HOW TO BECOME A WORLD CLASS MANUFACTURING PLANT: OPERATIONAL EFFICIENCY, EMPLOYEE PRODUCTIVITY AND STRONG ORGANIZATIONAL CULTURE IN THE COMPETITIVE AUTOMOTIVE INDUSTRY

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Foreword

The PhD thesis was elaborated throughout my research activity at the Faculty of Management in Production and Transportation from the Politehnica University of Timişoara and my working experience at the Continental Automotive Romania plant in Timişoara between the years 2014-2017.

My research activity and scientific results obtained throughout my PhD studies are due to a great extent to the competence and collaboration with my supervisor during these studies, therefore I would like to thank Prof.univ.ing.dr.ec. Marian MOCAN for his guidance, counseling and valuable advice provided throughout these last 3 years.

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Finally I would like to state a very special thank you to my family who have supported me throughout these years to achieve my goals and follow my professional career and of which I am very proud of. Gracias por todo !

Timişoara, September 2017 ing. Francisco Xavier Pujol

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How To Become A World Class Manufacturing Plant: Operational Efficiency, Employee Productivity And Strong Organizational Culture In The Competitive Automotive Industry

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Cuvinte cheie:
automotive industry, world class manufacturing principle, value chain approach, production flow principles, motivation and mindset in organizational culture, formula of added value, systems thinking

Rezumat:
The goal of the thesis was to design a simple, practical and relevant methodology to help improve and increase the performance of a manufacturing plant from the automotive industry.
The thesis presents a short overview of the automotive industry on several levels in order to provide a complete setting upon the issues and importance of the companies which are part of this complex and very competitive supply chain. Some of the most important performance assets in automotive industry, as well as their strategic and operational implications are presented: the value chain approach for assessing competitive advantage and customer value is particularly highlighted, showing the necessary steps that should be taken in order to obtain highly effective processes and efficient results within the manufacturing activity of the plant.
The thesis then emphasizes the current challenges and assets in automotive industry production that car manufacturers are facing and are trying to adapt to in order to gain a more competitive position on the globalized car market. The challenges of cultural differences and features of the Romanian work culture are equally important to understand a specific working environment.
A consistent part of the main challenges related to managing production in automotive industry is also included and analyzed, as well as many practical issues related to operational effectiveness and to the fact that best results are only possible with the total implication and hard work of the best people to achieve operational performance, productivity and adding value capability.
The thesis then shows hoe measuring the degree of value added activities within a company is a means for continuous improvement towards world class manufacturing (WCM): the effectiveness improvement chart (EIC) as a measuring tool of the performance state of the company, its progress and dynamics and its potential to grow further in the future. The last part of the PhD thesis is dedicated to formalizing the effectiveness of the systems thinking process and emphasizing the Macro approach, to achieve world class manufacturing competitiveness, and the Micro approach, to source organizational culture and operational effectiveness, as they both support the plant’s global approach to become a world class manufacturing plant.

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1. AUTOMOTIVE INDUSTRY – GENERAL INFORMATION

1.1. Automotive industry: worldwide figures and features

Globalization, the rapid technological development and customer pressures on price have brought about one of the fiercest challenges upon the automotive industry within its existence. World car production has almost doubled within the last 20 years, from 50,046,000 vehicles in 1995 to 90,780,583 in 2015. China is since 2009 the largest car manufacturing country with a share of over a quarter in worldwide production figures (24.5 million cars produced in 2015), more than the United States (12.1 million vehicles) and Japan (9.27 million vehicles), the traditional car manufacturing countries, combined. Automotive industry has had similar dynamics in other Asian countries as well, with South Korea (4.55 million vehicles) and India (4.12 million cars) being currently ranked fifth and sixth in worldwide car production. Mexico continues its stable growth to 3.56 million cars produces in 2015, while production figures in Brazil have dropped by nearly one million to only 2,429,463 vehicles (27% decrease). In Europe Germany is the leading car manufacturer (ranked fourth in the world) with a production of over 6 million cars in 2015, while Spain (2.73 million vehicles) and France (1.97 million) complete the top three European carmakers [82].

According to estimates of IHS Automotive and OICA (International Organization of Motor Vehicle Manufacturers) figures 89,677,983 vehicles were sold worldwide in 2015, with the Asia, Oceania and the Middle East accounting for roughly 50%, America with slightly over 28% and Europe with more than 21%. Toyota is the leading car brand for the fourth consecutive year, with sales of over 10.15 million vehicles in 2015, as the Japanese carmaker has retained first position for seven of the last eight years (in 2011 General Motors overtook Toyota, following the Great East Tohoku earthquake and tsunami that struck Japan in March). Volkswagen, meanwhile, despite the Dieselgate scandal in September maintained second position in 2015 car sales with a slight decrease from its 10.1 million vehicles sold in 2014 to just under 10 million (9.93 million in 2015), a decrease of just 2% according to the Volkswagen Group. Sales of Volkswagen models dropped by 4.8% to 5.83 million, whilst Audi (1.8 million) and Skoda (1.05 million) models registered a growth of 3.6% and 1.8%. General Motors sold only 9.8 million vehicles in 2015, just under the 2014 record sales of 9.92 million, figure resulted due to increased demand within the United States (3.08 million vehicles) and growth in China (3.61 million vehicles), but also challenged by developments in South America and Russia.

General Motors is still the leading car brand in North and South America, as well as in China, whilst some of its models have had impressive developments in 2015. Cadillac sales went up by 8 percent globally, Chevrolet sales in North America increased by 6 percent and Opel/Vauxhall achieved its best sales result since 2011, with more than 1.1 million vehicles sold, despite its strategic departure from the Russian market, according to the company’s report.

1.2. Automotive industry in Romania: economic importance and main industry drivers

Automotive industry in Romania is a very important economic growth and welfare driver and has been constantly developing in recent years thanks to foreign investments developing business in the country. In 2014 the turnover of the automotive industry in Romania was of around 18 billion euros and makes up 12% of the country's Gross domestic product (GDP). More than two thirds of this amount is produced by the 600 companies that are part of the automotive industry's supply chain and their 203,000 employees. Car parts and accessories contributed with almost 8 billion euros, tires and plastics with around 3.2 billion and car components with 1.6 billion euros.

Romania has two major car manufacturers, Dacia and Ford, which reached combined sales of 5.3 billion euros (more than a quarter of the whole automotive industry turnover) in 2015 and average 400,000 vehicles in output ever year, most of production being exported, cars (5.3 billion euros worth of exports) and spare parts (mainly ignition wires) with 8.6 billion euros, accounting for 45.8% of Romania's export figures. Recently even Mercedes-Benz have invested 300 million euros in a factory in Sebeş for the production of some of its gearboxes, marking an important contribution to local employment (500 employees) and overall automotive industry development.

Other important names in automotive industry have invested in tire factories in Romania: Michelin in Zalău and Florești, Continental (in Timişoara) and Pirelli in Slatina. The average labor cost is 4.9 euros per hour and average employee costs range around 7,700 euros, whilst in other Central and East European (CEE) Countries, they are significantly higher, as is the case of the Czech Republic with 18,000 euros per average employee [4, 37]. In 2015 both turnover and exports increased by 7 and 10% for car parts, strengthening the position of the automotive industry (around 20 billion euros) in Romania's GDP.

A recent CENIT AG analysis highlighted that investments in automotive parts companies in Romania are higher than in other CEE countries and not only for new assembly lines, both also in modernizing existing ones, which means business is growing as well as the future perspectives. Also, interestingly Romania has started producing more complex parts as well (advanced electronics) in companies such as Bosch, Fujikura and Continental and is slowly introducing automation into factories through industrial robots, even in the Dacia factory in Mioveni, where currently 90% of all operations involve manual labor.

The Renault Group has the Dacia factory in Romania, in Mioveni, the main car manufacturer in the country and one of the most productive car manufacturing plants in the world with yearly outputs of around 340,000 vehicles for a maximum capacity of 350,000 in Romania's historic car manufacturing facility. In 2015 Dacia produced 339,179 cars in Mioveni, 362 more than in 2014, meaning a production site productivity of roughly 97% for the Romanian low-cost brand of the Renault Group. Almost half of the production was dedicated to the Duster model (169,455) in 2015, with the iconic Logan having 20% share of 70,225 (9.3% decrease in sales since 2014), while the newer Sandero model registered an impressive progress to 58,023 units.

Dacia sales have increased by 2% last year to 4.3 billion euros, whilst profit was around 100 million euros (20% increases since 2014), figures generated by its 13,884 employees [8, 10, 21]. Worldwide sales have reached a new record as 550,920 cars were sold, while on the local market Dacia saw its figures rise by 25.5% to 36,946 vehicles, almost a third of national sales in 2015 and more than double that that of Volkswagen (with 9,791 units sold) and Skoda, with 8,849 vehicles sold (the other top three brands) combined. Dacia's best foreign markets in 2015 were France (sales of 100,035 units), Spain (55,168) and Germany (47,453).

After having bought the former Daewoo plant in Craiova in 2008, Ford invested over 1 billion euros and transformed the factory in one of the most modern manufacturing facilities in Europe, enabling the site to produce innovative models such as the Ford B-MAX and the 1.0 liter EcoBoost engine. Plans at the time were to achieve a 300,000 unit production with the support of 7,000 employees, according to the American carmaker. The assembly of the B-MAX model began in 2012 and is produced exclusively in Craiova for the European market, but because of its low sales figures the facility has had to cut down on costs and has reduced employees as well as work schedules for current employees to hinder further laying off staff in addition to production being stopped for a couple of weeks in recent years.

Today just around 50,000 vehicles are manufactured in Craiova and the plant only employs 2,700 people, only a third of the initial employment plans. With a peak production of 68,000 vehicles in 2013 the Ford factory in Craiova suffered from the problems the American car manufacturer had in Europe, where it even closed down one of its factories in Genk, Belgium in late 2014 to optimize its operating costs and more recently shifted the production of its 1.5 liter EcoBoost engine from Craiova to Bridgend, Wales after Ford received a 21 million euros aid from the Welsh government in exchange for maintaining the 2,000 jobs at the British factory. The American carmaker has however announced the introduction of a new Ford model (EcoSport) in production for the end of 2017 in Craiova, but until then the plant will continue to run at very low capacity and both operational and financial activity will be very weak [111].

1.3. Automotive industry in the Western Region of Romania: the challenges of a highly concentrated and competitive automotive region

One of the most important regions in Romania where automotive industry has an extensive activity is the Western Region, especially Timişoara and Arad. 5 out of the top 10 European automotive industry suppliers are based in this region, with Continental Automotive being the top automotive supplier in Romania with sales of over 600 million euros in 2015. Johnson Controls and Delphi Automotive from Sânnicolau Mare and Valeo and TRW Automotive Safety Systems from Timişoara complete the list of top automotive suppliers which are present in the Western region. Other important names in Timişoara are Hella (with around 380 million euros in sales), Mahle, Autoliv and Dräxlmaier Group, whereas the main companies operating in Arad are Takata with sales of over 500 million euros and Leoni Wiring Systems with over 170 million euros. In Timişoara Continental produces interior electronics (Continental Automotive) mainly for Daimler, tires (Continental Automotive Products) for all cars, being one of the most important international tire brands, and timing belts (Contitech) for Mercedes-Benz. Mahle produces engine components mainly for Volkswagen, Audi and General Motors, while the lighting section is divided between Hella for the German market, Valeo for the French market and Elba as the main supplier for the Dacia factory in Mioveni. Autoliv and TRW both produce seatbelts as well as steering wheels and airbags, whilst the main cabling players in Timişoara are Kromberg & Schubert for the German market and Lisa Dräxlmaier for BMW. Other cabling manufacturers are Delphi Packard (from Ineu and Sânnicolau Mare) and Leoni Wiring (from Arad), while Webasto Automotive produces heating and air conditioning systems. Raal West provides filters for Audi, Volkswagen, Daimler, General Motors and Porsche, SEWS-R from Deva makes car cables for French carmaker Renault whereas Dura Automotive assemble window regulators, door safety systems and sensors. Prevent Automotive from Deta manufactures seating covers whilst the Japanese company Vogt Electronic from Jimbolia, where car seats are also made (mainly for the German car brands), produces sensors.

