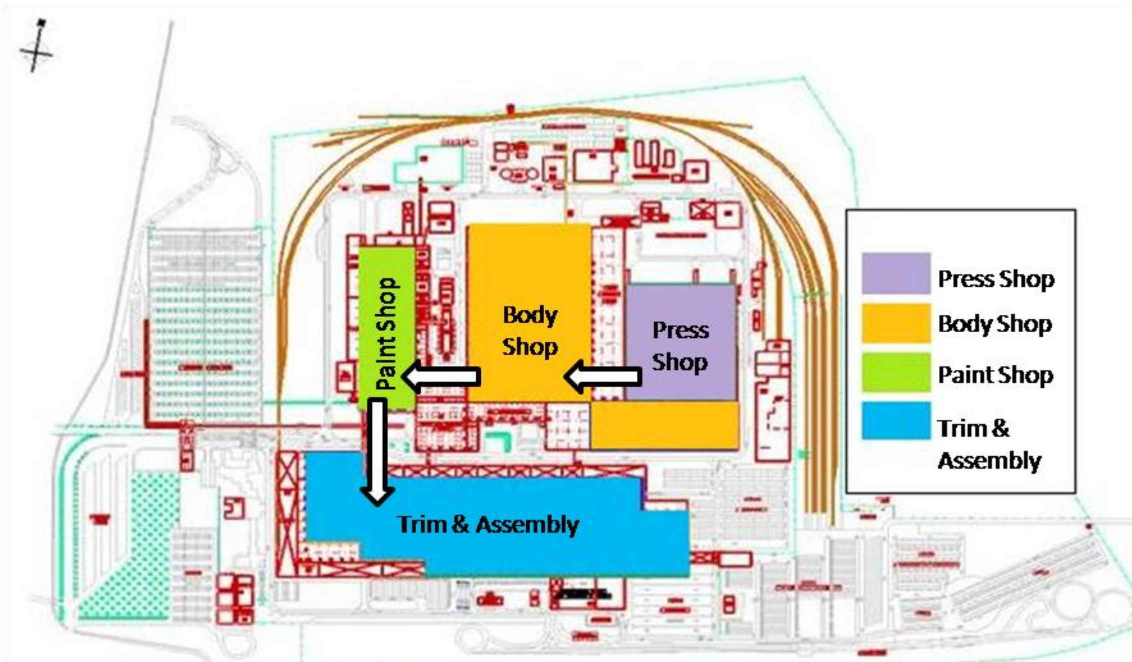

Figure 20 – Plant Layout

3.2.3.1. Press Shop

In the 23000 m^2 of the Press Shop (Figure 21), is done the cutting and stamping of the car body panels from steel reels. In 2009 was produced a total of 138 parts for Volkswagen Sharan And Seat Alhambra, 78 parts for Volkswagen Eos and 70 parts for Volkswagen Scirocco, which represents the majority of the body panels of those cars. The equipment includes 5 tri-axial stamping presses and 6 presses in tandem line supported by a reel cutting machine. Actually this area is working in a 2 shift pattern.

Press Shop is also supported by a sub-area for preventive and corrective maintenance of all machinery.

Figure 21 – Press Shop

3.2.3.2. Body Shop

Here is done the Construction of the cars body. The main steps in this area are parts preparation, welding the body and quality control and use high-tech tools. There are hundreds of robots which apply automatically up to 94% of the thousands welding points needed (5745 for MPV, 4825 for Eos and 4373 For Scirocco). This area does not work with the same shift pattern for all models in order to adapt to the needs of each model and optimize the utilization of the different working teams.

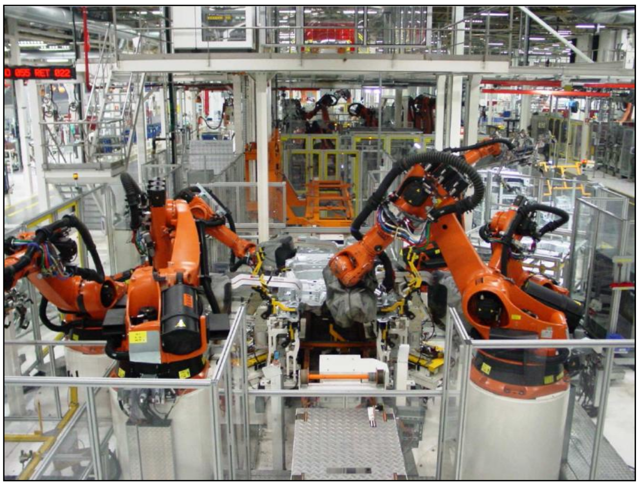

Figure 22 – Body Shop

3.2.3.3. Paint Shop

Paint Shop is considered a lean area as there are no intermediate stocks between process operation steps and all product variations share almost all operation sequence (which takes about 6,5 hours). Operations include PVC application, electrostatic primary application and different enamels application. Although all the process is much automated, some operations are performed by humans to guarantee maximum quality.

Figure 23 - Paint Shop

The operations sequence follows the same physical line and that is possible for all car models. The set-up times are reduced to minimum and it is possible to deal with a completely random sequence of the models. That is possible with a correct line configuration.

3.2.3.4. Trim & Assembly

Sometimes referred as Final Assembly, it is the largest production area (with around 52 542 m^2) and with more employees assigned (more than 1000). With a “just-in-time” logistic concept implemented, aiming to reduce material stocks in the factory supported by a highly sophisticated Production Control Computer System that allow the material to be collected from the supplier and delivered directly in production line, at the point of assembly and sequenced according to the scheduled production. After the Paint Shop, each car body is prepared and tagged before entering in a “firs in/first out” sequence and each car will be assembled according to the specifications and with the parts and accessories assigned to it in a “one line concept” layout as in Figure 25.

Figure 24 – Trim & Assembly

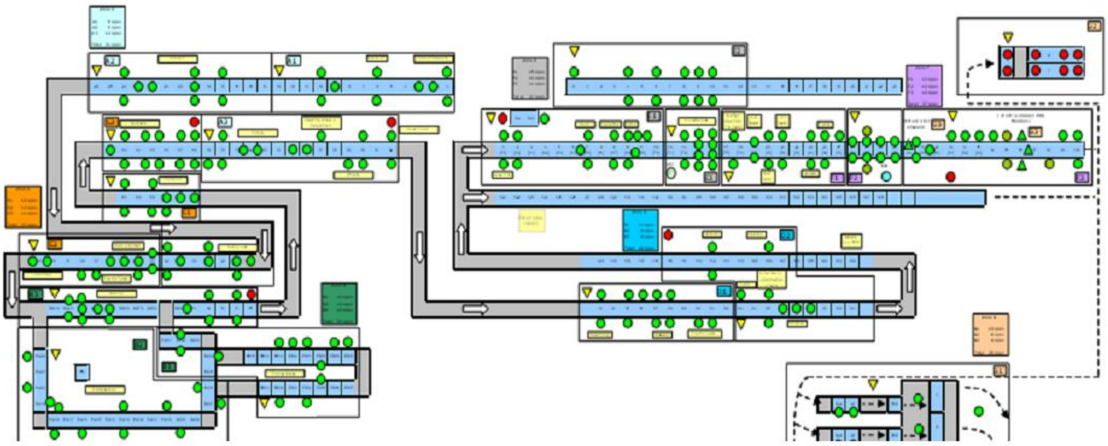

Figure 25 – "One line concept" layout

3.2.4. Products

The most recent Product range includes Volkswagen Sharan, Seat Alhambra, Volkswagen Eos and Volkswagen Scirocco.

Volkswagen Sharan and Seat Alhambra, usually designated as MPV (Multiple Purpose Vehicle) as if where one unique product as they share the majority of specifications

All these products were mainly developed in Germany, at Volkswagen AG. In spite of participating in launch of the models building pre-series and other phases of the new projects, Volkswagen Autoeuropa focuses the attention on the production only. For that reason is considered a production unit. Some parts of the vehicles are produced outside the plant, in the industrial park suppliers or in other parts of the world. For example, engines 2.0/2.8 are from VW Salzgitter (Germany), 1.8 T from Audi Gyor (Hungary) and 1.9 TDI from VW Polkowice (Poland).

Also the commercialization is not of Autoeuropa's responsibility. In Portugal, the Volkswagen models are marketed by Siva and Seat Alhambra by Seat Portugal.

		
MPV (VW Sharan & Seat Alhambra)	VW Eos	VW Scirocco

Figure 26 - Products

3.2.5.Suppliers

Volkswagen Autoeuropa has more than 600 suppliers worldwide. Although only 10% of the suppliers are settled in Portugal, the parts they supply represent more than 50% of the value of the products. Some of them have settled in the nearby Industrial Park which streamlines a more efficient delivery system based on sequenced delivery and just in time concepts.

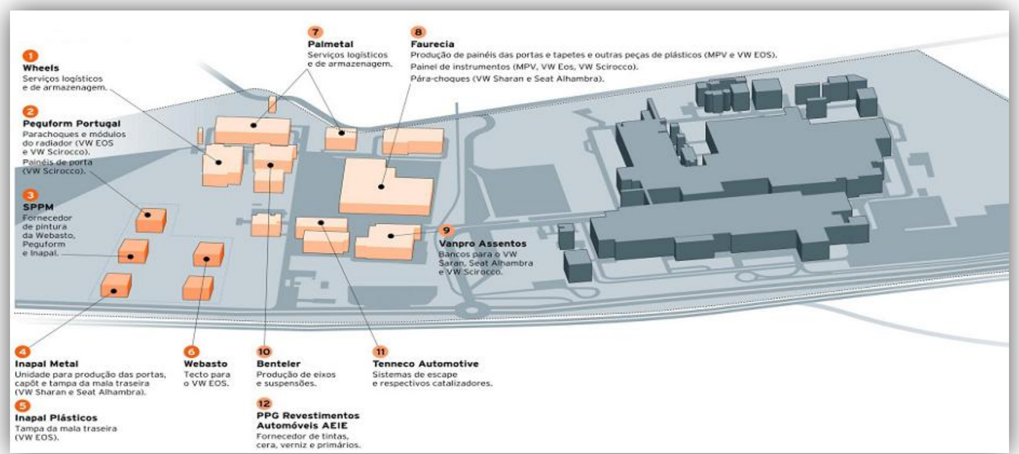

Figure 27 - Industrial Park

The majority of supplies include steel reels for press shop, powertrain and all the parts and components as bumpers, seats, suspension, instrument panels, etc to be assembled in Trim & Assembly Area. Other suppliers provide some pre-assembled parts for body shop, paint for paint shop and other types of consumables. These supplies are included in the internal processes as in Figure 28.

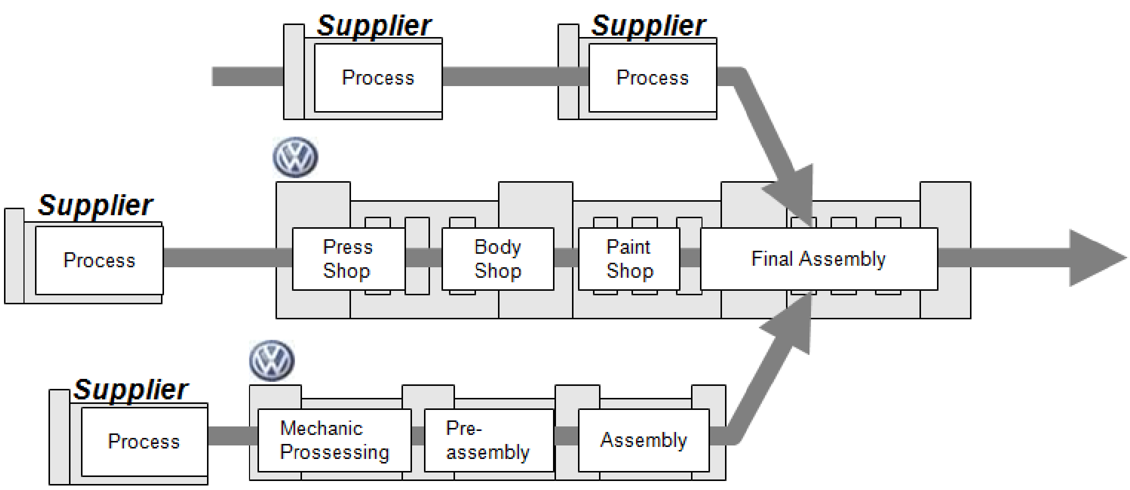

Figure 28 - Role of suppliers

3.2.6.KPIs in Volkswagen Autoeuropa

Before starting do explain in detail the actually used KPIs in use in Volkswagen Autoeuropa that are subject to this project, some considerations and concepts that will be used in this chapter (and others) must be clarified.

All the three KPIs targeted by this project are KPIs related to manpower performance and lay on *Production* business activity according to the classification on Table 1 in Chapter 2.

These three KPIs are Organizational Hours per Unit (OHPU), Hours per Unit (HPU) and Productivity. OHPU will be subject of further details in Requirements chapter.

Organizational Hours per Unit (OHPU) is the ratio between working hours performed by all employees and production volume during a month and cumulatively during a year. It is a core KPI and is also used for benchmarking between the group plants and among the entire industrial sector so the values are arranged in specific splits for comparability.

$$\text{OHPU} = \frac{\text{Actual Working Hours}}{\text{Production Volume}}\ [\text{hours /unit}]$$

Hours Per Unit (HPU) is similar to OHPU but refers only to employees related with production process. It is calculated daily and is the ratio between effective working hours and production volume. Effective working hours is obtained multiplying the number of direct employees attending to work and the effective working time considered for the current day (excluding breaks and other possible downtimes).

$$\text{HPU} = \frac{\text{Attendance} \times \text{EWT}}{\text{Production Volume}}\ [\text{hours /unit}]$$

The KPI *Productivity* refers to the ratio between monthly production values and the number of employees in each of the organization's areas.

$$\text{Productivity} = \frac{\text{Production Volume}}{\text{Manpower}} \times \frac{229}{\text{Working Days}}\ [\text{units/employee}]$$

These KPIs are the basis for the strategic and tactical levels of performance monitoring and management. Its analysis is the trigger for several improvement and process optimization workshops as in Figure 29.

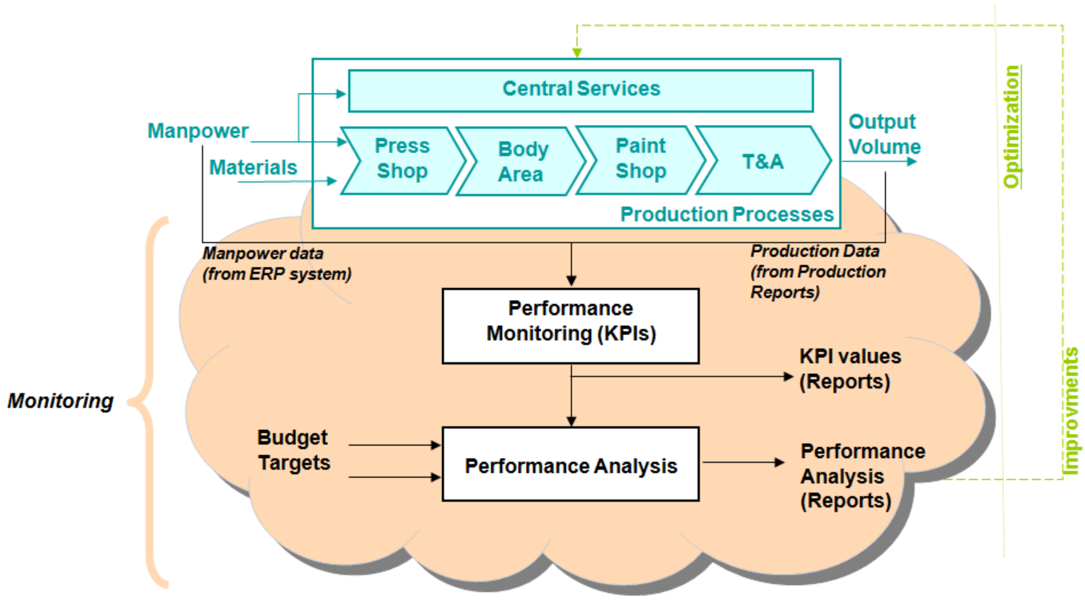

Figure 29 - Performance Management in Volkswagen Autoeuropa

This is the scenario where this work has been developed. In the next chapters will be presented the major intermediate and final results obtained.

Chapter 4.

Functional Analysis and Requirements Specification

4.1. Organizational Hours Per Unit (OHPU)

Organizational Hours per Unit (OHPU) is one of the core metrics universally used to measure labour productivity. Periodic reports, actually monthly, of its values are essential for benchmarking between different plants and to support strategic decision.

In Volkswagen Autoeuropa, it is considered a KPI of high importance and its values are part of the data used by the Volkswagen Group high entities to monitor the performance of the all the plants of the group spread all over the world.

The equation for OHPU is as follows:

$$\mathrm{OHPU} = \frac{\text{Actual Working Hours}}{\text{Production Volume}}\ [\text{hours /unit}]$$

Where "Actual Working Hours" relates to the actual labour hours carried out by employees during the considered period in the calendar. As an example for a normal attendance day it is considered, for each employee, the "Paid time" (8h/day) for the morning and afternoon shifts. In Figure 30 and Figure 31 is detailed the definition of effective working time for the different shifts.

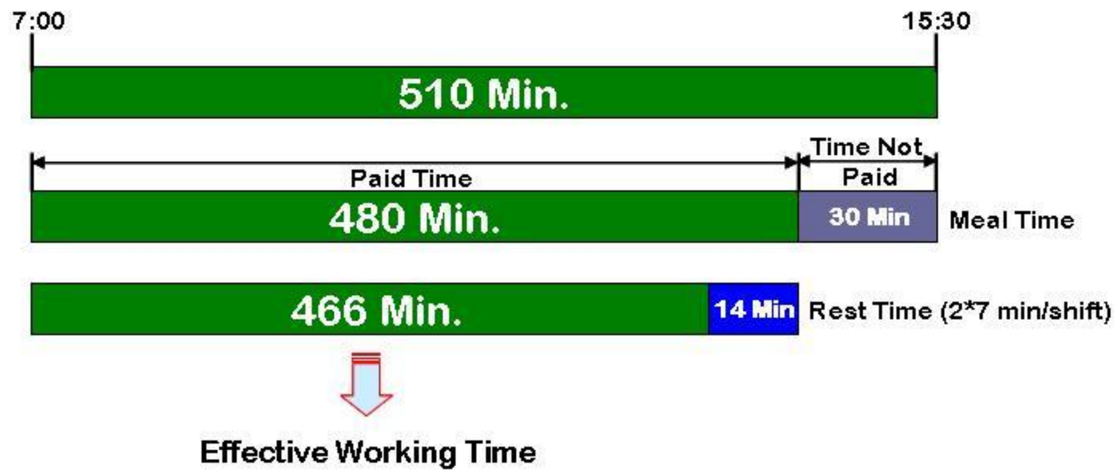

Figure 30 – Morning Shift time Split

For the night shift, the "Paid Time" is reduced to 376 minutes corresponding to approximately 6.3h/day.

Figure 31 – Day time Split

However, some "paid hours" are not included in Total Working Hours parameter as summarized in Table 2.

Table 2 - Included / Excluded Hours in OHPU

Hours Included	Hours Excluded
• Normal Working Hours (presence hours) Includes ○ Breaks ○ Meetings • Overtime	• Absence leaves (justified or not) • Meal Time • Travel Time (business trips or similar) • Training Hours • Hours dedicated to unaccounted functions.

"Production Volume" for each product and for each time period the report refers to, is collected from Production Monitoring Systems and relates to the total sum of successfully finished units after passing the last quality checkpoint.

Considering working hours as an input and production volume as an output, OHPU is by definition the inverse of actual labour productivity, that means, obviously, that lower OHPU value represent higher plant productivity.

Classification of employees in Organization Structure is simply done by cost center. Each employee is attributed to a cost center and each cost center belongs to a specific and unambiguous division in the Organization.

The actual Structure from the Organization Organogram is in Figure 32. Each employee is considered in one division only and the hierarchical dependency is not relevant for the indicator.

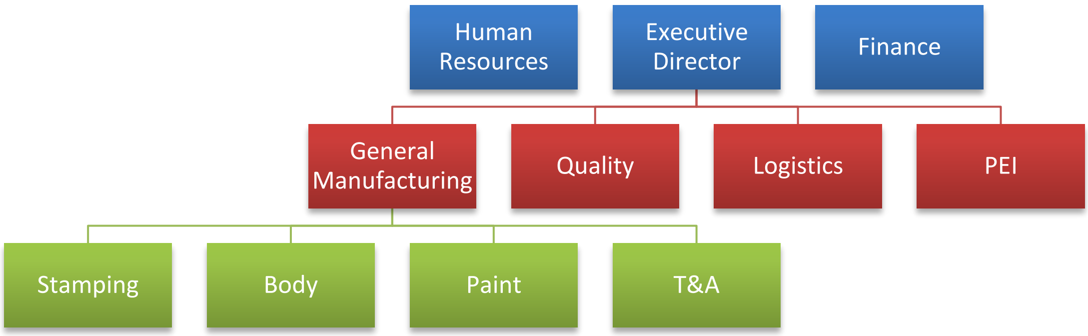

Figure 32 - Volkswagen Autoeuropa Organogram (as used for OHPU)

However, the calculation of the required values implies several more complex aspects.

The OHPU Reports requires the data to be divided according to different criteria. The "Total Working Hours" are sliced in subtotals for each required split. This will allow doing several breakdown structures for different analysis.

The actual splits are:

- Core Business Areas
  - Manufacturing
  - Central Site Services
  - Logistics
  - Maintenance
  - Quality
  - Support Dedicated
- Major Assembly Areas
  - Body
  - Paint
  - Trim & Assembly
  - Central Site Services
- Labour types
  - Direct Manpower
  - Indirect Manpower
  - External Services

  - Temporary Agency Manpower
- Products
  - MPV (VW Sharan and Seat Alhambra)
  - VW Eos
  - VW Scirocco

Core Business Areas

This breakdown divides Manpower by the main Core Business of the plant independently of the official position on organization, Assembly Area or labour type. Classification is made and revised periodically by each area and for each employee. The possible classifications are: Manufacturing, Central Site Services, Logistics, Maintenance, Quality and Support Dedicated.

Manufacturing is associated to processing vehicles through all the operations sequence.

Central site services are responsible for some administrative functions and others.

Logistics include transport, material handling, parts receiving and sequencing.

Maintenance includes all planned, routine, preventive and corrective maintenance as machinery repair, adjustments and cleaning.

Quality is obviously related with product and processes quality assurance and inspection.

Support Dedicated supports the production in a functional area, Engineering, IT support for production systems, process improvement and reporting (except quality reports).

Major Assembly Areas

Besides being included a Press Shop in Volkswagen Autoeuropa, OHPU is only applicable to the other tree Production Areas. In automotive benchmarking groups, automotive manufacturers' plants are divided in "Vehicle Assembly", "Stamping", "Engine" and "Transmission" plants. Press shop is placed in "Stamping" category and performance is analyzed as if it was a different plant and other metrics are used. However, data related to Press Shop is collected the same way as for Body Shop, Paint Shop and Trim & Assembly. The methods to achieve its particular metrics are out of the scope of this work and will not be detailed.

Figure 33 – Assembly Areas Considered for OHPU

For all employees must be a correspondence with the assembly areas independently of the nature of work of the employee so the sum of working hours of all three equals the plant total. Direct employees are assigned directly to one of them, while for indirect employees must be applied a division criteria. The actually used method is to divide the total accounted hours (for each indirect employee) by each assembly area using the percentage of direct employees of each area, the Areas Split. Each employee can be classified as:

- Body
- Paint
- T&A
- Body + Paint + T&A
- ...

This is one of the possible methods to estimate the amount of work performed in non-production areas that is somehow dedicated to each assembly area.

Labour Types

Direct workers are the ones who perform operational activities related to value-adding to output products (station preparation, loading, joining, fabrication, assembly, finishing, etc). Indirect employees perform all the “non-direct” work necessary to support direct operations (this includes maintenance, logistics and quality as well as other typical office functions).

Temporary Agency Manpower and External Services are categories for employees not included in Payroll (independently of performing direct or indirect work) and the information about these groups is from the responsibility of each area and is processed as explained later.

Products

For Product breakdown is applied a method similar to the one used in Major Assembly Areas breakdown. Each employee working hours must be divided by each product so the sum of working hours related to each product equals the plant total working hours. Each employee can be assigned to only one, to more than one or to all the products. The number of accounted hours for each employee will be divided by each one of the products he is assigned to, according to the percentage of production volume of that product over the total volume of the assigned products.

4.2. OHPU “As-Is” Process Model

The second step of the adopted methodology is to model the process in cause “as-is” now in order to identify improvement opportunities in process himself and as a starting point to identify functional requirements for the information system to be developed.

The process for obtaining OHPU values and reports can be divided in three major steps as in Figure 34.

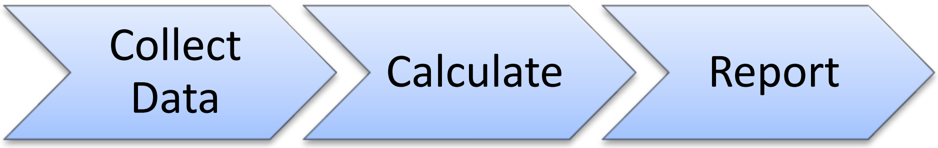

Figure 34 - Major Steps identified for OHPU

4.2.1. Step Collect Data

Collection of all the needed data is the first and most critical step as involves managing various types of information organized in different file types and even ad-hoc information from different entities with different responsibilities. Four activities have been identified corresponding to each of the four major sources of information (Manpower Classification, Payroll Hours, Extra-Payroll Hours and Production Volume).

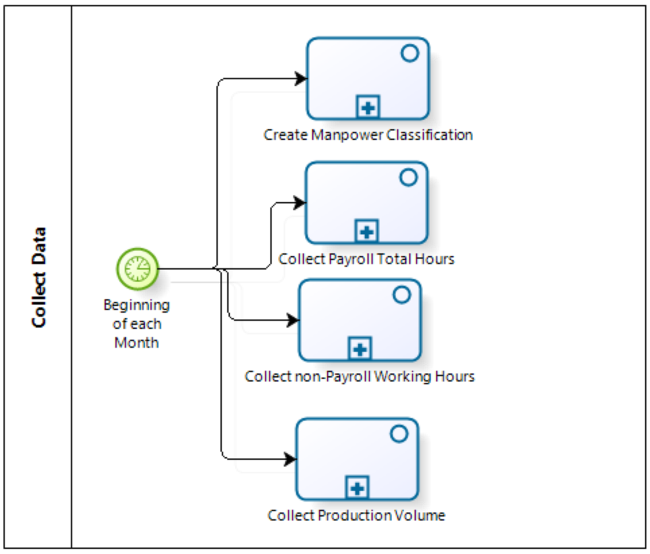

Figure 35 - Step Collect Data

4.2.1.1. Activity Create Manpower Classification

Ambit: The Manpower Classification will be the basis for all calculations related to working hours. Activity starts in the beginning of each month and ends when a valid Manpower Classification (related to the previous month) is obtained.