The main advantages of Romania and more specifically the Western region are the fact that costs are lower than in other CCE countries, enabling a best cost advantage for potential investors from the automotive industry. Another advantage is the geographical position on the Western region, very close to the border with Hungary, with a very good infrastructure (access to the motorway, good road links to all major cities within the area, motorway extension and construction of further sections under way, international airport, multimodal hub, etc.) for exporting products towards Western Europe. The area is also developing technology and an important and dynamic business center, with several companies working on technological products and services to face and meet the challenges of tomorrow. This has also had an effect on the population, as the workforce is very well qualified and employees are very skilled to handle complex jobs as well as managerial responsibilities. Human resources are very well qualified also thanks to the academic infrastructure in the region, where there are many university choices as well as a large variety of faculties and specializations which prepare students for most of the jobs and positions at the companies from the automotive industry, with the Politehnica University from Timişoara as the main provider for technical higher education graduates.

Most of the jobs required certain specific skills, which enable providing high value added activities for companies such as IT, research and development, engineering or innovation and enable gaining a competitive advantage over competition. Exporting high added value products is also reflected in the development of the areas where these automotive companies are located and the improvements can be seen in the quality of life of the habitants of the region. There are not only advantages however in this setting, as the fact that non-employment is very low in the region, under 1% (Sânnicolau Mare is particularly well-known for its reputation of being the only city in Romania with 0% unemployment) lead to very tough problems of finding people to work for these companies. Certain companies provide transportation and shuttle services for their employees who come from other cities within the area in a range of 50-100 kilometers or even from abroad (cities close to the borders with Hungary or Serbia) and are faced with the challenge of keeping their best employees and personnel fluctuation low, based on the continuous career opportunity and remuneration competition within automotive industry players from the Western region [99].

1.4. Automotive industry in Romania: growth evolution and perspectives

The main problem for automotive industry development throughout the whole of Romania is however the lack of a quality, fast and reliable motorway network. Competition is harsh between CCE countries (Czech Republic, Slovakia, Poland, Hungary, Romania and Serbia), but all manufacturing plants from Slovakia, Poland and Hungary have one common trait: the interconnectivity of their motorways with the main European corridors. Slovakia, a country with a population of only 5.4 million people, has 3 car manufacturing companies: Volkswagen (including its Audi and Porsche brands), Peugeot Citroën and Kia. Poland has Volkswagen, Fiat and Opel factories, while Audi has its biggest engine factory in Hungary, where Daimler and Suzuki also have plants.

All these major carmakers have also set up an important and extensive network of suppliers that have developed the automotive industry in those countries, attracted high value added jobs and created the basis for further development. Romania has only Renault's low-cost brand Dacia and a Ford plant in Craiova, which is currently producing only 15% of its designed output. The lack of vision for developing infrastructure saw Renault build a new Dacia plant in Morocco instead of extending its activity in Romania and has prompted Mercedes to choose Hungary for its Mercedes-Benz factory in Kecskemét in 2012 where the German manufacturer will build a second car plant which is going to be the largest greenfield investment ever made in Hungary [126].

The Romanian automotive industry has grown throughout the last 10 years from around 3.8 billion euros to almost 20 billion in 2015. Romanian car manufacturer Dacia is the main driver of the industry, with a share of 22%, but the third world automotive supplier, Germany's Continental is close behind after having developed its business in Romania in recent years with its 7 divisions [2]. The growth of the automotive industry has mainly been generated by the companies that are part of the supply chain of several car manufacturers around the world.

In 2005, the year the iconic Dacia Logan model was launched, the suppliers of the automotive industry had a contribution of 2.4 billion euros to the overall turnover which increased to 15 billion in 2015. In 2009 Dacia and Ford, Romania's two car manufacturing companies, had a combined turnover of 2.6 billion euros, which has doubled and has reached 5.3 billion in 2015, with Dacia having more than 80% contribution (4.3 billion euros turnover) and being the country's main exporter.

Ford is currently Romania's number 4 exporter, but after the B-MAX model will be joined by the EcoSport in 2017, the American brand should improve its position. Meanwhile the top 10 automotive industry suppliers with operations in the country have had a contribution of over 10 billion euros in 2015, after a positive dynamic and a healthy 6% increase since 2014. With 2.3 billion euros turnover (14% increase since 2014) and 16,500 employees, German company Continental is Romania's most important automotive supplier in 2015.

The Renault Group is the main employer in the country with around 17,000 employees, more than 80% work at the Dacia plant in Mioveni, the biggest Romanian company for the third consecutive year after turnover and the driver of automotive industry development in the last decade [23].

2. PERFORMANCE ASSETS IN AUTOMOTIVE INDUSTRY: STRATEGIC AND OPERATIONAL IMPLICATIONS

2.1. Competitive advantage

In view of the development of the car as a means of transport, its social role and increased importance of features and new technologies, the automotive industry and more specifically the car manufacturers and their suppliers have had to adapt to dynamic changes to meet technological and customers' requirements. Most often the decision to buy a car is made based on subjective criteria rather than on an objective shortlist of compared features, with the latter being used as a means of validating the choice of the buyer. Nevertheless most of the features and characteristics of cars are the same, which means that car manufacturers have to be competitive and try to gain an advantage over their competitors in order to maintain or improve their sales.

According to the world's leading source of financial content on the web, competitive advantage refers to certain conditions (cost structure, brand reputation, perceived product quality, customer support, etc.) that allow a company to produce goods or services either at a lower price or in a more desirable fashion for potential customers, enabling the company to generate higher sales or superior margins than its competition [55].

"Competitive advantage is a superiority gained by an organization when it can provide the same value as its competitors but at a lower price, or can charge higher prices by providing greater value through differentiation" [21]. Michael Porter [90] identified the two basic types of competitive advantage: cost advantage and differentiation advantage.

Competitive advantage is also in direct linkage to the company's main area of expertise, as it results from matching its core competencies to the opportunities which occur at a certain moment of time in the marketplace. Competitiveness also mainly depends on the capacity of the company to innovate and upgrade within its industry. Pressure and challenge from its competitors urges the company to seek improvement, enabling those who succeed in this approach to gain an advantage through continuous adaptation to the demanding market [91]. Japanese companies gained their initial advantage in the electronics industry (which today is more and more present in the automotive industry as well), by emphasizing smaller and more compact, lower capacity models. The importance of these features was not acknowledged at the beginning by their international competitors who perceived the changes as useless (less important, less attractive and also less profitable). Certain innovations can yield competitive advantage on international level, whilst also anticipating specific domestic needs. Swedish company Volvo had succeeded by anticipating the market opportunity for product safety and is one of the forerunners of the increased safety features fitted on to modern cars.

A company is therefore able to deliver a competitive advantage when it can either provide the same benefits as competitors, but at a lower cost (competitive advantage through cost advantage), or deliver benefits to its customers that exceed those of other companies or their competing products (competitive advantage through differentiation advantage). Competitive advantage thus becomes a source of wellbeing for both the company and its customers, enabling the creation of products and/or services with superior value for its customers as well as increased profits for the business entity as shown in figure 2.1 [96].

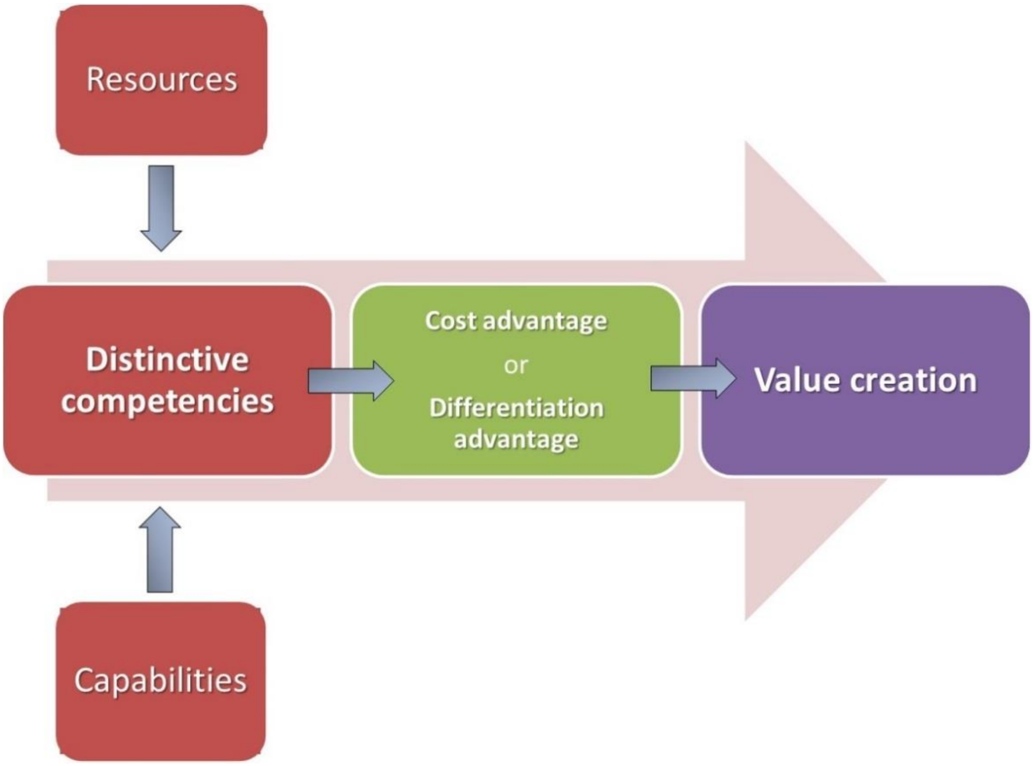

Figure 2.1. A model of competitive advantage (adapted after [96])

Competitive advantage is only an intermediate stage of the process, as the ultimate goal is to create and provide value to the customer [93]. The two possible sources of competitive advantage are seen as positional advantages, as they refer to a company's position within overall competition on a specific market and therefore a result of a previous process. This result is generated by using resources and capabilities downstream in the process (resource-based view) which are at the basis of value creation and have a decisive role in the success of the whole process.

According to the resource-based view, competitive advantage can only be achieved if the company has superior resources and capabilities than those of its competitors. This superiority enables a medium or long-term asset for the company and hinders the competitors to reproduce or replicate it, thus maintaining the advantage. The more sustainable the competitive advantage is, the more difficult it is for competitors to neutralize it.

The specific resources and capabilities of a certain company form its distinctive competencies. These specific characteristics enable the firm to have its own approach towards important issues such as quality policy, innovation, efficiency, or customer responsiveness, all of which can be leveraged to create a cost advantage or a differentiation advantage, according to the company's strategy and policy [80].

The American automotive and energy storage company Tesla gained widespread attention after producing the first fully electric sports car (Tesla Roadster), followed by the Model S luxury sedan which was sold in over 100,000 units by end of 2015 and Model X crossover. Tesla cars can already range 300-500 kilometers depending on driving style on the motorway and the company is working on extending the autonomy towards 1000 km, which will make it have an autonomy close to that of a conventional Diesel engine. Tesla has thus gained a competitive advantage, but it is not the only company who seeks to differentiate itself, as keeping in line with technological development is vital in the automotive industry for remaining on the market. Projects as are electric cars, autonomous drive (inspired by the internet of things), car to car communication (with spider web type interconnectivity), the Uber shared taxi application for smartphone users (very open, fast, flexible and dynamic use of personal cars which helps reduce CO2 emissions in cities) or innovative car displays are already under way and will soon become reality after their implementation and will probably be fitted as standard on future cars. These technological changes will further challenge car manufacturers and their suppliers as they need to be ready for the future innovations that will shape the automotive industry.

A company will therefore only achieve a competitive advantage if it manages to perform one or more value creating activities in a way that creates more overall value for its customers than that generated by the competition.