Objectives: Obtain a consistent classification of each employee belonging to Payroll in the terms required by OHPU.

Inputs: Manpower Status, Previous month Manpower Classification.

Outputs: Current month Manpower Classification.

Actors: Human Resources Department, Strategic Industrial Engineering Team, Each Organizational Structure Division responsible (Executive Directors; Finance; Human Resources; General Manufacturing; Planning, Environment and Infrastructures (P.E.I.); Quality; Paint; Body; Final Assembly)

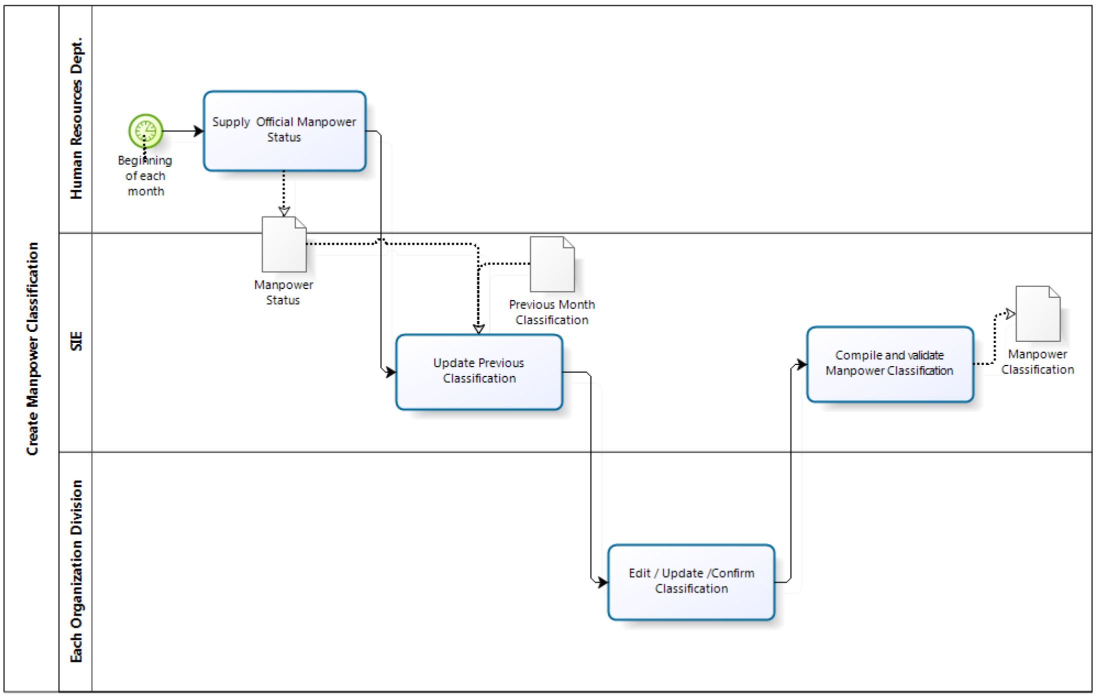

Figure 36 - Activity Create Manpower Classification

<u>Task Supply Official Manpower Status</u>

Responsible: Human Resources Dept.

Sequence of Operations:

1. Collect Manpower official Status from ERP (SAP-HR) as-is in the last calendar day of the previous month.
2. Validate data.
3. Send excel file to SIE Team by e-mail.

Alternative sequence of Operations:

1. SIE Team directly accesses ERP (SAP-HR) and collects the same report.

<u>Task Update Previous Classification</u>

Responsible:

SIE Team.

Sequence of Operations:

1. Receive Manpower Status form Human Resources Dept.
2. Merge Manpower Status with the previous month classification and identify changes in employees' status namely in the fields: Administrator name; Cost Center; Group; Sub-Group; Organizational Unit.
3. Send merged version to the assigned person from each of the Organizational Structure Divisions (Executive Directors; Finance; Human Resources; General Manufacturing; Planning, Environment and Infrastructures (P.E.I.); Quality; Paint; Body; Final Assembly) by e-mail.

<u>Task Edit/Update/Confirm Classification</u>

Responsible: Assigned person from each of the Organizational Structure Divisions (Executive Directors; Finance; Human Resources; General Manufacturing; Planning, Environment and Infrastructures (P.E.I.); Quality; Paint; Body; Final Assembly)

Sequence of Operations:

1. Receive new possible Manpower Classification.
2. Edit or update and confirm, for all the employees assigned to its Organizational Structure division the assortments: OHPU accounted; Excluded Percentage; Excluded Reason; Labor Type; Core Business Area; Major Assembly Area; Car.
3. Send edited version to SIE Team.

Alternative sequence of Operations:

1. Receive new possible Manpower Classification.
2. Communicate changes by e-mail.
3. SIE edit the Manpower Classification with those changes.

<u>Task Compile and Validate Manpower Classification</u>

Responsible: SIE Team

Sequence of Operations:

1. Receive Manpower Classification from each Organizational Structure division responsible.
2. Compile changes, identify and solve irregularities and finally validate the Manpower Classification.

4.2.1.2. Activity Collect Payroll Total Hours

Ambit: Total Payroll Hours contains the majority of the accounted hours for OHPU. The Process starts in the beginning of each month when accessing the Payroll information related to the previous month and ends when that information is integrated with the Manpower Classification.

Objectives: Obtain for each employee in Payroll, the total accounted hours for OHPU.

Inputs: Payroll Total Hours (from ERP system SAP-HR).

Outputs: Updated Manpower Classification.

Actors: SIE Team

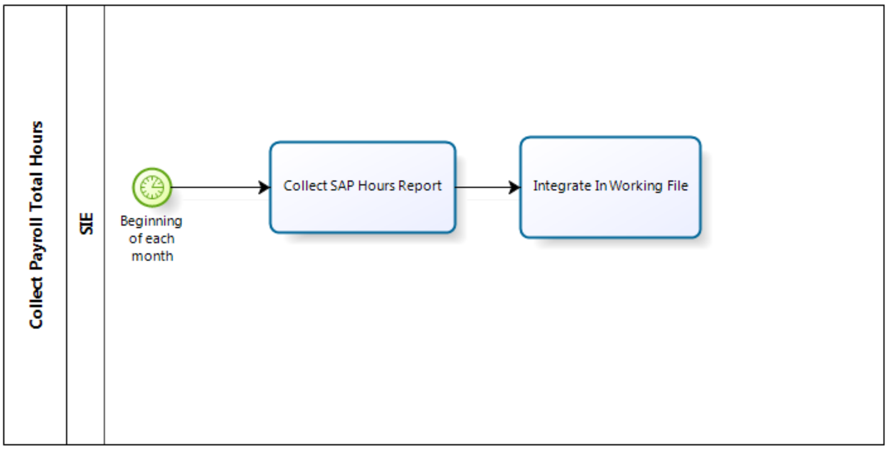

Figure 37 – Activity Collect Payroll Hours

<u>Task Collect SAP Hours Report</u>

Responsible: SIE Team

Sequence of Operations:

1. Access the ERP System (SAP-HR) and download "SAP Hours Report" for the previous month.
2. Save in Working Folder.

Notes:

"SAP hours Report" is exported as an excel file and contains, for each employee, between other information, the number of hours performed during the month concerned divided by different categories with its associated codes (attendance, overtime, travel, ...)

<u>Task Integrate in Working file</u>

Responsible: SIE Team

Sequence of Operations:

1. Merge the working hours with the Manpower Classification for each employee in Payroll.

4.2.1.3. Activity Collect non-Payroll Hours

Ambit: Some workers are not included in Payroll and the amount of work performed must be included in Total Hours somehow. This information is sent by several entities in ad-hoc way.

Objectives: Obtain amount of work extra-Payroll to be accounted for OHPU.

Inputs: Ad-hoc data related to workers not included in Payroll

Outputs: Group of files with usable information related to non-payroll workers.

Actors: SIE Team, Logistics Department, HR Department, each Major Assembly Area (Press Shop, Body Shop, Paint Shop, Final Assembly)

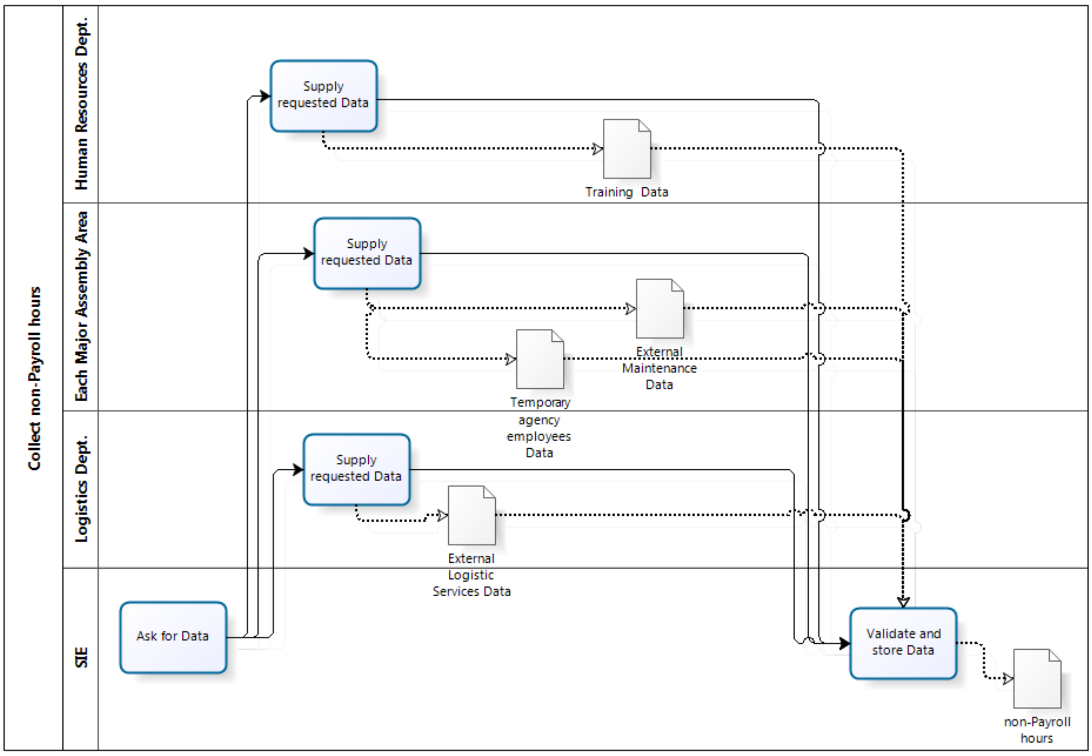

Figure 38 - Activity Collect non-Payroll Hours

<u>Task Ask for Data</u>

Responsible: SIE Team

Sequence of Operations:

1. Contact all the other actors in order to supply the needed data

<u>Task Supply Requested Data</u>

Responsible: Logistics Dept., HR Dept., Each Major Assembly Area.

Sequence of operations:

1. Compile and supply the requested data

Task Validate and Store Data

Responsible: SIE Team

Tasks:

1. Receive all the related data, validate and store in working folder.

4.2.1.4. Activity Collect Production Volume

Ambit: At the beginning of each month, the number of units of each model produced in the previous month is already known. Those values are collected from a production monitoring system and must be validated as official.

Objectives: Obtain official production volume values.

Inputs: n.a.

Outputs: Official Production Volume data.

Actors: SIE Team, Finance Dept.

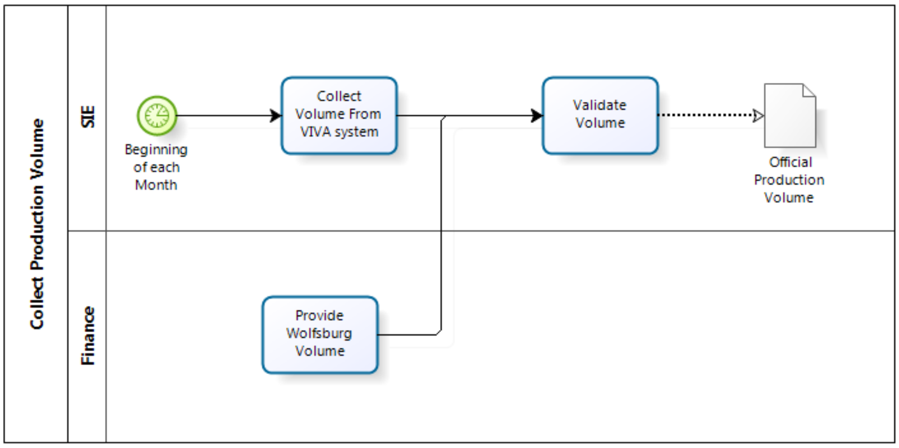

Figure 39 - Activity Collect Production Volume

4.2.2. Step Calculate

Ambit: With all the information collected, the OHPU values are calculated according to the defined rules and in the required cluster breakdown.

Objectives: Obtain all needed values for required OHPU breakdowns.

Inputs: Current month Manpower Classification,

Outputs: OHPU results data.

Actors: SIE Team

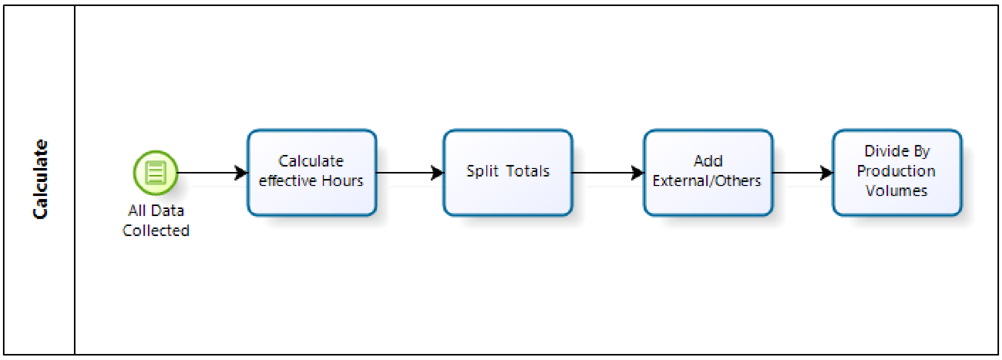

Figure 40 - Step Calculate

Task Calculate effective Hours

Responsible: SIE Team

Sequence of Operations:

1. Filter Hours to be excluded to each Payroll employees according to the defined rules.
2. Add for each employee in payroll the number of hours related to training (or others).

Task Split Totals

Responsible: SIE Team

Sequence of Operations:

1. Group and sum the total hours for each classification of each required cluster breakdown.

Task Add External/Others

Responsible: SIE Team

Sequence of Operations:

1. Add to total hours of each cluster, the equivalent hours related to work performed in External Maintenance, External logistics and Temporary agency workers (when applicable).

Task Divide by Production Volumes

Responsible: SIE Team

Sequence of Operations:

1. Organize the different clusters according to the required breakdowns and divide related working hours by each car or total plant production volume in order to obtain the OHPU values for each combination.

4.2.3. Step Report

Ambit: With all OHPU values calculated, monthly reports must be created to make the results available to stakeholders.

Objectives: Disseminate OHPU results.

Inputs: OHPU results data.

Outputs: Graphical reports

Actors: SIE Team

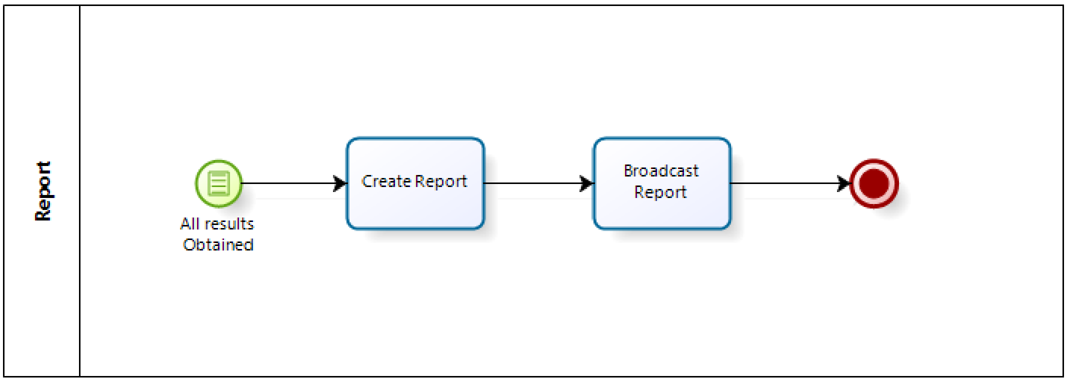

Figure 41 - Step Report

<u>Task Create Report</u>

Responsible: SIE Team

Sequence of Operations:

1. Compile all the OHPU results for the concerned month.
2. Prepare a report with relevant numeric results and graphics.

<u>Task Broadcast Report</u>

Responsible: SIE Team

Sequence of Operations:

1. Finalize report and block further changes.
2. Broadcast the report for interested stakeholders.

4.3. OHPU "To-Be" Process Model

The to-be process is defined by improving or, alternatively, leaving behind some of the issues of the current process.

The major issues identified are:

- Mindless repetitive and non value adding tasks,
- Excessive file exchange,

- No use of versioning or other file control,
- Susceptibility to human error,
- No tracking of data changes,
- Requires much effort to repeat the sequence of operations

Additionally, it should be noted that there were actually no explicit defined targets for the final values although they are defined.

By creating an information system based solution to support the actual process, most of the workflow issues will be extinct. The major benefits obtained are performance increased employee performance and data consistency and less susceptibility to error.

A possible swimlane activity diagram for the to-be process is in Figure 42.

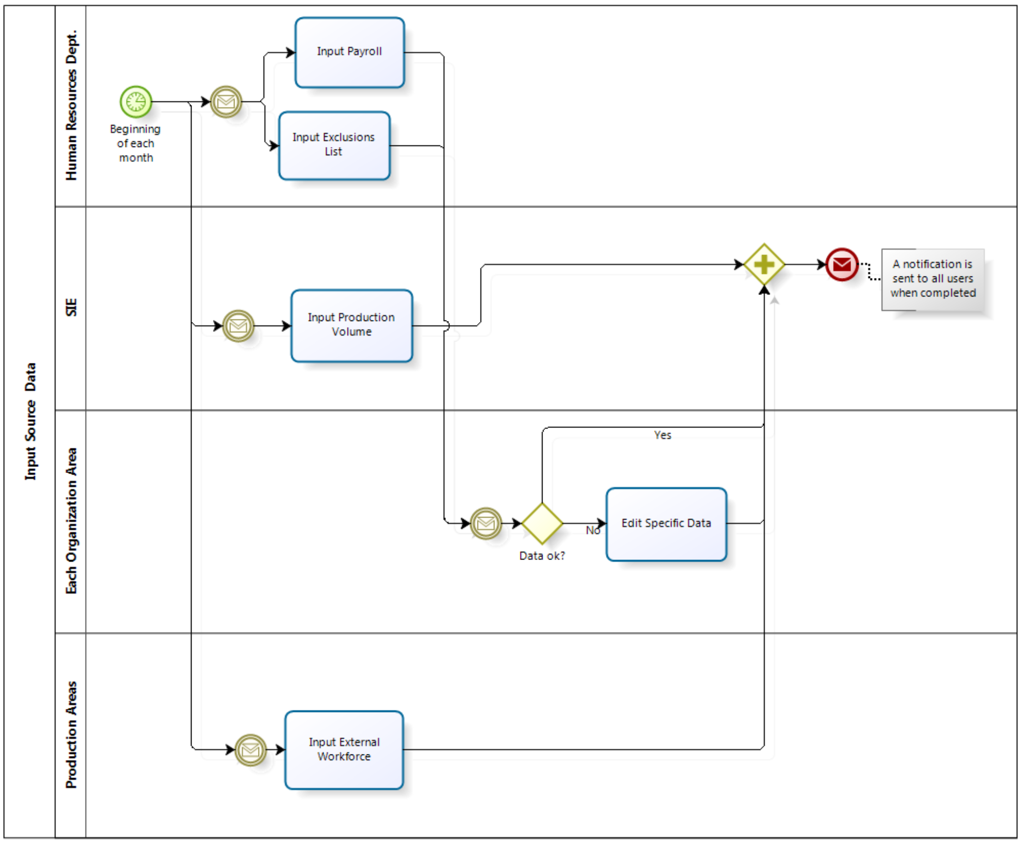

Figure 42 - Activity Input Source Data

Each participant is notified when he is expected to perform any action. In this case, in the beginning of each month, it is required to input all data related to the previous month.

4.4. Functional Requirements

With the purpose of presenting a detailed description of the KPI System, was prepared a requirements document in accordance with the IEEE Std 830-1998, (IEEE Recommended Practice for Software Requirements Specifications). It explains the purpose and features of the system, the interfaces of the system, what the system will do and the constraints under which it must operate. That document is intended for both the stakeholders and the developers of the system.

Product Functions

The software will be a system for KPI calculation and historic storage as well as forecast based on predictable scenarios. The system will be designed to optimize the SIE department work by automating calculation processes, providing data integrity and consolidating the processes involved. The software will facilitate all different roles by managing the workflow associated to the processes.

The major functions identified as requirements for the system have been divided into different categories: general, data and reporting functions.

General Functions:

- The system must allow the following user levels with different permissions (as in Table 3):
    - Admin – SIE Department users
    - Supervisor – Responsible for each Area.
    - Regular User – Other users with dashboard access only.
- The system must be configurable to send notifications on some operations via e-mail.

Data Functions:

- The software is intended to Calculate KPI automatically. Data sources, algorithms and methods (as well as adding new KPIs) must be editable.
- Input of data can be made by different ways:
    - Importing files with specific format (by user),
    - Automatically importing from other systems (to be defined),
    - Directly adding/editing via interface.

Reporting Functions:

- The software is intended to produce reports with the KPI values and other relevant data.
    - These reports can be graphics and/or tables and must be configurable.
    - All data must be stored for future revision or for other purposes.
    - Must be possible to export reports in different file formats.
- The software is intended to predict KPIs values based on possible scenarios.

Table 3 – User Characteristics

User Levels / Functions	Admin	Supervisor	Regular User
View dashboard	✓	✓	✓
Insert/Delete/Edit all data	✓		
Insert/Edit Specific data	✓	✓	
Advanced configurations	✓		

4.5. Specific Requirements

4.5.1. External Interfaces

The system initial setup will include the OHPU performance indicator. For this kpi, major inputs are tables with different types of information. For all inputs the user must have the option to import files from a selected location. Possible interface with other systems and databases is to be defined.

The major monthly data inputs are:

- Payroll – list information about all accounted hours for each employee,
- Production Volume – list the number of produced vehicles of each model for each day of the month,
- Exclusions – list information about occurred events that must be subtracted to accounted attending (training hours and others),
- External – contains the amount of work, in hours, preformed by external entities for each area (temporary work agency and others).

4.5.2. Use Cases

The system must comply with a list of uses cases organized as follows in the next sections.

4.5.2.1. Use case Packages

The use cases will be divided into four major packages as in Figure 43.

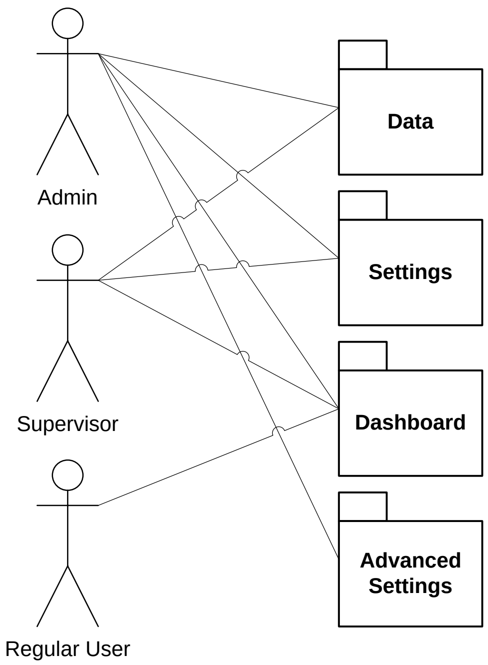

Figure 43 – Use Case Packages Diagram

"Data" package includes all use cases to support all data sources importing, editing and visualization.

"Settings" package is related to workforce classification and setting other assumptions and values.

"Dashboard" package accommodates all the required visualization options.

"Advanced Settings" includes configurations of user accounts and permissions, KPI advanced definitions.

4.5.2.2. "Data" use cases:

- Manage Payroll: User imports payroll file with daily information for working hours of all employees from a specified location. Data can be edited later.
- Manage Production Volume: User imports Production Volume file. Daily values and monthly cumulative can be changed as well as Product Volume Mix.
- Manage External Workforce: User imports external workforce reports. Each Area Supervisor can edit the values related to his Area.
- Manage Exclusions List: User imports lists related to training or other excludable events included in payroll.

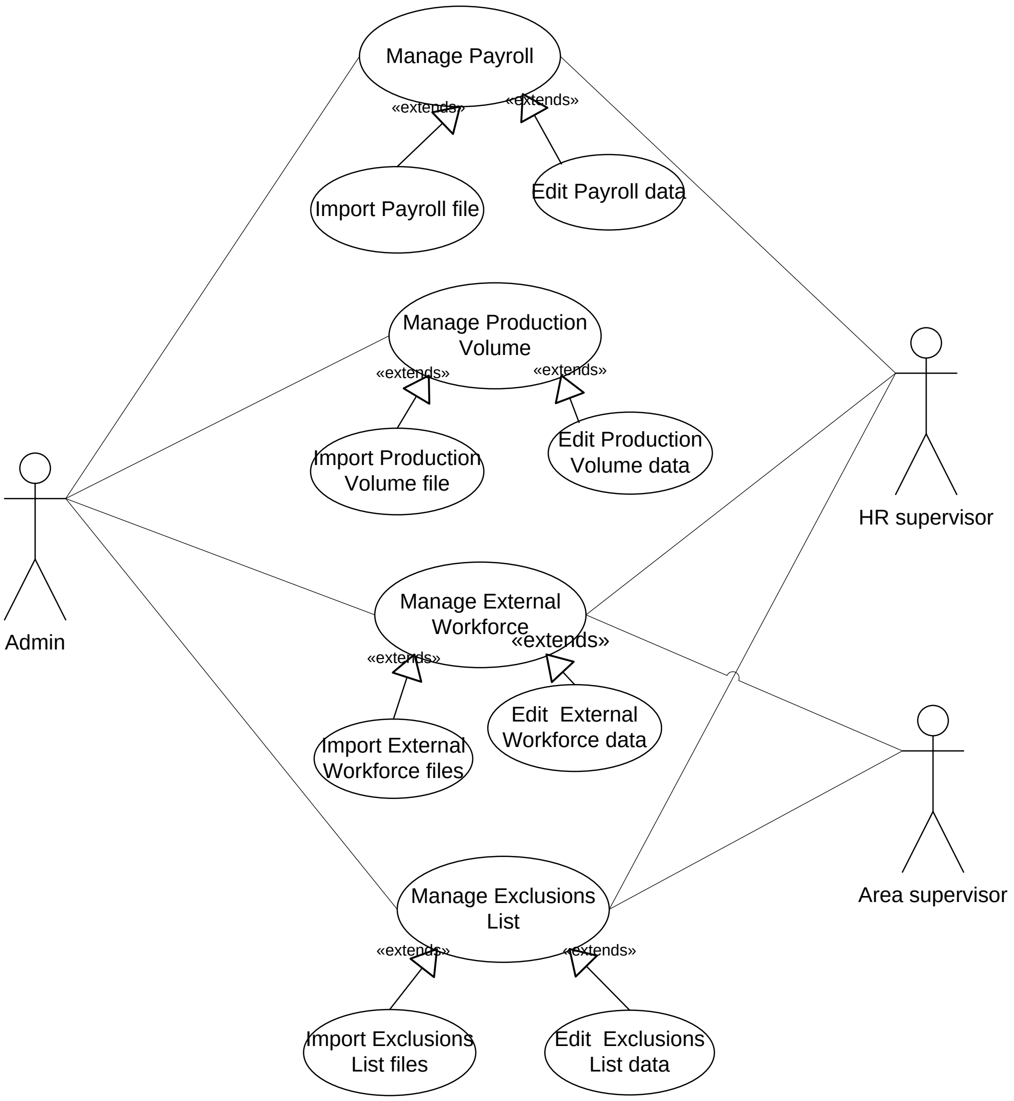

Figure 44 – Data Use Cases Diagram

4.5.2.3. "Settings" use cases:

- Classify Cost Centers / Organizational Units: User classify each one according to the required splits. New classifications are possible along time.
- Manage Classification Exceptions: User creates individual classification for an employee different from its organizational unit during a period of time.
- Set Targets: User defines kpi targets for each month, product and production area.
- Set Area Mix: User defines mix weight for each production area.