2.2. The value chain

According to business dictionary (an easy-to-use, concise, clear and comprehensive business glossary with over 30,000 definitions that span across critical business-related topics including entrepreneurship, management, small business, economics, human resources, recruiting and corporate strategy) a value chain is composed of "interlinked value-adding activities that convert inputs into outputs which, in turn, add to the bottom line and help create competitive advantage" [22].

Value chain refers to a company's internal activities which take place whilst transforming inputs into outputs. The process is often assessed and called value chain analysis (VCA) as primary and support activities that add value to the final product are highlighted and then analyzed in order to reduce costs or increase differentiation [113]. A certain good or service is considered to have value if the customer is willing to pay for it. A value chain represents the entire series of activities that create and build value at every step within the processes of a given company. The value the company delivers to its customers is thus the sum total of the value built up all throughout its internal processes [117].

In short, a value chain is a set of activities a company performs in order to deliver a valuable product or service for the market. According to Porter a value chain typically consists of (1) inbound distribution or logistics, (2) manufacturing operations, (3) outbound distribution or logistics, (4) marketing and selling, and (5) after-sales service (primary activities). These activities are supported by (6) purchasing or procurement, (7) research and development, (8) human resource development, (9) and corporate infrastructure (support activities) as is shown in figure 2.2.

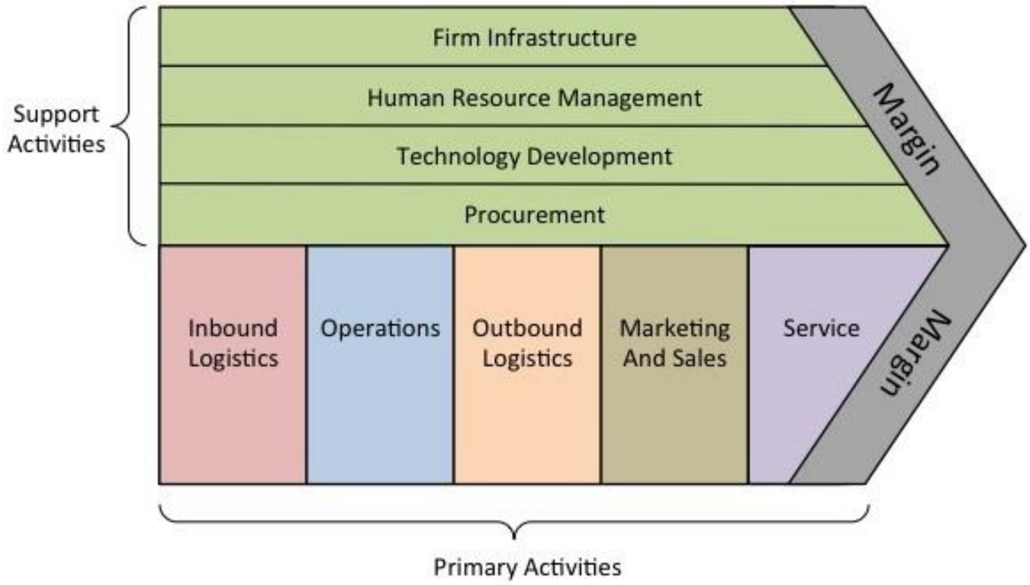

Figure 2.2. Porter's value chain [90]

Porter's value chain concept is in line with the lean production philosophy of Toyota, as its main goal is to separate the useful activities within a company (which enables it to gain competitive advantage) from the wasteful activities (which hinder the possibility of a company to gain competitive advantage). The focus on activities and processes that create value enable the firm to achieve sustainable benefits (lower manufacturing costs, higher pricing ability, improved brand image, faster and more adapted response capability to possible threats or occurring opportunities, etc.).

Value chain analysis is used as a strategic tool to measure the importance of the customer's perceived value, especially within industries with dynamic changes or harsh competition as is the automotive industry. This allows companies to determine which of their internal activities and value-creating processes can enable strategic advantages (that are to be upheld) and which of these arouse disadvantages (that are to be eliminated). Value chain analysis thus becomes an essential means for assessing competitive advantage [53].

The concepts, tools and techniques of the VCA especially apply to all organizations that are part of the complex and highly competitive automotive industry supply chain and produce and sell an automotive product on a continuously changing and worldwide dynamic market. The correct applying of the core principles will enable organizations to link the value chain analysis to their organizational goals, strategies and objectives (strategic management policy) and understand the value chain approach for assessing competitive advantage (strategic management results).

The idea of a value chain comes from business management and was first launched and popularized by Michael Porter [90] who argued that customer value accumulates along a chain of activities that lead to an end product or service. The value chain principle is based on the process view of organizations as is provided by the Theory of Systems. This theory suggests viewing a manufacturing company as a system, made up of several other subsystems, each having to be provided with certain inputs that will flow through the transformation processes and generate specific outputs. The entire process (input, transformation and output) involves the acquisition and consumption of several resources as are materials, equipment, labor, buildings, land, money, administration and management. The way in which the company's value chain activities are designed and carried out determines the level of costs and affects profits [34].

Porter describes the value chain as the internal processes or activities a company perform "to design, produce, market, deliver and support its product." He further states that "a firm's value chain and the way it performs individual activities are a reflection of its history, its strategy, its approach to implementing its strategy, and the underlying economics of the activities themselves" [90].

On the other hand, Porter deals with the competitive advantage in the context of competitive strategy. He sees the competitive strategy as the determination of a firm's position in a competitive environment. The purpose of competitive strategy is to gain insights about the market through understanding and predicting the economic factors, especially other competitors' behavior. The competitive strategy causes a firm to produce a product that is not producible by the competitors.

Companies need to understand every single part of this value system in order to achieve and sustain a competitive advantage, and to support that advantage with information technologies. Porter viewed the value chain in light of primary and support activities. Primary activities are directly involved in transforming inputs into outputs and in delivery and after-sales support, being part of the operations and activities of any manufacturing organization within the automotive industry. The primary activities are inbound logistics, manufacturing operations, outbound logistics, marketing and sales, and after-sales service.

Inbound Logistics is the process of receiving raw materials that will be transformed into finished goods at the end of the transformation processes of the company. The main activities associated with inbound logistics are material handling, warehousing and inventory control of input materials, which cover a wide area of small operative tasks of arranging the inbound movement of materials, parts, and/or finished inventory from suppliers to manufacturing or assembly plants, warehouses, or retail stores. Quality of materials chosen, transportation and communications are equally important.

Operations represent the value-creating activities the part of the manufacturing plant concerned with managing the processes that transform the specifically needed inputs (in the forms of raw materials, labor and energy) into the desired outputs (in the form of goods and/or services). The degree of reliability of this activity mainly depends upon the machine tools, preventive maintenance and building design and operation of the linking processes throughout each step of the manufacturing operations. This is the place where added value is created and thus productivity at this stage needs to be maximized.

Outbound Logistics starts with order processing and mainly refers to the distribution of the goods towards the designated customers. The process is also in charge with warehousing, storage and movement of the final product and the related information flows from the end of the production line to the customers (order fulfillment). Packaging, transportation and traceability are important factors within this activity.

Marketing and Sales handles the commercial part of the company's activity and is in charge of selling the product and/or services. Other important responsibilities include the process of advertising, communication, pricing and channel management of the specific goods in order to target the right customers and to achieve the company's objectives. The activity also deals with creating, delivering and exchanging offerings that have value for customers, partners or even society in general.

Service is an important part of the process with the role to maintain and enhance the product's value through customer support and repair services and includes all the activities required to keep the product/service working effectively for the buyer after it is sold and delivered. Communications and information systems are important factors within this activity [96].
Primary activities are backed by the support activities: purchasing or procurement, technology development, human resource management and company infrastructure. All the support activities are handled by the organization's staff functions.

Procurement is the function of purchasing raw materials, supplies, as well as other consumable items and inputs (goods, services or works) as well as assets from an outside external source which will be used in the value-creating activities.

Technology development essentially refers to know-how, procedures and technological inputs needed in every value chain activity as it pertains to equipment, hardware, software, procedures and technical knowledge brought to bear in the process of transforming inputs into outputs by the company. It also includes research and development, process automation and other technology development used to support the different value-chain activities.

Human resource management handles all matters concerned with current or future employees and consists of all activities involved in recruiting, hiring, training, developing, compensating and (if necessary) dismissing or laying off personnel. Human resource management is also in charge of selection, promotion and placement, as well as appraisal, rewards, management development and labor/employee relations as to assure a very good organizational culture and a pleasant and motivational workplace for all the company's employees.

Company infrastructure consists of activities such as strategic management, planning, finance, accounting, legal, finance, control, government affairs, public relations, quality assurance and general management [47].

Having a correct overview on the company activity and processes and knowing where value is added can lead to important productivity gains throughout the entire manufacturing plant and can increase overall efficiency and provide the needed support for all its departments. The goal of this entire value chain approach is to provide value to the customer through quality products that are also competitive on the market, which can be achieved if the company is functioning properly in its whole. All companies have several specific departments which interact and work together throughout the manufacturing process according to certain linkages between them. A linkage exists if the performance or cost of one activity is influenced or dependent upon that of another bringing about the challenge of rendering the entire process as efficient as possible. Competitive advantage as well as a reliable value chain can only be obtained by a good coordination of linked activities in order to maximize the total value added at the end of all processes [103].

The complete overview of a company's value chain may also provide very useful in deciding whether certain activities should or not be outsourced. The consequence of a thorough understanding of the linkages between value adding activities is the ability to make better decision regarding a make-or-buy strategy which ultimately leads to cost or differentiation advantages.

The company's value chain is also linked to its suppliers and buyers and is usually integrated within a more complex supply chain, therefore the effectiveness of upstream and downstream value chains is equally important. The complex automotive industry supply chains and their globalized links result is a larger stream of activities which are integrated into the production and corporate strategy (as well as the specific policy) of the leading link (usually the car manufacturer) as is often referred to as the value system. The development of a competitive advantage depends not only on the individual value chain of the leading company, but is also affected by the value system of which it is a part and therefore an integrated customer value policy throughout the main links of the supply chain will provide a more effective and sustainable long-term asset for both the company and its business partners.

This view is also promoted by Shank and Govindarajan, who provide a wider description of the value chain than Porter and consider the company as part of the overall chain of value-creating process ("The value chain for any firm is the value-creating activities all the way from basic raw material sources from component suppliers through to the ultimate end-use product delivered into the final consumer's hands" [108]).

Similar to the theory of the optimization of the whole rather than of its intermediate individual processes, the value chain's role is to provide customer value at the end of the process, therefore the end result is much more relevant than one individual process within the company. This is similar when expanding the value chain to the level of a system, which ranges outside the company's boundaries and reaches within its supply chain. Suppliers of raw materials and components and their buyers need to have the same views in order to be competitive as upstream partners for plants, who compete with other internationally based factories and also face the value chain challenge up to the disposal and materials recycling phase to achieve a strategic advantage over their competitors.

The integrated value chain within a complex industry such as the automotive industry is presented in figure 2.3.