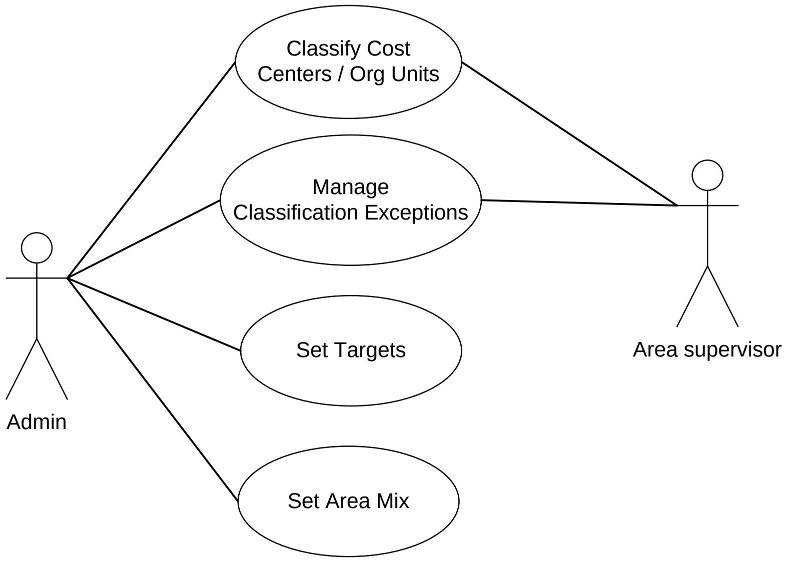

Figure 45 –Settings Use Cases Diagram

4.5.2.4. “Dashboard” use cases:

- Select Split: User selects the split for visualization. Within each split can be picked different clusters.
- Select Product: User selects individual products or plant totals.
- Show/Hide Target: When available, user chooses to visualize targets or not.

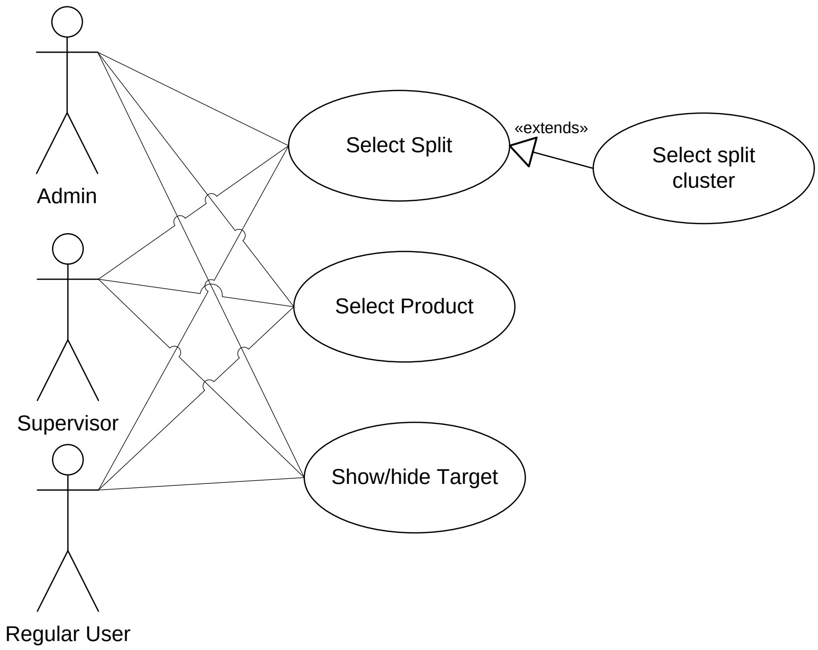

Figure 46 – Dashboard Use Cases Diagram

4.5.2.5. “Advanced Settings” use cases:

- Manage User Accounts: User configures user accounts adding/removing users and editing permissions.
- Add New KPI: User creates new kpi in the system.
- Edit KPI: User edits kpi selecting data sources and relationships creating the calculation algorithm.
- Edit Dashboard: User configures the dashboard display options.

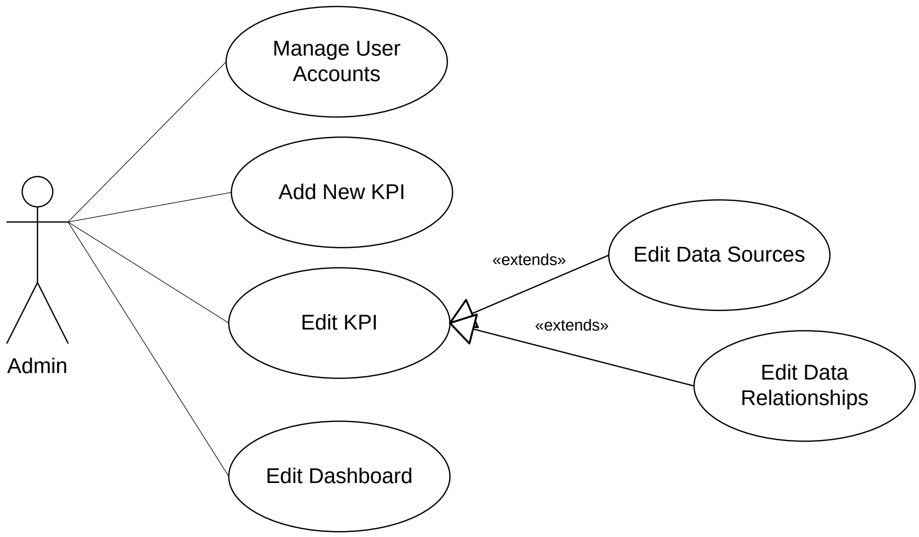

Figure 47 – Advanced Settings Use cases Diagram

4.5.3. Other non-functional requirements

Auditability

The system must keep safety backups for an indefinite period of time to prevent loss of data and all changes in data must be recorded in a trace file with before and after values.

Design Constraints

The options available for the database are MySQL 2005&2006 and Oracle 10G. This is a constraint imposed by the IT department.

Chapter 5.

Prototype Development

5.1. Module context

As stated in 3.1.1.2, the Functional Modules to be added to the VFF framework can be of different nature. The two main types are Client Modules and VF Manager Plug-in Modules. About the deployment approach, the modules can be Pure client, Pure Server, Client-Server and Client adapters for existing applications.

The module that will be developed will be able to interact with the VF Manager using directly web-services provided by the VF Manager module. Once this module is being developed oriented to the VFF requirements, the KPI module will be able to simple connect the web services provided.

For this work, only Business Logic / Functionalities implementation was considered.

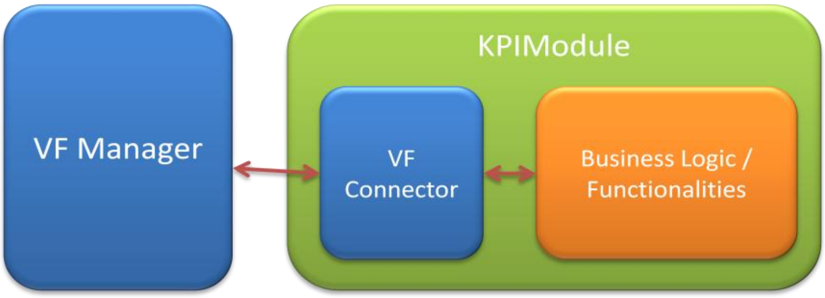

Figure 48 – KPI Module in VFF context

5.2. GUI Interfaces

The acceptance of a software system depends in a large degree on the quality of its user interface. Prototyping is an excellent means for generating ideas about how a user interface can be designed, and it helps to evaluate the quality of a solution at an early stage by evaluating feedback from end-users. The development of a Graphical User Interface (GUI) prototype must be an iterative process along with requirements analysis helping to define how the functionalities will be available to users as well as navigational issues exploring the usability of the system.

There are several methods and tools for prototyping and different types of prototypes. During this project were developed a so called horizontal prototype, which provides a broad view of the system focusing on user interactions for requirements system scope validation at high-level.

The navigation model is hierarchical as in Figure 49. The main user interface screens are presented next.

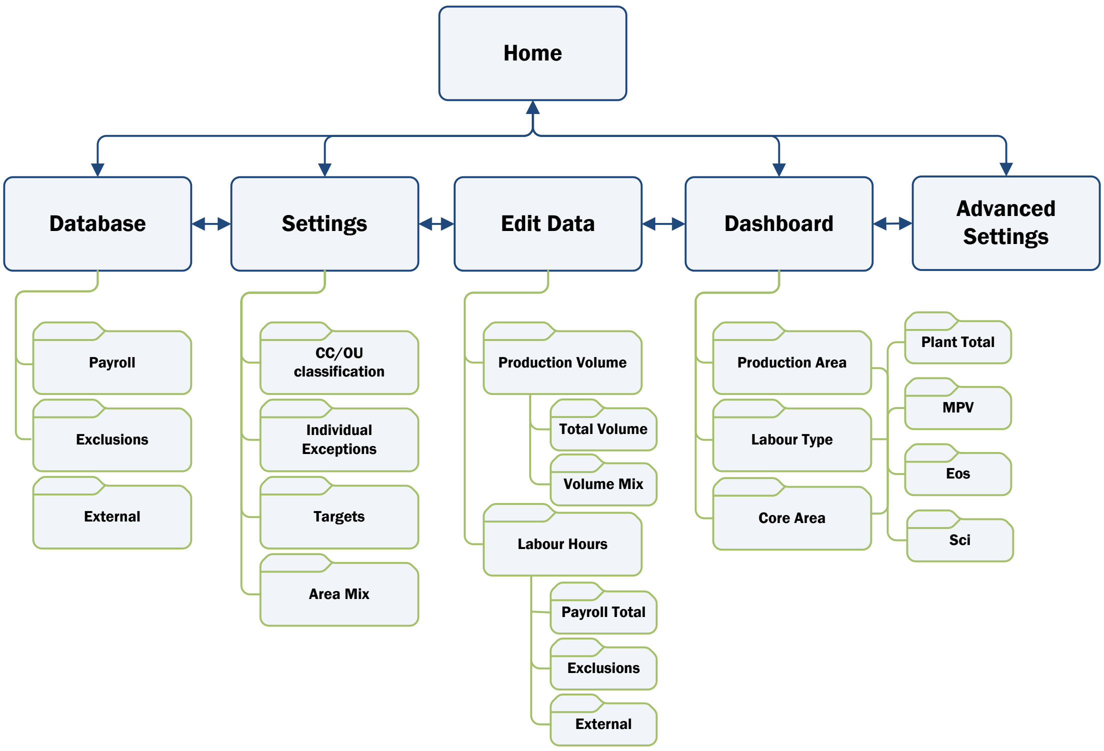

Figure 49 - Hierarchical Navigation Diagram

5.2.1. Entrance User Interface

Once the user enters the application, the log in form is presented to proceed to authentication. Each user is associated with one of the different permission levels that conditions access.

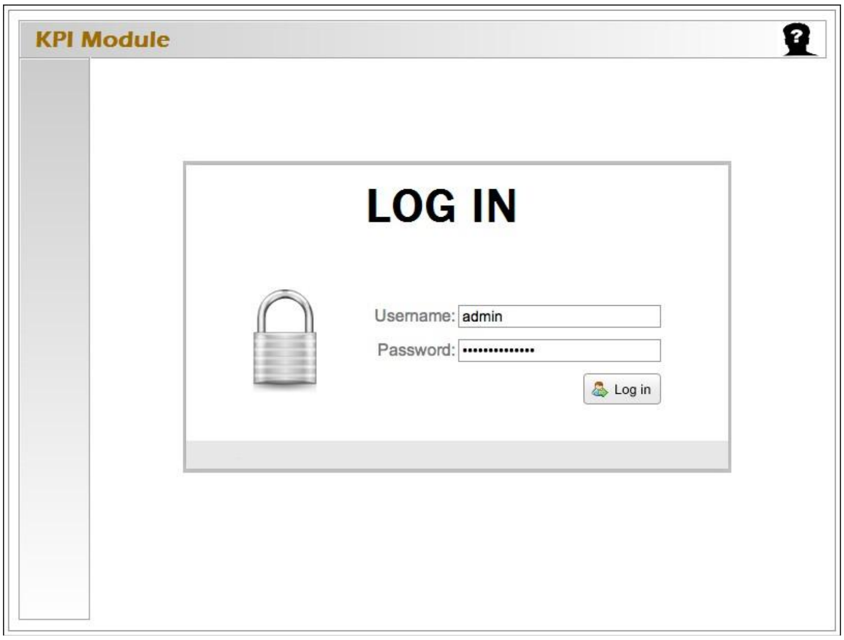

Figure 50 – Log In Screen

After authentication, user is prompted with Home screen which allows navigation through the first navigational level interfaces:

- Database
- Settings
- Edit Data
- Dashboard
- Advanced Settings

In Figure 51 is presented the Home screen for Admin User accounts. For other users, the available options are as in Table 4.

Table 4 -Home Screen Options by User Level

Available Options \ User Levels	Admin	Supervisor	Regular User
Database	✓	✓	
Settings	✓	✓	
Edit Data	✓	✓	
Dashboard	✓	✓	✓
Advanced configurations	✓		

Figure 51 – Home Screen

5.2.2. "Database" User Interfaces

Navigating to Database page are available three tabs:

- Payroll,
- Exclusions,
- External.

For each tab, are available the functions to import files and view data for Payroll, Exclusions List (Training and Others) and External Workforce (Temporary Employees, External Maintenance) respectively and for each month (selected in the period browser). These cover the uses cases related to import files in Data package. Additional functionalities are printing and exporting data to excel and pdf files.

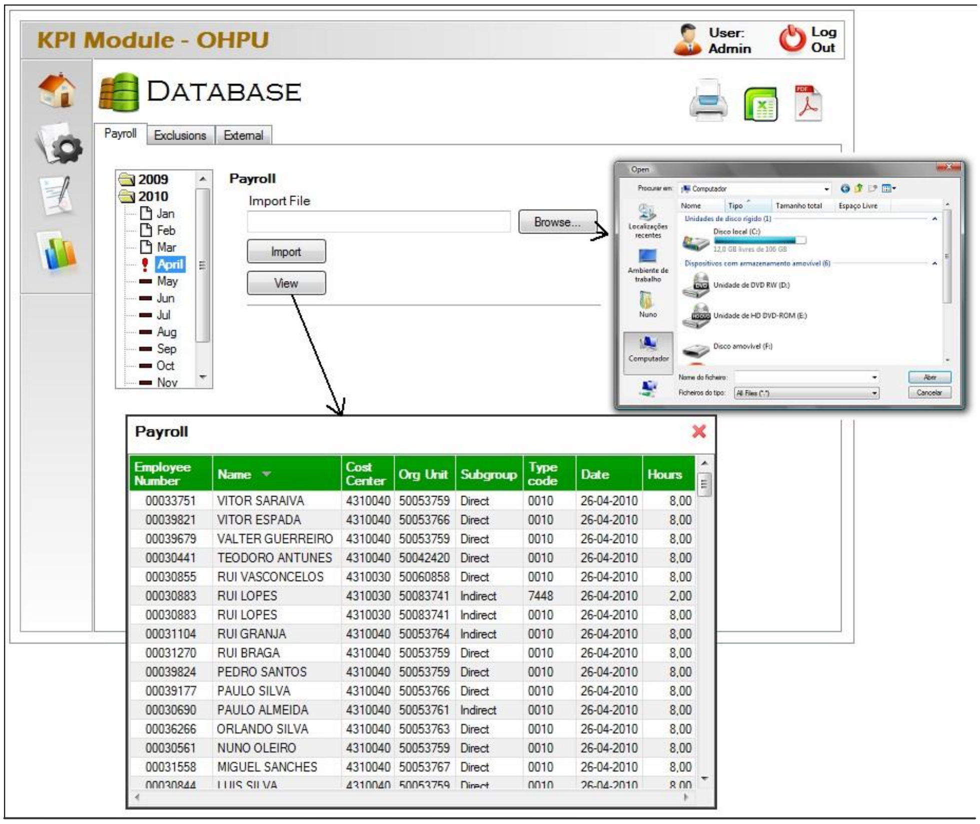

Figure 52 – Database – Payroll Screen

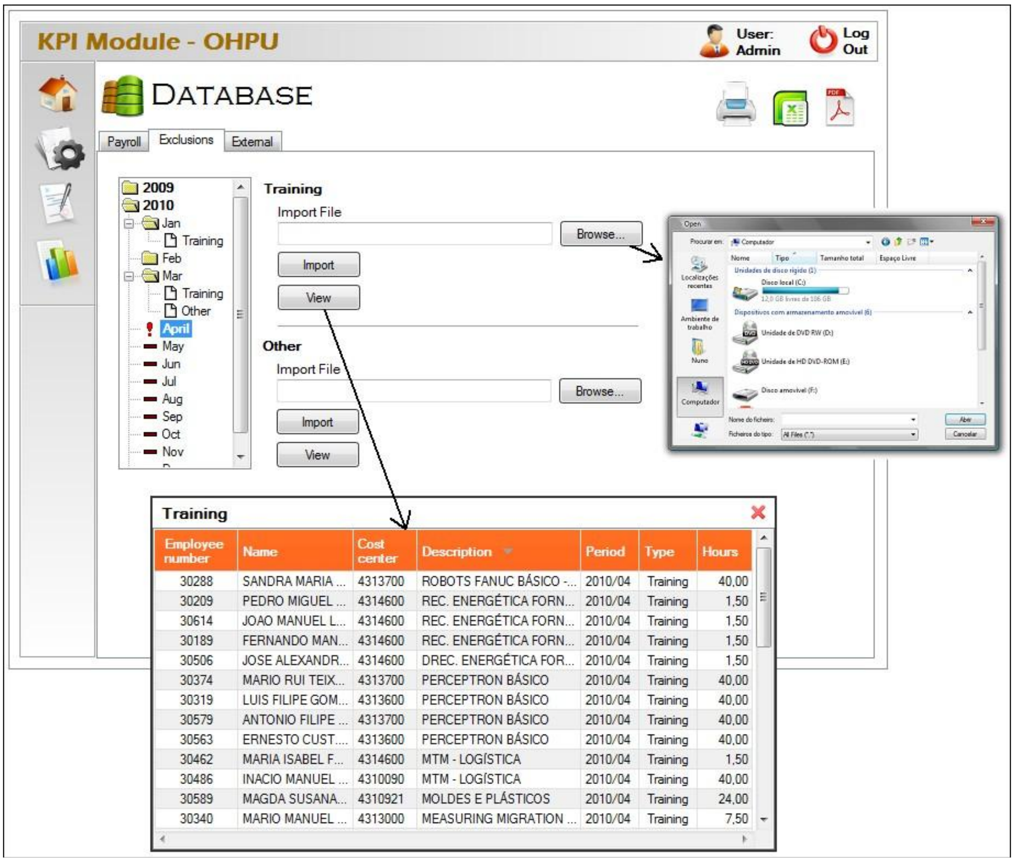

Figure 53 – Database – Exclusions Screen

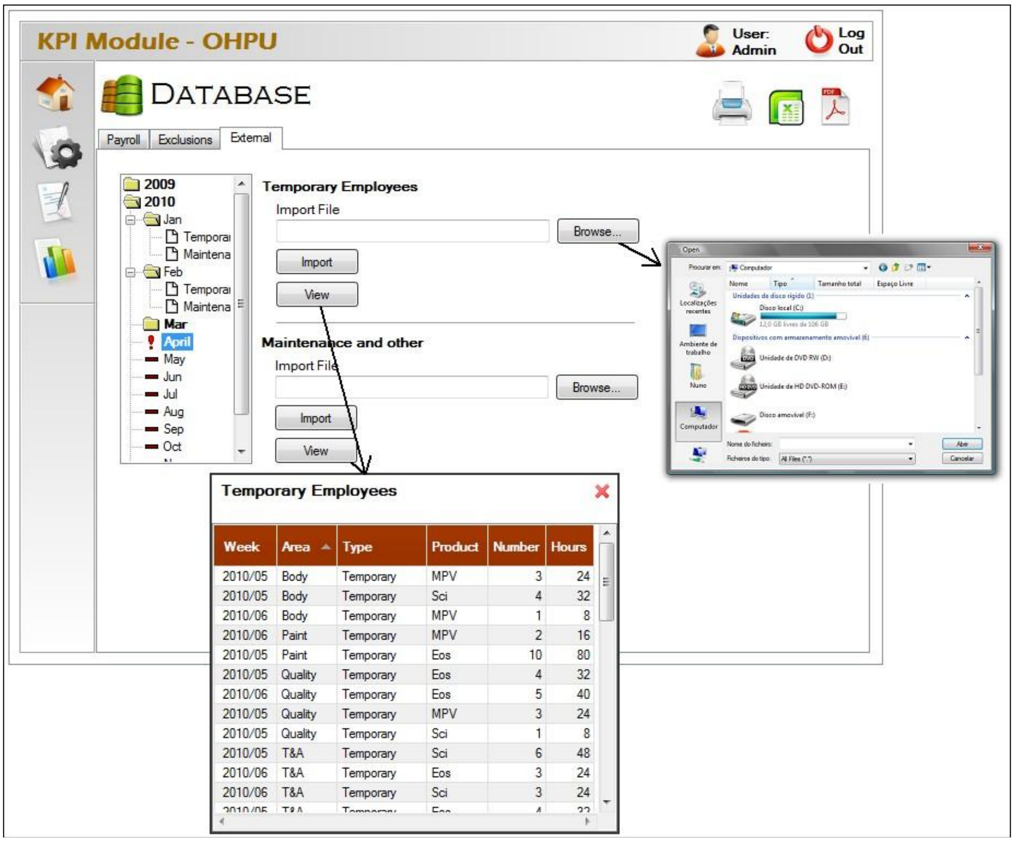

Figure 54 - Database - External Screen

5.2.3. "Edit Data" User Interfaces

In Edit Data page, user is alowed to check the arranged data and edit some values. Different data is organized in different tabs:

- Production Volume
  - Total Volume
  - Product Mix
- Labour Hours
  - Payroll Total
  - Exclusions
  - External

On Total Volume screen is presented the number of produced vehicles on a daily basis for the selected period. The user is allowed to change its values if not the actual ones.

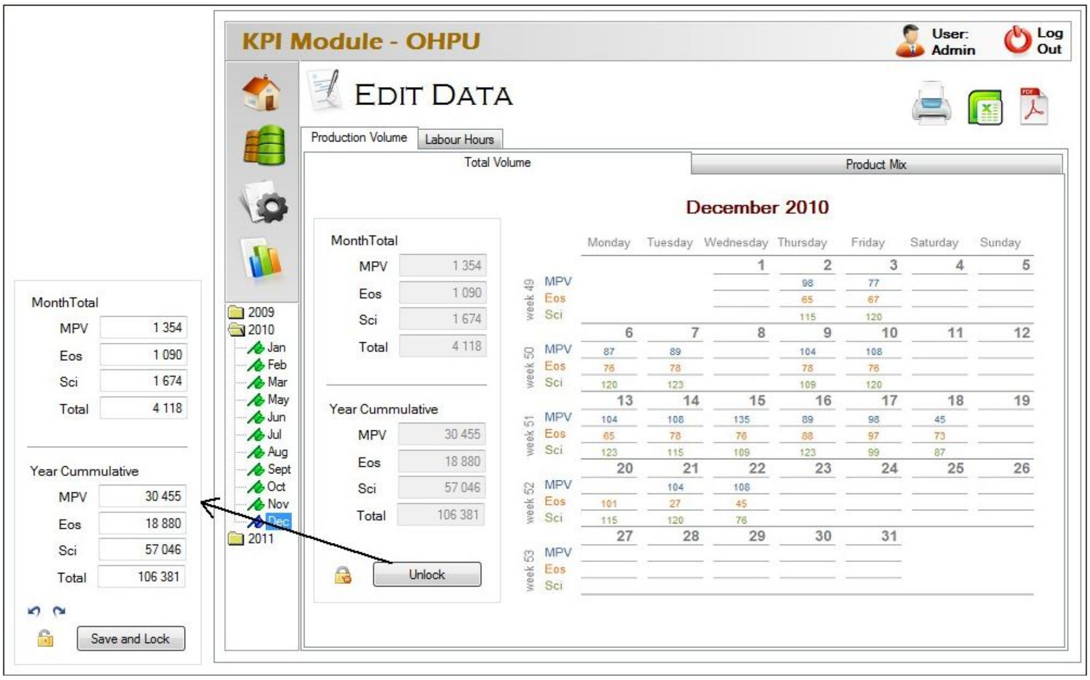

Figure 55 – Edit Data – Total Volume Screen

Edit Volume Mix screen allows editing percentage wheights for each possible combination on multi-product classification. Default values are calculated from the month cummulative production volume.