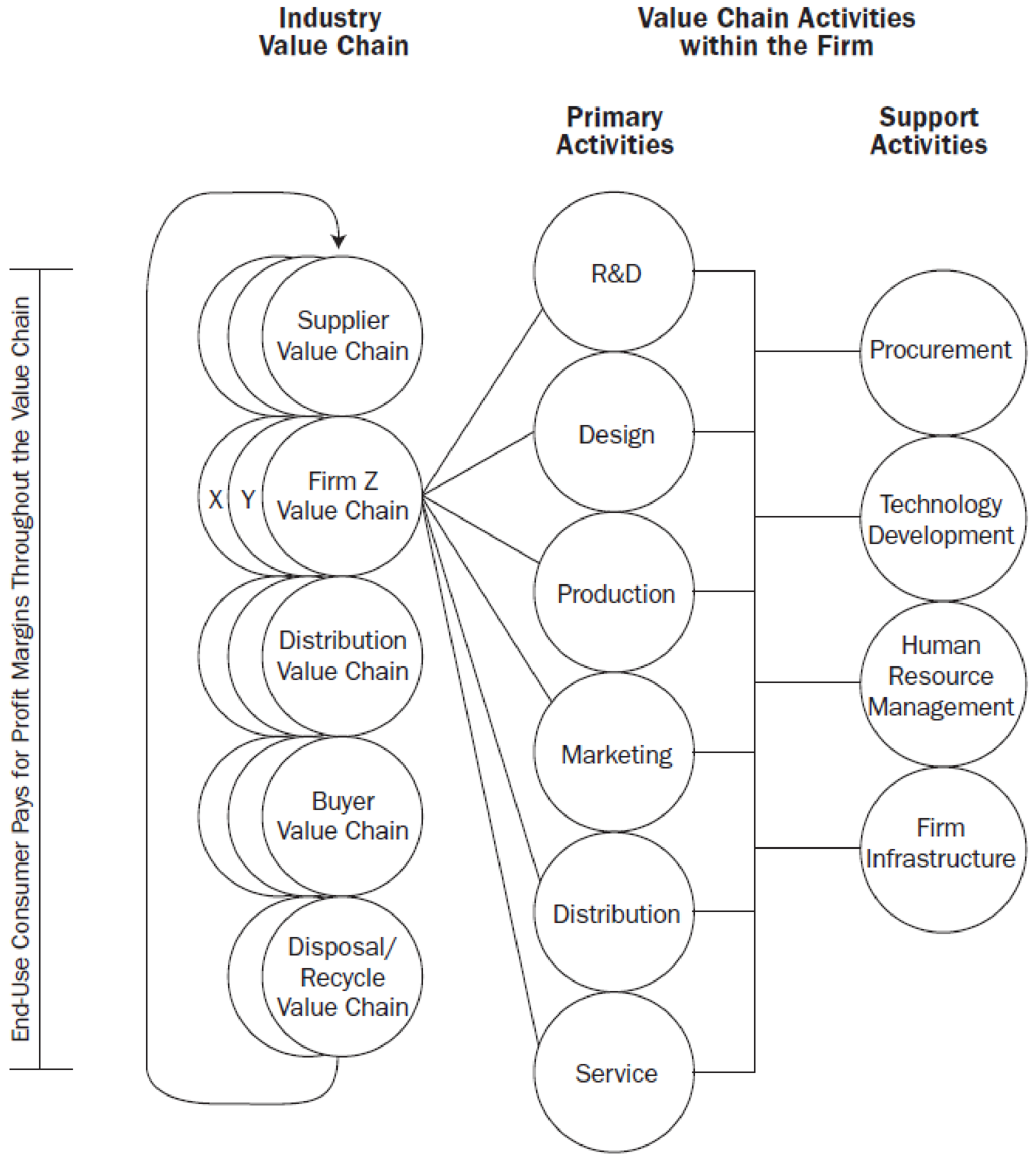

Figure 2.3. Integrated value chain within a complex industry (adapted after [53])

2.3. The value chain approach for assessing competitive advantage and customer value

Competitiveness in automotive industry is very high and the difference between companies that succeed and those who struggle is often made by the ability to provider customer value as well as to have an efficient internal organization, which are usually interconnected. The focus is on the one hand on the product the customer wants and for which he is willing to pay (customer value) and on the other hand on managing to be competitive on the market by being able to cope with competition (competitive advantage).

The effectiveness of the functioning of the company is mainly dependent on its ability to offer value to its customers and the incurring cost of creating that customer value, as a correct balancing of these efforts is often the key to achieving a sustainable business and a competitive automotive supply chain link.

Competitive advantage of a company's products and/or services can be achieved via two possible strategies: the first strategy relates to the customer's perception over the specific product. Thus, if the product or service is considered better than others existent on the market thanks to superior attributes or features, then the customer is more likely to pay a higher price (sometimes even a premium price) relative to the price they will pay for other competing products and/or services (differentiation advantage).

The second strategy is the more likely one and is related to the cost/price of the provided product and/or service, as it becomes interesting for the customer when the amount he has to pay for it is below that of the average competitor (low-cost advantage) [100].

Differentiation Advantage

A differentiation advantage occurs when after considering all relevant attributes to the buying decision a customer perceives the product of one specific company as being the best or of higher quality and decides to buy it rather than a comparable one, because of certain features which are considered superior.

The competitive advantage of the product may be one of several: more reliable product, timely delivery, wider range of products, brand confidence and awareness, innovative technology, other customer-relevant factors. A differentiation advantage enables the possibility for the company to increase the product's price and to obtain more benefits or to maintain price and increase market share of the same product.

Best Cost Advantage

A cost advantage occurs when a company can manage to provide a similar product with that of the competition, but at a lower selling price as well as with inferior incurring production costs, making its product have a stronger position than the average product on the market.

A cost advantage enables the possibility for the company to maintain prices at the same level in order to gain market share and continue to keep its current profitability or to steadily raise the price until it matches that of competing products and increase its profit margin.

This is possible to achieve in Romania considering the implementation of 3 important points:

1. applying the total value chain concept: enabling an easy organization with a clear focus only on creating value and avoiding waste
2. improving the material flow: supplying the machines in order to perform constantly and achieve a continuous flow without interruptions
3. inventory reduction: reduce unnecessary inventory that only consumes space, financial means and handling time without it being absolutely necessary within the proper functioning of the production or flow process

The focus needs to be on everything (individual processes as well as the global functioning of the factory) in order to improve the total value chain concept.

Competitive advantage can be achieved in Romania, especially through lower cost advantage due to several facilitating conditions present within the target area: access to low-cost raw materials, high qualified human resources, innovative process technology and low-cost production.

The relationship between low-cost advantage and differentiation advantage is shown in figure 2.4.

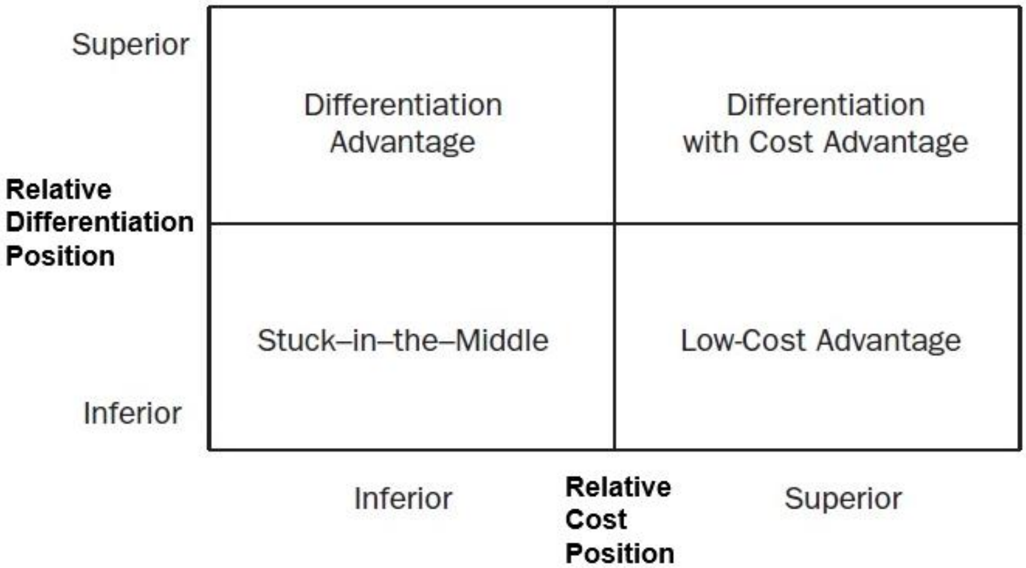

Figure 2.4. Competitive advantage positioning [108]

Competitive advantage can be achieved either through a superior relative cost position or through a superior relative differentiation position. A competitive advantage through lower cost offers an equivalent product with comparable or matching customer value for a lower price than those of competitors. A competitive advantage through differentiation offers improved or distinct features which customers perceive as being of higher value than a similar product from the competition for a comparable or matching price [51].

Ideally companies will be in the best competitive position if they can achieve both a cost and differentiation advantage, which implies a very good value chain and should avoid the "Stuck-in-the-Middle" situation where they do not possess neither a cost nor a differentiation advantage as this would lead to important competitive problems in the short and medium-term.

The harsh competition as well as the continuous innovative and technological challenges within the automotive industry has made most of the supply chain links mainly focus on supplying the requested parts for their industry partners. These companies perceive their mission as being that of creating the products or services needed by their business partners and only acknowledge the end result of their process. These companies however neglect the importance of the activities which contribute to the end result and their effectiveness and do not support the importance of the internal value chain. This vision affects their long-term competitiveness and adds additional setbacks on their medium-term ability to be flexible and adaptable to inherent technological and brand specific changes or upgrades. Companies that are however aware of the strategic importance of their internal processes and activities thrive by concentrating on them and enable both their customers and themselves to receive maximum benefits through the value chain.

The companies that manage to thrive in the automotive sector have their own organizational culture and know how to use the value chain approach to highlight their products and/or services from competition and enable the asset of competitive advantage. The success of the overall process depends upon the quality of the individual analyses performed within the value chain approach in order to point out the different sources of improvement for the proper functioning of the company.

The value chain approach is one of the most important parts of strategic planning. Value chain analysis is, similarly to strategic planning, a continuous process of founding strategic decisions after gathering, evaluating and communicating information (strategic thinking) within targeted areas with the goal to gain competitive advantage [52]. Assessing competitive advantage within the value chain approach is done with the help of internal cost analysis, internal differentiation analysis and vertical linkage analysis.

2.3.1. Internal Cost Analysis

= The goal of the internal cost analysis is assess all internal processes within the company and identify the processes which create customer value. This enables the manufacturing facility to understand the cost of their internal processes and activities and source relevant drivers of profitability as well as relative cost positions

According to Management Accounting the 5 main steps of internal cost analysis are [72]:

1) identify the plant's value-creating processes
2) determine the portion of the total cost of the product attributable to each value creating process
3) identify the cost drivers for each process
4) identify the links between processes
5) evaluate the opportunities for achieving relative cost advantage

1) identify the plant's value-creating processes
= identifying the value-creating processes implies the manufacturing unity to adopt a process perspective. The process perspective means having a horizontal view of the organization which ranges throughout the entire manufacturing process, from introducing the required inputs up to gathering the desired outputs, which are needed further downstream in the supply chain. Focusing on the process means shifting emphasis away from what actual work is done to how that work is done within all stages of manufacturing, as having effective processes is the primary source of competitive advantage. The Pareto principle (80% of sales are brought by 20% of customers) applies here as well, therefore by redesigning processes, using benchmarking and applying best practices a company can achieve continuous improvement, which enables waste elimination, cost savings and quality reliability which bring about competitive advantage and customer satisfaction.

2) determine the portion of the total cost of the product attributable to each value creating process
= after the value-creating processes are identified, they need to be assigned their individual costs, which allows the company to trace areas where improvements can have an important impact on overall added value and quantify them for a better overview. A classic and detailed accounting approach is not necessary as relevant rough estimates should provide a more than enough overview to have a proper assessment of the incurred costs for each process. After summing up the entire cost at the end of the manufacturing process, the main improvement areas will arise according to their share in the global cost of the whole manufacturing process. The fact that in practice work cells rarely are able to operate at full capacity is also to be taken into account when estimating the cost for certain operational activities within manufacturing. This arises another important and sensible aspect related to work processes (the use of human workforce or automation to perform certain tasks), which sometimes gets neglected because of a narrow short-term vision of immediate profits, hindering business development and further customer value creation.

3) identify the cost drivers for each process
= one of the most sensible parts of the value chain analysis is to correctly identify the main sources of cost for each individual process as well as for the whole chain of interlinked processes. This enables managers to set priorities and better assess the relevance of improvement ideas for an effective cost advantage within the manufacturing process of the company. Besides the efficient use of material and physical resources, the motivation and implication of human resources is equally important for the effectiveness of the value chain approach. Workforce involvement, active participation and empowerment are important motivational sources in building a strong organizational culture focused towards providing high customer value.