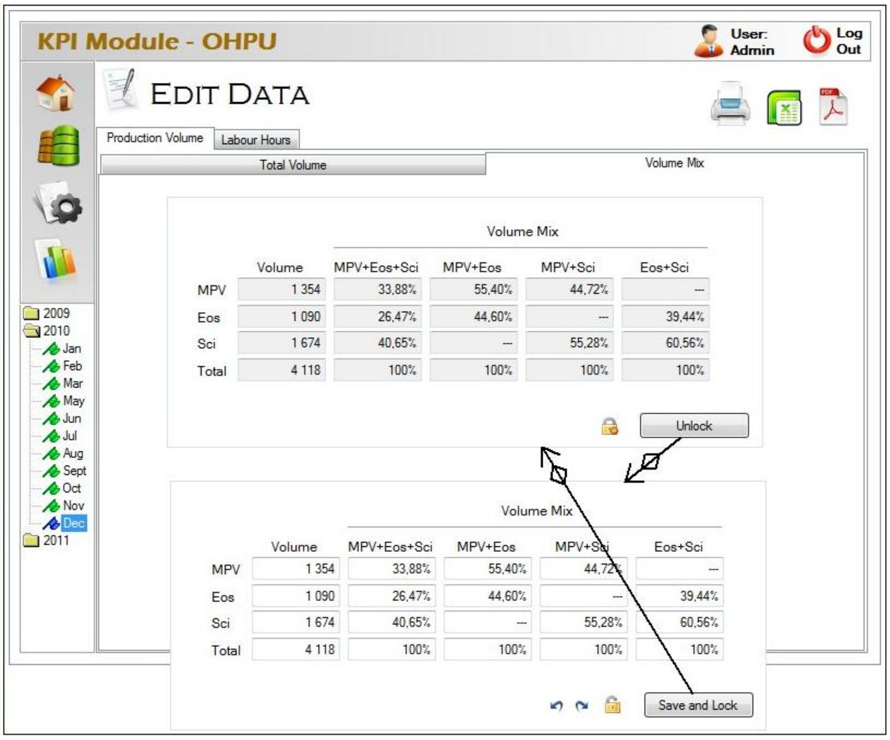

Figure 56 – Edit Data- Volume Mix Screen

Edit Payroll Total Screen allows user to validate the total accounted working hours for each split and for each product. Additionally, user can visualize the totals per employee and edit some abnormal results from the source data.

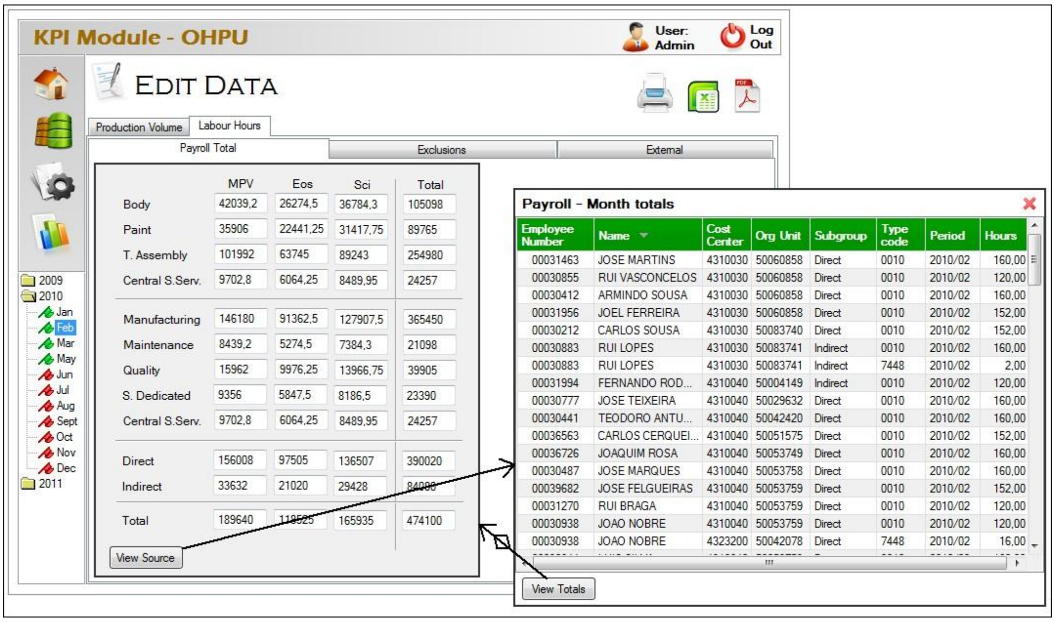

Figure 57 – Edit Data – Payroll Total Screen

Similarly, in Edit Exclusions Screen, user can validate the total exclusions (training or others) for each split and by product as well as edit exceptions individually.

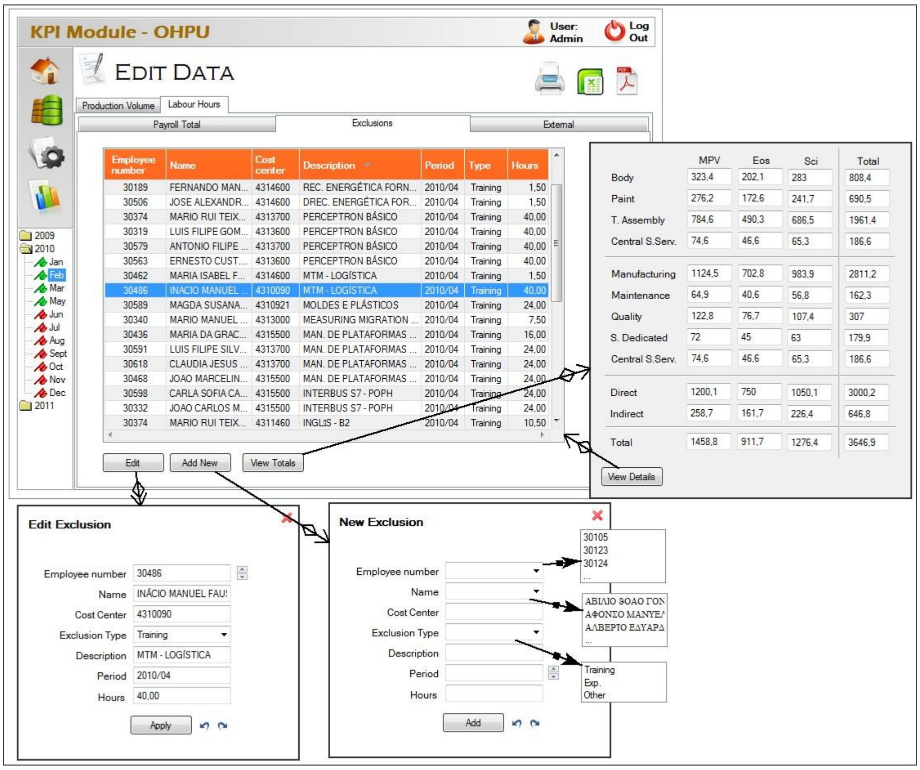

Figure 58 – Edit Data – Exclusions Screen

The same for Edit External except that all external workforce is assigned to a Production Area and a Product.

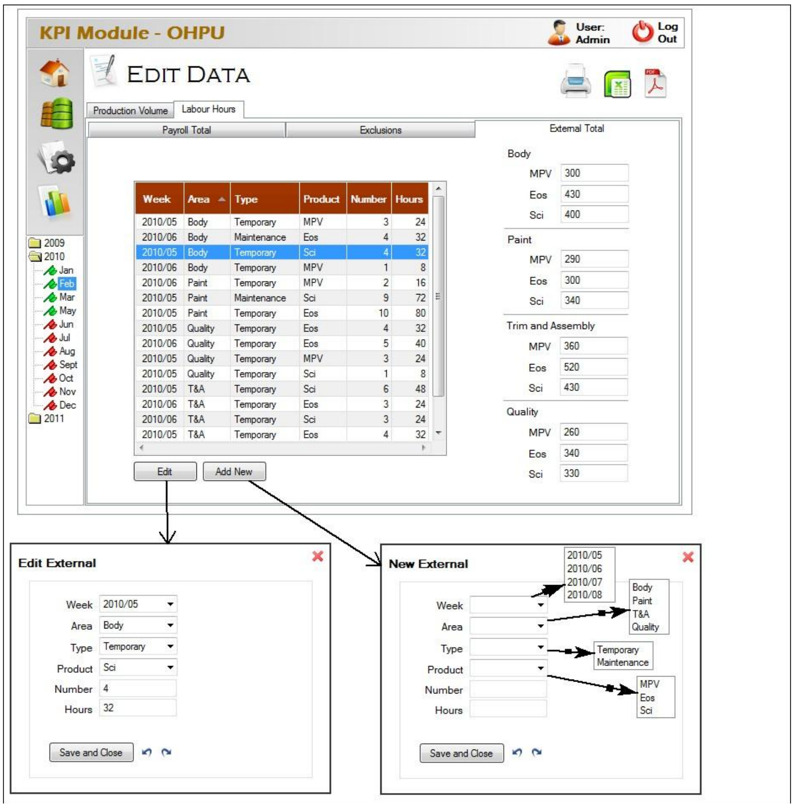

Figure 59 – Edit Data – External Screen

5.2.4. "Settings" User Interfaces

Settings page is supposed to cover all uses cases from Settings Package. In this page are available four options:

- Cost Center Classification
- Individual Exceptions
- Targets
- Area Mix

Cost center Classification makes it possible to assort each organizational unit in terms of the kpi specific splits. Each classification has a time range which and in the same reporting period can be active several different classifications for the same organizational unit.

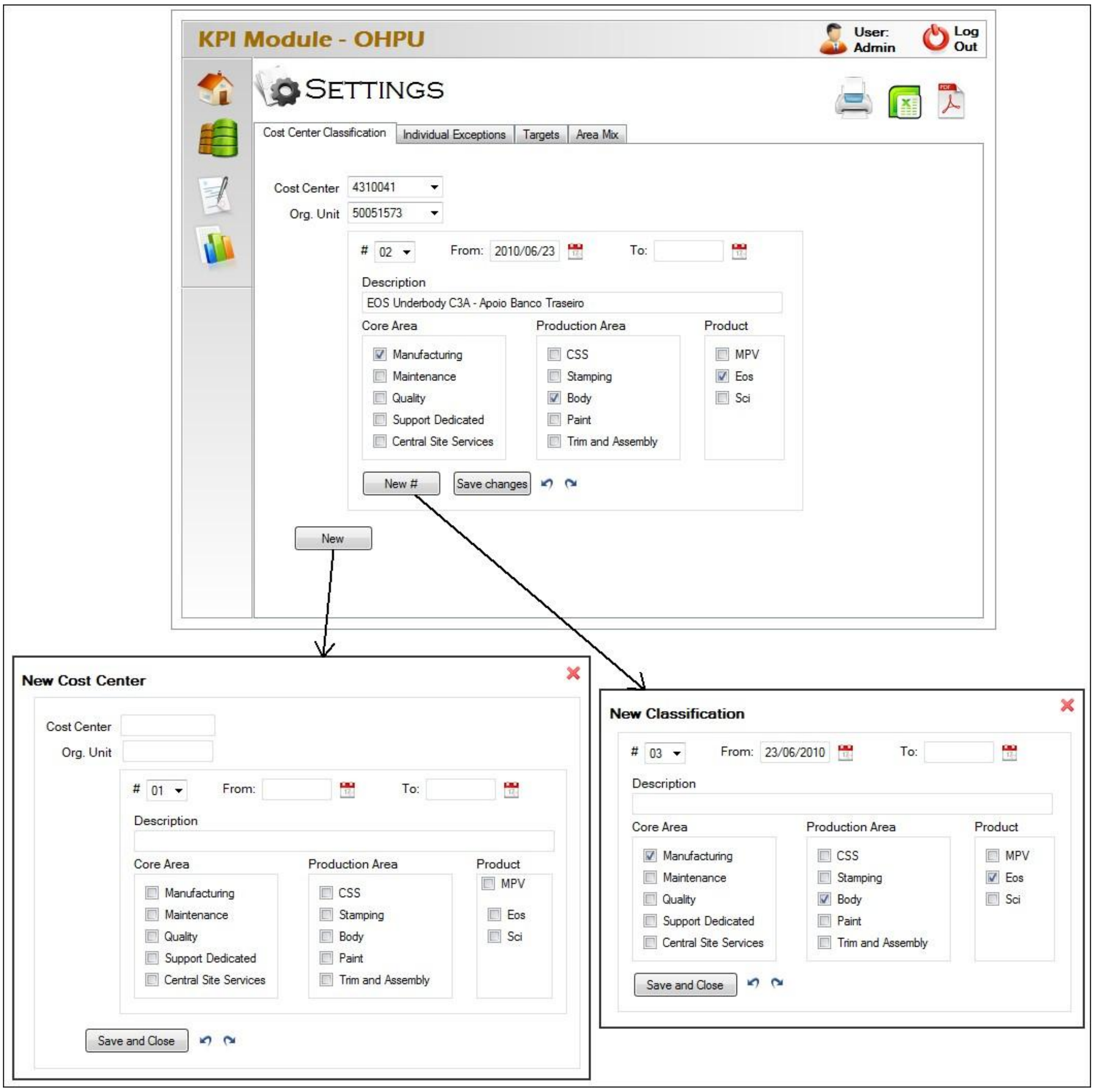

Figure 60 – Settings – Cost Center Screen

Additionally, in Individual Exceptions Screen, employees can be assorted differently from the default classification of the organizational unit he belongs to.

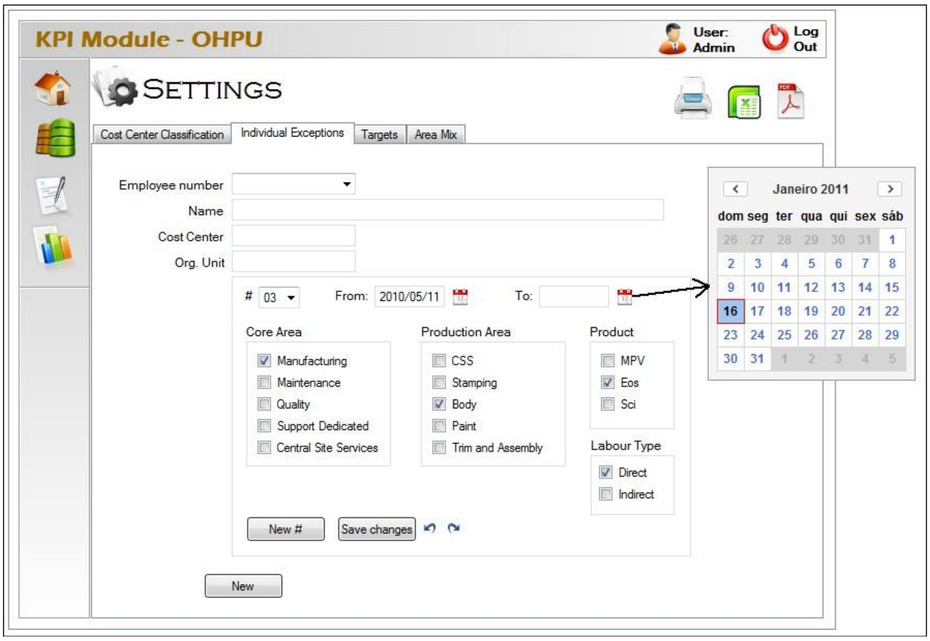

Figure 61 – Settings – Individual Exceptions Screen

Targets must be defined each month for each production area and by product. Its values can though be changed.

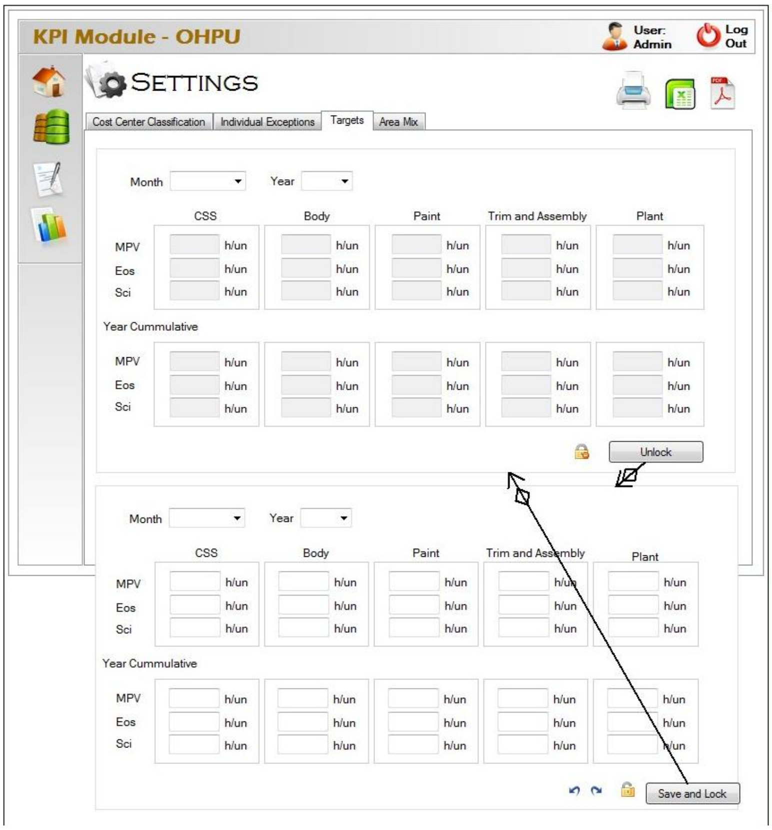

Figure 62 – Settings – Target Screen

The parameter Area Mix is by default calculated by the ratio of employees. However, different weights can be defined for specific time periods.

Figure 63 – Settings – Area Mix Screen

5.2.5.“Dashboard” User Interfaces

In the dashboard page, all authenticated users will be able to see the OHPU evolution in the different Splits:

- Production Areas
- Labour Types
- Core Areas

for each product and plant totals.

Additionally there are the options to select a single cluster of a split and show/hide the respective target values.

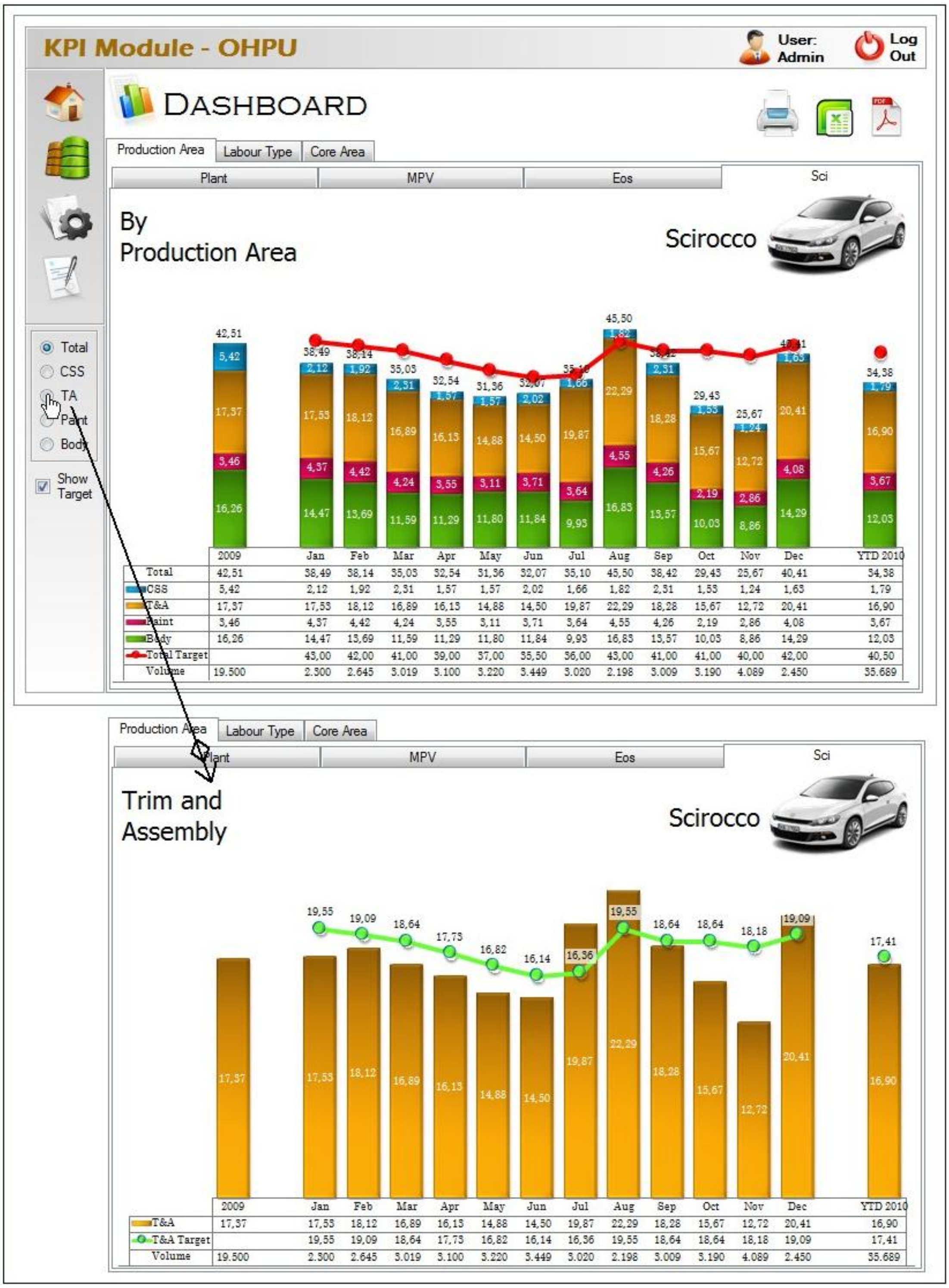

Figure 64 – Dashboard Screen 1

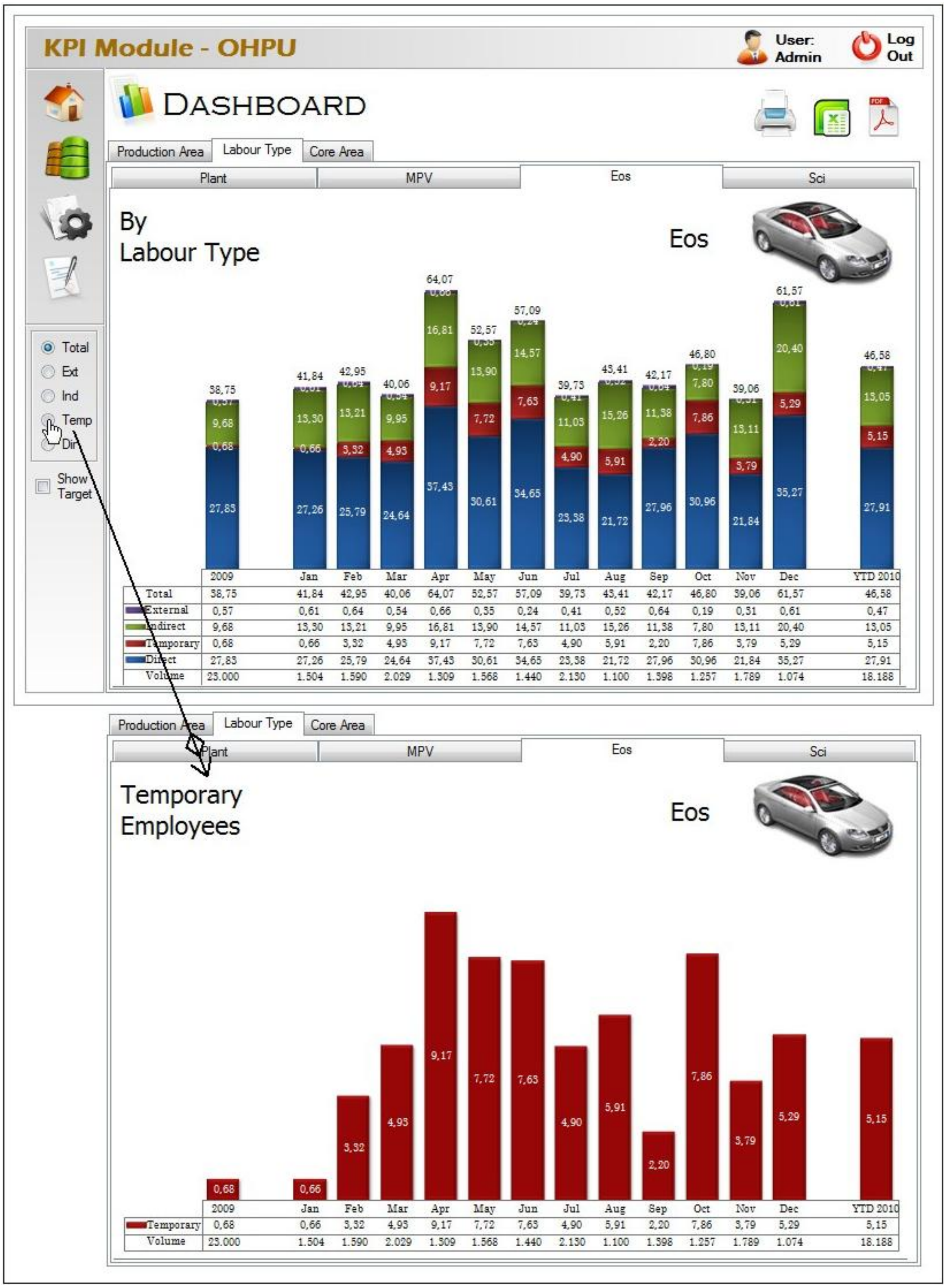

Figure 65 – Dashboard Screen 2

Chapter 6.

Conclusions

In the context of the work in this project, it was explored the main concepts involved in the performance measurement and management, particulary in automotive industry sector. Performance measurement has been defined as the process of quantifying both efficiency and effectiveness of operations and reveals to be the basis for improvement by making aware for possible problems and identifying best practices constantly monitoring performance and performing periodic benchmarking. There are several generic frameworks that can be adopted to manage performance in different perspectives which are composed by a group of performance measures and the respective relations among them. To make possible comparison between similar factories the performance measures and indicators details must be explicitly defined.

In the case of the automobile industry, Harbour Report is an important reference for benchmarking. From the prominent HPV (hours per vehicle) to other less relevant metrics, the assumptions in calculation are imposed and each plant must adapt the internal processes to them which is particulary difficult when, for historical or other reasons, the organization structure is very different from the standards.

Performance measurement and management can be an arduous task if the process to collect data, calculate performance measures and communicate results is not well defined and is not supported by the appropriate tools. The work performed during this project focused in modeling that process for a particular performance indicator and identifying a possible solution for an information system based solution which included requirements specification, and interface with users prototyping.

Along with this project was developed a requirements document based on the IEEE std 830-1998 “Recommended Practices for Software Requirements Specification” which proved to allow more efficiency in communication between all stakeholders establishing a basis for agreement on what functions the system was supposed to perform and aiding in the iterative process of development and enhancement.

For future work, is expected to be done the same effort in different KPIs in order to obtain a platform for a complete performance management system with the most important KPIs and the possible correlations between them as well as the integration in the Virtual Factory Framework and its tools supporting the different phases of the factories life cycles.

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