4) identify the links between processes
= after conducting the analysis upon each individual process and its contribution to the value chain, one of the most important things which assure a proper functioning is the way these activities are linked with one another and build a continuous flow within the manufacturing process. The effectiveness of these dependent activities and their linkages is given by the number of bottlenecks and incurring problem

areas which need to be eliminated as soon as they are identified in order to strengthen the value adding processes and their final output. Sometimes improving an individual process without assessing the impact upon the rest of the interlinked processes may not necessarily lead to an improved overall process, thus the importance of always optimizing the whole is essential for an effective value chain approach. One important indicator of the functional effectiveness is the number of transfers between processes: fewer transfers enable time and cost reduction and have a significant impact upon keeping individual and overall costs low and customer value high.

5) evaluate the opportunities for achieving relative cost advantage

= reducing costs within a value chain approach does not enable superficial strategies like reducing costs per department by random percentages given from top management, as the end output and customer value achieved is more important than the appearance of a better functioning individual unity of the business entity. The goal is to provide value to the customer and that can only be done by meeting demands and expectations which occur at a certain moment. Isolated cost reduction does not enable companies to suddenly become more competitive, but an effective customer-focused approach does and lays the foundation for a long-term and sustainable development of its business. Renault enabled a strategic partnership with its suppliers with its 5% yearly price reduction policy, when it imposed a strict price reduction with its main suppliers in exchange for long-term and solid agreements which helped both the French carmaker and its business partners to have a stable perspective and common focus on customer value [45].

2.3.2. Internal Differentiation Analysis

= The goal of the internal differentiation analysis is to analyze all internal processes within the company and identify the processes which are possible sources of differentiation and thus create customer value. This enables the manufacturing facility to identify opportunities for creating and sustaining superior differentiation, another important driver of profitability and competitive advantage. This approach is more sensible as it implies understanding and anticipating customer demands and providing a difference which gives the edge over other competitors and a superior perceived value of the products and services by the customer [15].

Differentiation can be achieved by having a more customer-oriented approach in certain areas which are of importance to the customers and for which they are willing to pay a premium in exchange for the product meeting their specific needs and/or desires: internal processes, product features, warranty and/or price.

1) internal processes

= in automotive industry especially car manufacturing brands conduct periodical audits upon their main suppliers and they often have strict or specific requests upon certain areas (production, product quality control, packaging specifics, labeling, etc.) that they impose their suppliers to uphold at all times. This is a challenge most of the times for suppliers as they may well supply goods to several carmakers and thus they need to maintain focus on their tailored production lines and shipping details to maintain high customer service. Meeting customer demand however and good collaboration and communication with the carmaker however can enable a tight and long-lasting partnership between the business partners and source a sustainable competitive advantage.

2) product features

= throughout the last couple of years cars have been fitted with more and more features and extras, whilst some have been even introduced as standard on all cars. Differentiation can be achieved in this matter if the product is considered either esthetically appealing and/or has functionally superior features, as buying a car implies an important amount of subjectivity. The Mercedes-Benz S-Class is a benchmark luxury car and has been a forerunner in differentiation through air conditioning, anti-lock brakes (ABS), airbags, traction control or the Electronic Stability Program (ESP) and has earned its "special class" high quality model name (S-Class comes from "S-Klasse", an abbreviation for Sonderklasse which in German means "special class") throughout the last decades.

3) warranty

= every new cars sold has a warranty, where the car manufacturer guarantees the proper functioning of the vehicle for a certain amount of time. This usually ranges from 2-4 years within a certain mileage limit that covers an average number of kilometers the car drives without the need for repairs and the burden of cost for the owner. The extent of the warranty is also a quality declaration made by the carmaker, as extending warranties implies additional service costs for the dealer's garages and should there be issues, these will affect both brand image and balance sheet. Most car dealerships may offer to extend the warranty for an additional 1-2 years (for a premium) in certain conditions and depending upon the car's service history, but by far the most impressive bid on the automotive market is South Korean carmaker Kia, who offers a 7 year warranty on its cars.

4) price

= price is not always viewed as the only mattering end-tag in the decision to buy a certain product, as is the case of the car, where there are several subjective criteria to be accounted for as well. Price is often related to value to customer, where the price-quality ratio is a key element in the decision-making process and depending upon the features of the product and the customer's perception upon their utility for his own purposes, he may be willing to pay a higher price if his overall assessment is that of a fair price for which he receives good value.

An effective internal differentiation analysis depends upon the ability of the company to objectively assess its strengths and weaknesses and know if it is capable of providing specific resources and skills (and ultimately enhanced customer value) which can provide a sustainable competitive advantage over its competitors. More important sometimes than the actual capability is the customer perception upon the product and his assessment of value for money, which can only be maintained on long-term if the quality of the company's products is meeting or exceeding customer requirements.

2.3.3. Vertical linkage analysis

= is the acknowledgement if the fact that each link in the automotive supply chain is an integral part of the value chain and needs to be aligned with the carmaker's policy in order to be effective and generate overall benefits

A good collaboration among upstream and downstream partners in the automotive industry supply chain provides the basis for competitive advantage through the value chain approach and the sustainable development of the carmaker and its business partners. One of the most impressive examples in this sense was the problem Toyota faced in 1997, after the fire at one of its main suppliers which made brake fluid proportioning valves. At the time it seemed production at Toyota would have been stopped for a several weeks until restoring the Aisin plant, but thanks to an impressive effort by the Japanese manufacturer's suppliers, their engineers and overtime shifts, the factory managed to resume production within less than a week and avoided huge losses. After the incident both Toyota and Aisin later refunded their suppliers and business partners for the valves and their employees' overtime. Additionally the Japanese manufacturer financed the re-tooling of the plant with equipment and provided a bonus to the suppliers involved in solving the problem [79].

Collaboration among industry partners and their understanding of the importance of the overall value chain approach is very important when trying to deliver high customer value with reduced cost and is one of the most important pillars than support a sustainable competitive advantage.

2.3.4. Organizational and managerial challenges of value chain analysis

Conducting a value chain analysis is a complex process and it is subject to certain difficulties in assessing up-to-date dynamic data changes throughout the process flow from within the manufacturing process as well as from the external suppliers of the automotive supply chain. Usually data is used from the previous financial year and thus conducting analyses based upon static data may sometimes alter the quality of the obtained results and their effectiveness as valid system data.

For making proper decisions these cost structures, asset and revenue data should be revised and kept up to date in order to provide decision makers with reliable information as a source for value chain improvement. This is important also when considering the interconnectivity of the automotive supply chain and the fact that the value chain of the carmaker is also linked with that of its main suppliers and their record keeping needs to be equally valid to render an effective and up-to-date integral value chain from upstream to downstream.

Besides identifying cost drivers for each activity which adds value, linkages between internal processes as well as linkages with the value chain alongside the supply chain partners, there is also the challenge of rendering accurate profit margins of the business partners. This is made more difficult as companies and plants rarely operate at full capacity, therefore the actual capacity utilization may vary from year to year and month to month, affecting productivity for the business unit as well as an effective data report for the value chain approach.

Performing an accurate value chain analysis is thus a serious challenge due to data reliability and calculation difficulties, but the approach in itself can provide a valuable overview on the activities which provide customer value as well as some pertinent figures of cost structure for certain activities and processes, their role and contribution to the overall value chain as well as an insight towards the company's competitive situation.

Value chain analysis is one of the most practical approaches within a company where strategic planning and accounting figures can have a practical common point and form the basis for effective management decisions and changes in order to implement an effective value chain and provide good customer value.

This approach requires a level of awareness from all major decision makers involved, but also from those in charge of providing the much needed data and depends on the implication of the employees working at the processes where customer value is created. Every contribution and idea for process improvement may make a huge difference in the effectiveness of the customer value creating approach and is an important source for competitive advantage and the sustainable development of the company.

Value chain analysis also implies acknowledging the fact that such an approach is part of strategic thinking and requires constant awareness in order to be able to continuously adapt to an improved workplace structure while maintaining the process flow. Management has to identify the needed changes or the desired improvements also based upon data coming from information systems which support planning and monitoring of the value-creating processes and their result effectiveness according to company specific key performance indicators (KPIs).

2.4. Organizational structure

Every organization has a certain type of structure on which its specific organization and responsibilities are based upon (formal organization). The formal organization is the one which is rather predefined (organizational chart, job description, reporting relationships, etc.) and put in place in more or less the same manner and simple to understand and follow.

Besides the formal organization there is also an informal organization in every company which arises due to evolving relationships between employees and specific patterns of human interaction that are not officially prescribed and form the company's working climate. As far as formal organization is concerned, according to [27] these standard structures can be categorized into the following types of organizations in factories:

1) Line organizational structure
2) Staff or functional authority organizational structure
3) Line and staff organizational structure
4) Committee organizational structure
5) Divisional organizational structure
6) Project organizational structure
7) Matrix organizational structure
8) Hybrid organizational structure
9) The Informal Organization

1) **Line Organizational Structure**:
= this is probably one of the simplest structures with a vertical responsibility breakdown where relationships are very clear and follow a clear and direct route, as shown in figure 2.5.
Some of the advantages of this type of organization are its simplicity (clear authority, responsibility and accountability), the ability to make fast decisions (flexible) and a greater closeness between managers and employees.

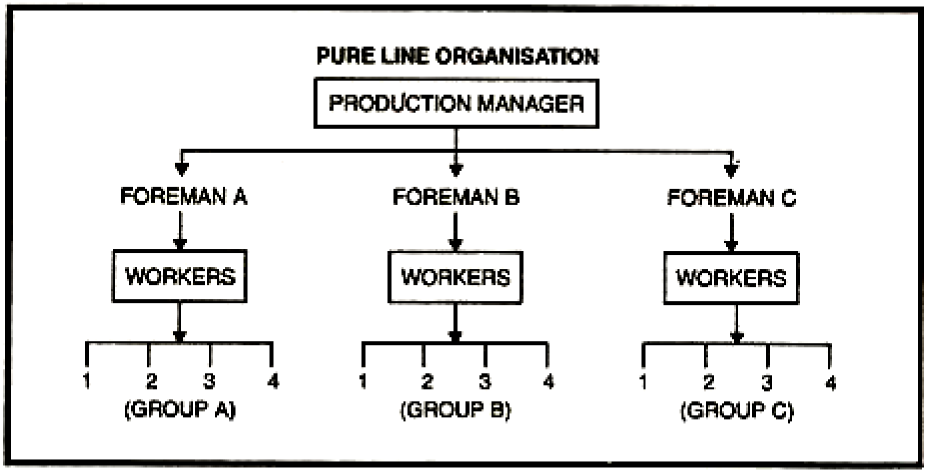

Figure 2.5. Example of line organization

Some disadvantages of this type of organization may also arise, as are: its ineffectiveness for larger companies (or in case of significant company growth), flexibility and speed of the decision-making process do not always guarantee the quality of these decisions and neglect certain specialist knowledge, managers may have to have extensive knowledge in other areas as well and get the impression of being experts in to many fields and the risk of overloading key employees, making the organization overly dependent on just a few people who are able to perform several tasks and jobs.

2) **Staff or Functional Authority Organizational Structure:**
= this type of organizational structure regroups two positions: the line position and the staff position. Basically this type of organization is similar to the line organizational structure with the additional feature of a staff position being able to intervene and also advise in the same manner as the direct line authority (see figure 2.6).

The line position is mainly responsible for assuring the achievement of the organization's goals (line authority) and has the direct authority, whereas the staff position additionally provides expertise and support for the line positions having the authority to advice over the line (functional authority). An example in this sense could be the production manager (line authority) who is assisted by a quality engineer (functional authority) that can also advice workers within his area of expertise.

The advantage is that through the additional staff position, the lack of multiple specialization is offset, but this in turn means unity of command is lost, which usually brings about the issue of confusion and sometimes the conflicting orders from multiple sources may also lead to a higher rate of ineffectiveness in functioning. This also gives the impression that authority is mainly existent only at higher levels, causing the distancing among workers and other employees and potentially being a source for demotivation from more ambitious employees.

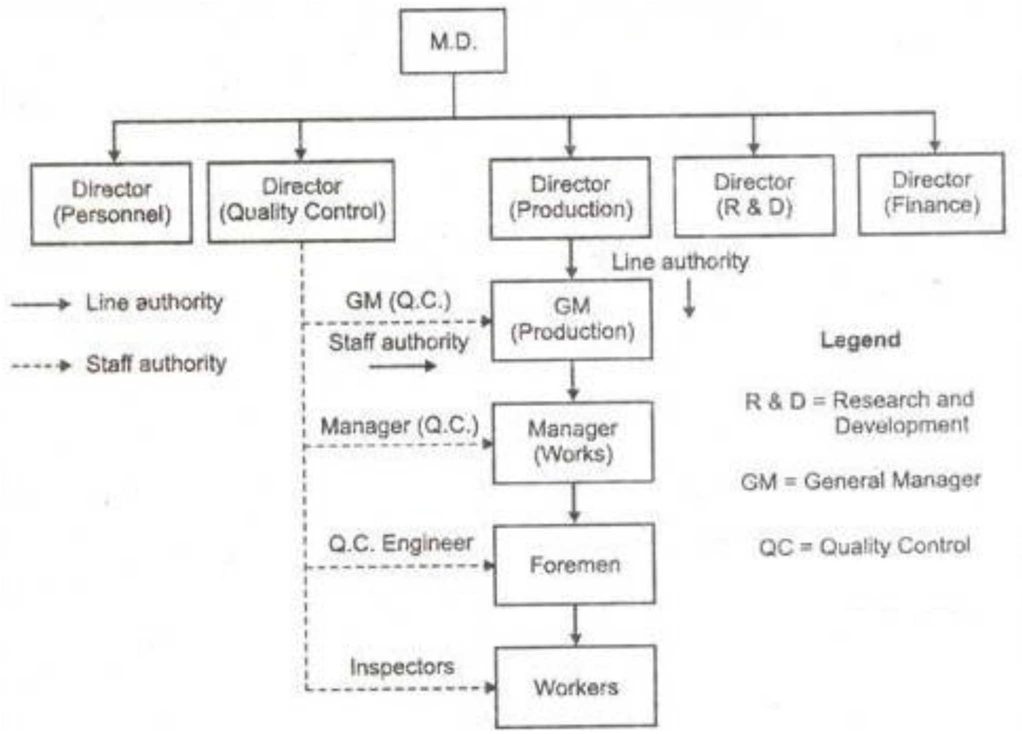

Figure 2.6. Functional authority organizational structure

3) **Line and Staff Organizational Structure**:
= this type of organizational structure is similar to the Staff or Functional Authority Organizational Structure (as shown by figure 2.7), but eliminates its main inconvenient, namely the lack of command unity and is the most common type of organizational structure found within companies.

It has the same vertical relationship between several functional levels, and as opposed to the previous type of organizational structure, in this case line managers are only provided with assistance from specialized personnel in order to support them in decision-making and in running an effective part of business.

Line managers are assisted by specialized staff in advising (Industrial Engineering, Planning, Management information system, Operations Research, Quantitative Techniques, etc.), service (Purchase, Maintenance, Marketing, Finance, etc.) and control (Cost control, Quality control, Auditing, etc.) which are designed to support the line manager's activity, without being able to overrule their direct authority. Another feature is that both line and staff have direct vertical relationship between different levels and that there is no need for all round executives as line authorities of routine and specialized decisions are relieved by the specialized staff.

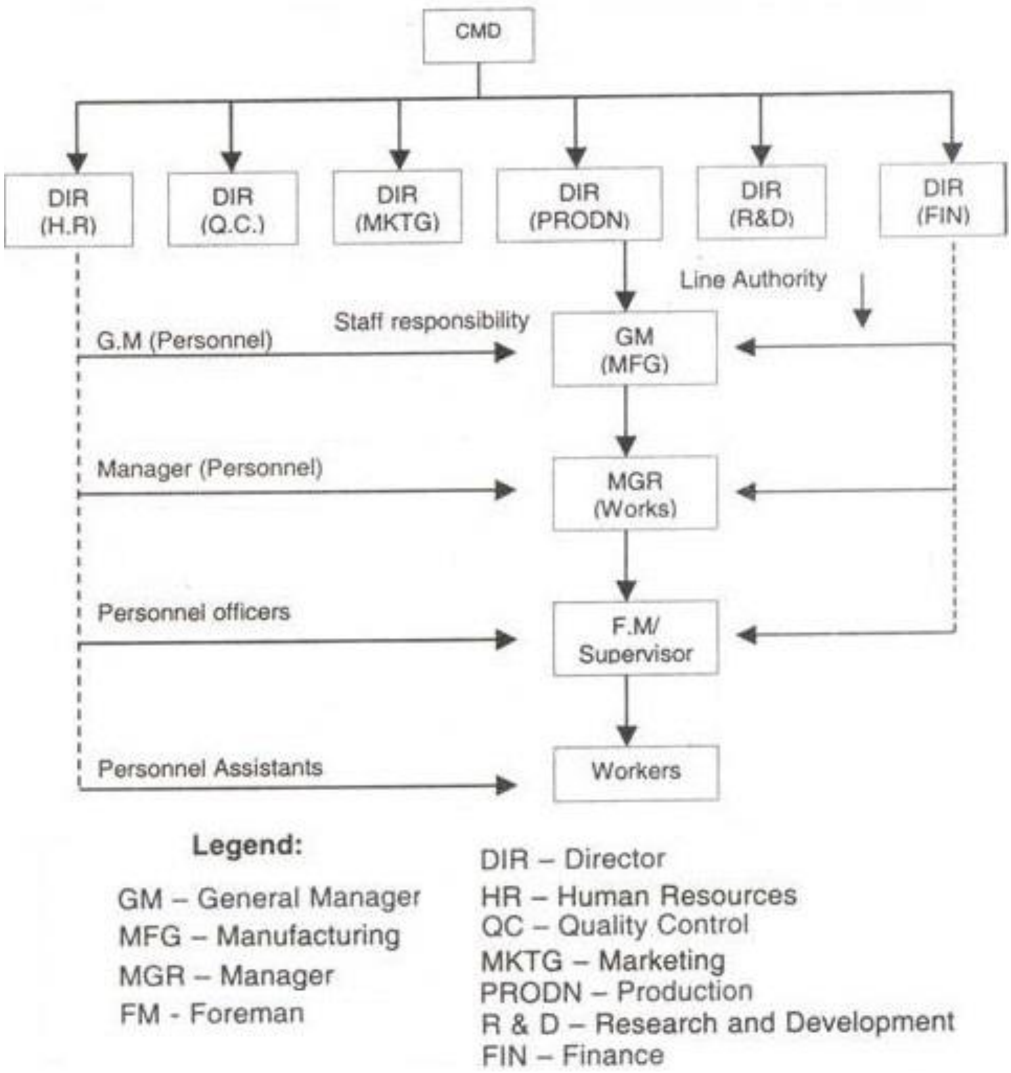

Figure 2.7. The line and staff organizational chart

There are also some disadvantages as well: despite the flexibility, conflicts between line and staff personnel may still arise, mainly because some line managers may not like it very much when they are told by staff personnel what to do or how they should do certain tasks (despite the staff's specialist knowledge and expertise in specific areas).

Staff may also feel less motivated as their role lacks authority and the line managers may prove reluctant to accept their counseling or advice, causing coordination issues and making communication more difficult.

4) **Committee Organizational Structure**:
= this type of organizational structure is mainly appropriate for handling specific situations and is usually used only for a short-term period or even once occurring situation rather than for longer timespans as outlined by figure 2.8.

The advantages of committee decisions are the fact that they are usually better than individual decisions as a group discussion often leads to creative thinking, motivating members to actively participate in the process of decision-making within the committee group and generates the basis for better interaction and coordination of activities amongst members.

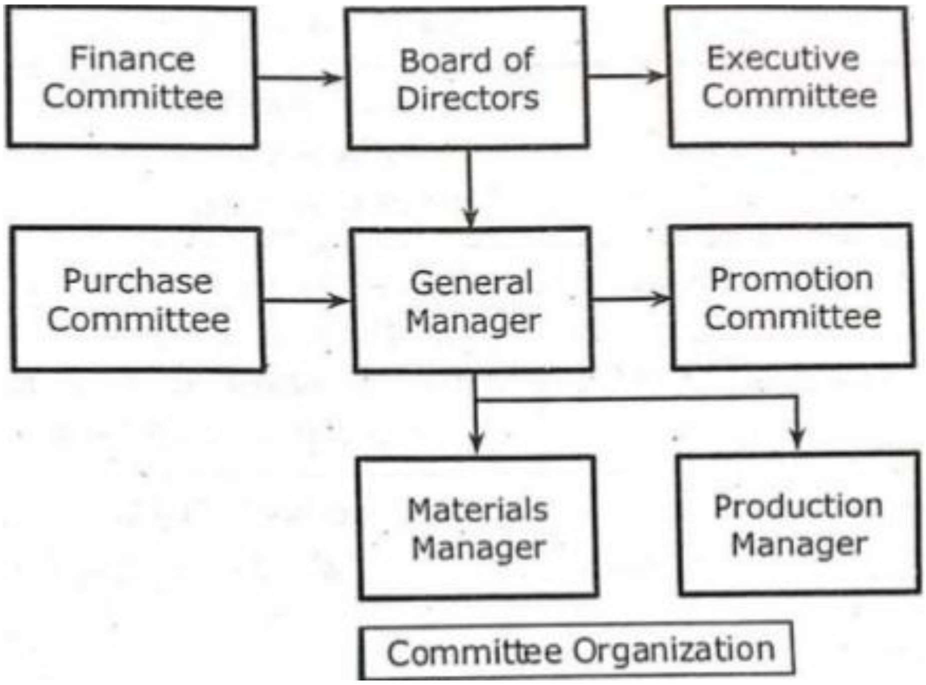

Figure 2.8. The committee organizational chart

There are however a few setbacks associated with this type or organizational structure as responsibilities for certain actions may be shifted amongst members, certain more delicate issues may lead to compromise or even indecision which can delay decision-making whilst consuming more time and financial resources as well.

5) **Divisional Organizational Structure**:
= this type of organizational structure is very flexible and open depending upon the functionality it is focused on, which may be based on function, product, geographical

area, specific project or a combination of the above (as presented in figure 2.9 below).

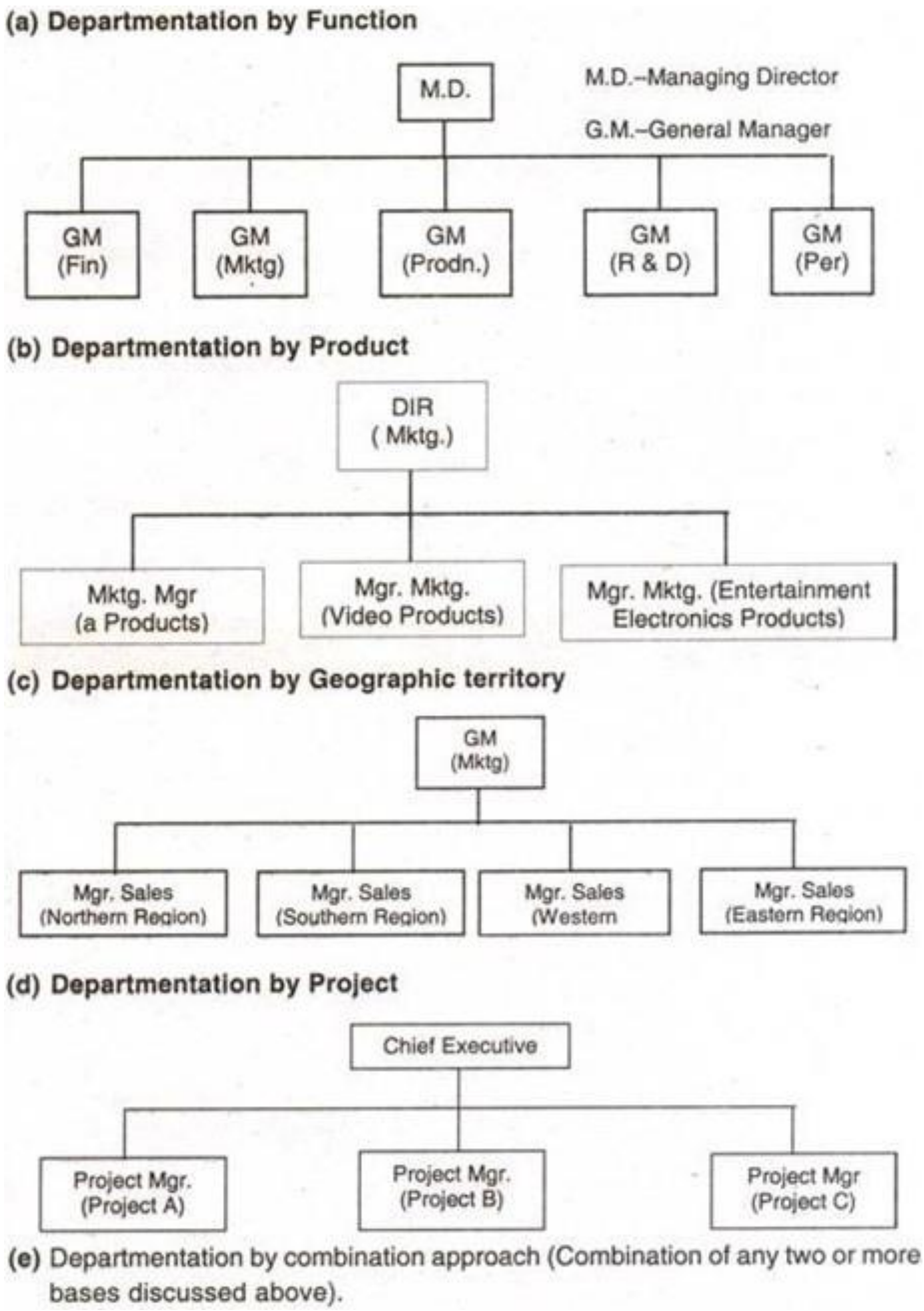

Figure 2.9. Organizational structures formed upon departmentation

6) **Project Organizational Structure:**
= this type of organizational structure is focused on specific projects, where usually activities range throughout several departments and with the previous organizational structures relationships would flow horizontally, diagonally upwards and downwards making it complicated to implement of them, therefore the project organizational structure has emerged (an example of such a structure is shown in figure 2.10). This structure features several specialists working within a designated team for a determined timespan (usually ranging from several months to a couple of years) in order to carry out complex and challenging projects with the help of required skills and competencies, before resuming their everyday jobs within the company. Typical projects may be within research and development (new product), industrial engineering (new company layout design and implementation), building a new factory (preparation and implementation), product development, etc.

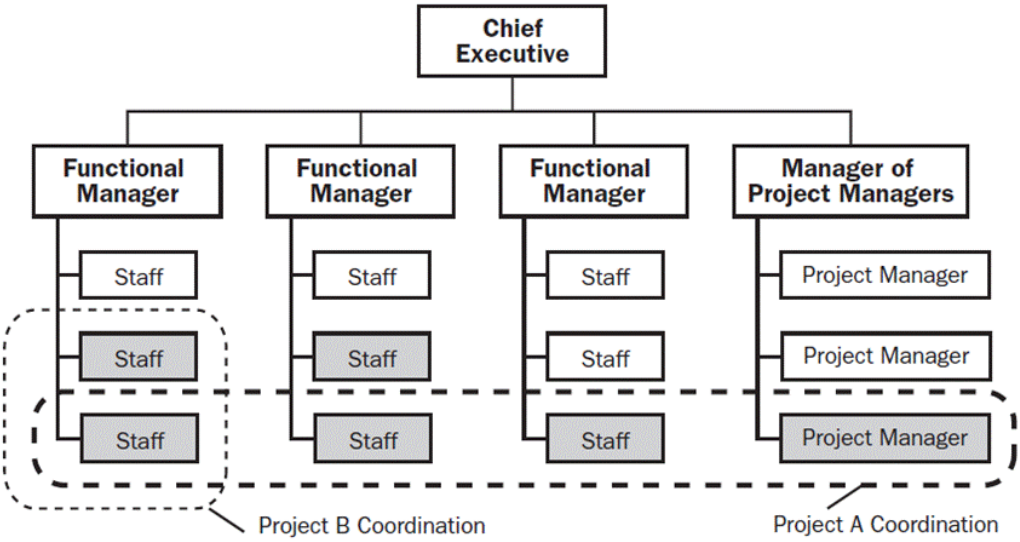

Figure 2.10. A project organizational structure

The project organizational structure basically features a temporary team working together to achieve a desired results with the following advantages: a new (and usually unique) project, which implies the challenge of success or failure after working and achieving complex independent and interlinked activities with the use of cross-department specialized skills necessary in order to successfully accomplish the goal of the assigned project within a specific deadline. For each project there is a provided budget, an expected level of quality of achieved work implied and an expected time of delivery or deadline, which gives the coordinates and the constraints of the task and its implications.

For each project there is an assigned project manager who needs to gather the needed resources and coordinate all steps of the process and ensure that all project specifications and objectives are met at the end. Some disadvantages may occur such as the priority of given tasks from project managers or the usual departmental manager of a project member which may arise tensions if the informal relationship between project manager and the departmental manager (functional manager) in question is not a good one. Also in order for the project to be effective, good communication and clear work breakdown structure between team members are of utter importance.

7) **Matrix Organizational Structure**:
= unlike the temporary project organizational structure, this type of organizational structure is permanent, but its goal is the same, namely that of achieving specific results with the help of specialist skills from empowered employees from different departments of the company. The divisions are horizontal and reporting is done according to the hierarchical functional structure as is shown by the example in figure 2.11.

The main advantages of this organization within a company are the focus on project or product coordination, decentralized decision-making, a flexible use of resources and support systems with the possibility to quickly adapt and respond to changes. These assets create the conditions to achieve company goals and usually have a high level of effectiveness.

The downsides are the prospect of overemphasizing decision-making on a group level and an excessive focus on internal relations, which can generate situations of confusion over responsibility or authority (potential lack of unity in command) and bring about conflicts in addition to the high administration cost.

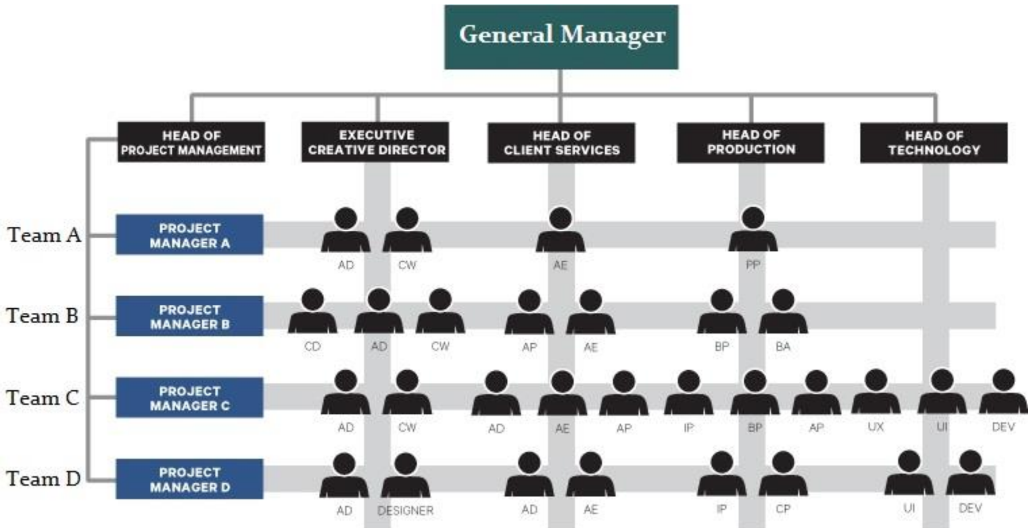

Figure 2.11. The matrix organization

This type of organization is mainly used to adapt to a rapidly changing external environment with both functional and product managers. Functional managers are responsible for specialized resources (production, scheduling, quality control, marketing, etc.) whereas product managers handle one or more specific products.

Product managers are in charge of product strategies and have the support of functional managers for additional resources whilst managing the budget.

8) **Hybrid Organizational Structure**:
= this type of organizational structure is usually employed by multinational companies who face the challenges of a dynamic business environment and the uncertainty associated with international orientation and commitment (see figure 2.12).

The corporate office of these companies is in their country of origin whilst their international divisions are established in various countries and sometimes continents around the world and report to headquarters. These structures are usually aligned with the company policy and may employ a functional or geographic structure in accordance with the focus is on international character.

The advantage of such organizations is a strong organizational culture which is aligned with corporate goals, functional expertise and efficiency and the ability to adapt in divisions (flexibility).

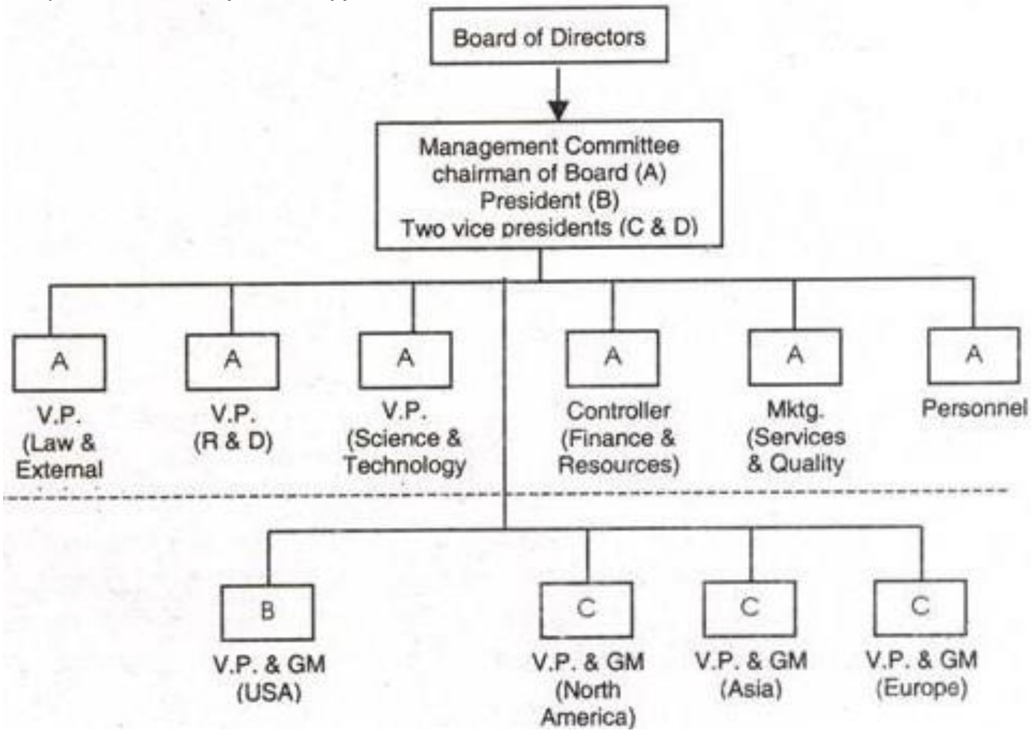

Figure 2.12. Hybrid organizational structure

The downsides are that the rigid organizational structure determines excessive administration overhead and career development is rather narrow, being limited to the company's specialized jobs which do not imply a broader understanding of cross-departmental specifics. An important inconvenient is the fact that such large organizations find it hard to quickly adapt to some unexpected situations as the response to exceptional situations is usually rather slow due to the complex decision-making path before reaching top management level.

9) **The Informal Organization:**
= although this type of organizational structure is not a formal or official one, it is still of great importance for the overall work climate within the company and has a great impact upon the motivation and productivity of the employees.

The informal organization is mainly set up by human interaction and the evolving relationships between employees which evolve, as does the organization itself.

The development of this informal organization (as shown in figure 2.13) is driven by the needs of personnel (friendship, affiliation, etc.) and is continuously changing due to the changes within the company (new employees, new appointments in other departments, changing managers, etc.), being very dynamic as people tend to grow and develop at a different pace.

As any other organizational structure however, it has its advantages and disadvantages. The benefits are mainly those of assistance and support for faster accomplishing of tasks, as a form of providing confidence (through communication, empathy, emotional support, etc.) and encourage better management.

Setbacks of this organization are the fact that this reduces predictability and control in view of the classic formal types of organization, if no positive relationship is present between certain employees, this may cause time increases in order to complete certain tasks and it may even get out of hand and work against the purpose of the formal organization.

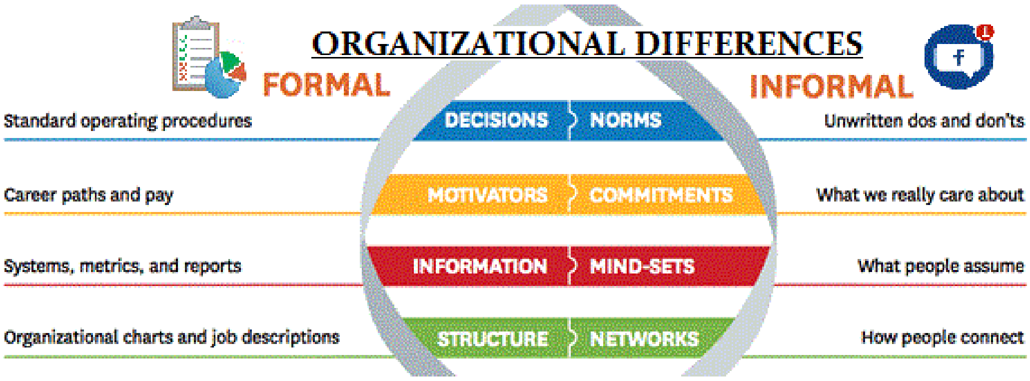

Figure 2.13. Informal organizational structure

Additional types of organizational structure may arise according to the specific needs and requirements of companies and may combine of select certain features of the previously presented forms of organization.

Depending upon the functioning there are classic responsibility charts or job descriptions, which may have only slight changes to better fit the specificity of the company's business (see figure 2.14) and in accordance with the organizational type the extent and level of responsibility and authority can range within certain boundaries (see figure 2.15) [46].

Responsibility Matrix

Title	Project Chartering Committee	Client Representative	Project Manager	Technology Team	Finance Team	Schedule Coordination Team
Scope Statement	✓	✓	✓			
Work Breakdown Structure		✓	✓	✓		✓
Budget		✓	✓		✓	
Quality		✓		✓		✓
Change Management Procedures		✓	✓		✓	✓
Change Approvals		✓	✓			

Figure 2.14. Responsibility matrix

Organization Type / Project Characteristics	Functional	Matrix			Projectized
		Weak Matrix	Balanced Matrix	Strong Matrix	
Project Manager's Authority	Little or None	Limited	Low to Moderate	Moderate To High	High to Almost Total
Percent of Performing Organization's Personnel Assigned Full-time to Project Work	Virtually None	0-25%	15-60%	50-95%	85-100%
Project Manager's Role	Part-time	Part-time	Full-time	Full-time	Full-time
Common Title for Project Manager's Role	Project Coordinator/ Project Leader	Project Coordinator/ Project Leader	Project Manager/ Project Officer	Project Manager/ Program Manager	Project Manager/ Program Manager
Project Management Administrative Staff	Part-time	Part-time	Part-time	Full-time	Full-time

Figure 2.15. Characteristics of organizations

The responsibilities in each of these cases need to be properly defined and adapt to the specific needs of the organization as well as to the moment of the project development and take into account all relevant characteristics in order for the organizational structure and its effectiveness to provide the expected results and a thorough understanding and performance of the entire project for the entire team.

2.5. Layout effectiveness and value chain improvement strategy

2.5.1. Layout effectiveness: improving productivity and work efficiency

A proper value chain analysis usually implies the contribution and cooperation among several managers in charge of the targeted processes, as well as industrial engineers, layout designers and production managers, which can provide essential data to properly assess and implement a functional value-creating process. After all calculations and redesigning of layout and process functionality are performed, the next step is to implement the changes and oversee the functioning and process flow tithing the new configuration.

When a plant wants to improve the cost, it must look at the following key areas which are subject to an effective improvement strategy: To improve the cost in production, the view must be global from the moment that the row material arrives to the plant until the finish products leave the plant and arrive to the customer (as shown in figure 2.16 below).

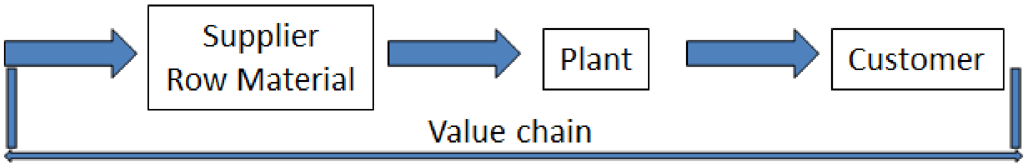

Figure 2.16. Simplified value chain

The process time finally indicates the process complexity. If the flow is perfect, the lead time is low and the value chain is working properly. But, if the process is not correct, then bottlenecks appear and those points represent complexity. The constant flow means avoiding complexity because the product is in a continuous process which means that there are no constrains and it`s easy to control all the blocking points.

The production is the result of avoiding the blocking points in the process. And the most important thing is to understand and see when a blocking point appears. If the production is not flowing, the blocking points are not visible because they are difficult to identify.

The organizations with no easy, clear and simplified process flow are those organizations that are trying to improve and show a lot of isolated results but in the end those results are not visible in the profit and loss statement (P&L) because optimizing a part of the process is introducing bottlenecks in the total process. And finally the theoretical savings are not really achieved, because most of the times the improvements are against the capacity to keep the flow of the value chain.

In order to improve the cost, the first step is to keep a clear production flow, simple and easy to understand. And then, focus can be shifted towards a holistic approach.

The total understanding of the value chain flow is necessary in order to keep on improving because decisions are always affecting the continuity of the production flow. The results of the savings are usually against the results of the output and finally producing the necessary quantity on time is the most important point to achieve targeted and desired results.

The main idea which needs to be emphasized is the fact that, in order to optimize the cost, first we need to optimize the flow. This means building a simple and easy production flow and designing an easy production layout. Without this concept of simplification, it`s difficult to have an effective holistic approach. In order to understand the total value chain it must be easy, simple and clear. When this step is finished it`s easy to improve because we can easily identify when an improvement decision can further enhance the output.

After improving the layout concept, the flow has been simplified and by using visual management the entire blocking points of flow have also been identified. The job of production is clear as it needs to produce and deliver only what the customer demanded and in the required time. The Just in Time (JIT) concept means a clear production flow avoiding any delay in the plan.

When we are looking at the plant delay causes, the first is the lack of a proper planning, and again we return to the flow concept which means to plan different steps in the production process. To achieve overall synchronization is actually very difficult because every individual process needs to be controlled and monitored and also well synchronized with the next process. Sometimes the equipment is shared for different products (more than one product being produced with the help of one equipment) and when a problem appears for one of those products it will affect the complete planning. This means it is necessary to control and reschedule the plan every time a problem appears and affects production.

The concept is wrong because the flow must be natural, which means having dedicated equipment to produce dedicated products or extra capacity to avoid planning changes. This is wise because any planning change generates a lot of extra problems, inventory misjudgment and even additional user changes, therefore reducing the cost is a good decision. And then, it is possible to optimize the headcount and extra capacity requirements, as well as the bottlenecks and everything that may affect value chain results.

Sometimes traditional management rules need to be adapted as there is no standard management technique that can solve all problems [20]. An excessive emphasis on manufacturing costs or on the sole idea of cost for that manner is wrong, as the goal is to sell certain products which need to be perceived as desirable by the customers and have to trigger their buying decision as shown in figure 2.17.

	Traditional Management Accounting	**Value Chain Analysis in the Strategic Framework**
Focus	Internal	External
Perspective	Value added	Entire set of linked activities from suppliers to end-use customers
Cost Driver Concept	Single cost driver (cost is a function of volume) Application at the overall firm level (cost-volume-profit analysis)	Multiple cost drivers – Structural drivers (e.g., scale, pe experience, technology d complexity) an – Executional drivers (e.g., participative management, total quality management and plant layout) A set of unique cost drivers for each value activity
Cost Containment Philosophy	"Across the board" cost reductions	View cost containment as a function of the cost drivers regulating each value activity Exploit linkages with suppliers Exploit linkages with customers Exploit process linkages within the firm "Spend to save"
Insights for Strategic Decisions	Somewhat limited	Identify cost drivers at the individual activity level, and develop cost/ differentiation advantage either by controlling those drivers better than competitors or by reconfiguring the value chain (e.g., Federal Express in mail delivery, and MCI in long distance telephone) For each value activity, ask strategic questions pertaining to: – Make versus buy – Forward/backward integration Quantify and assess "supplier power" and "buyer power," and exploit linkages with suppliers and buyers

Figure 2.17. The differences between traditional management and value chain approach (adapted from [108])

As competition is getting harsher, competitive advantage is the asset that will usually make the difference, especially in automotive industry and the challenge will be to provide as much customer value as possible to ensure business development and a reliable partnership within the automotive supply chain [11].

The traditional management approach based on cost also tends to ignore the fact there are several other inputs as well within the value added process besides manufacturing, such as engineering, maintenance, distribution and service and without an integral approach, both within the company and with its upstream and downstream business partners (linkages with suppliers and customers), a sustainable competitive advantage and the perspective to thrive in a highly competitive market (as is the car industry) are practically scarce.

Modern plant management needs to acknowledge certain important aspects as are the value chain approach and the idea of global optimization.

These ideas state simple concepts as is for example the focus on the entire value chain ranging from the first supplier of the manufacturing plant and until the end consumer, a supply chain network where many links are involved and where collaboration needs to be very good in order to provide high quality products, at the best possible cost and within the expected deadlines.

This is why the entire automotive industry supply chain partners need to have a common set of values and why competition is so harsh, because the dynamics of the industry within the last decade has been very fast, growth, changes and challenges have been constant and the need for effectiveness has been shifted away from an individual supplier of plant to the entire network for a more stable and lasting business partnership.

Improvements and cost reduction are always on the agenda in automotive industry and constant efforts are made to find such solutions. In an automotive plant near Timisoara, the costs had the following trend (see figure 2.18):

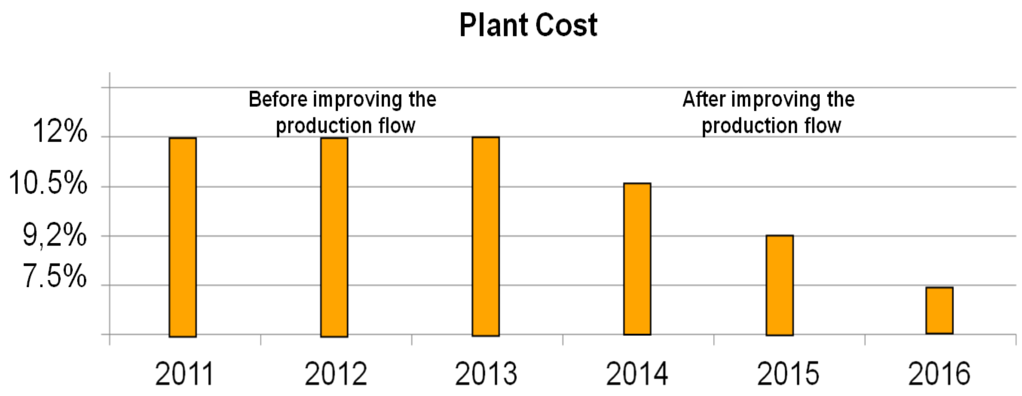

Figure 2.18. Cost comparison

All the steps made in the process flow improvement (layout design, organization and improvements) are represented in the following approach (figure 2.19):

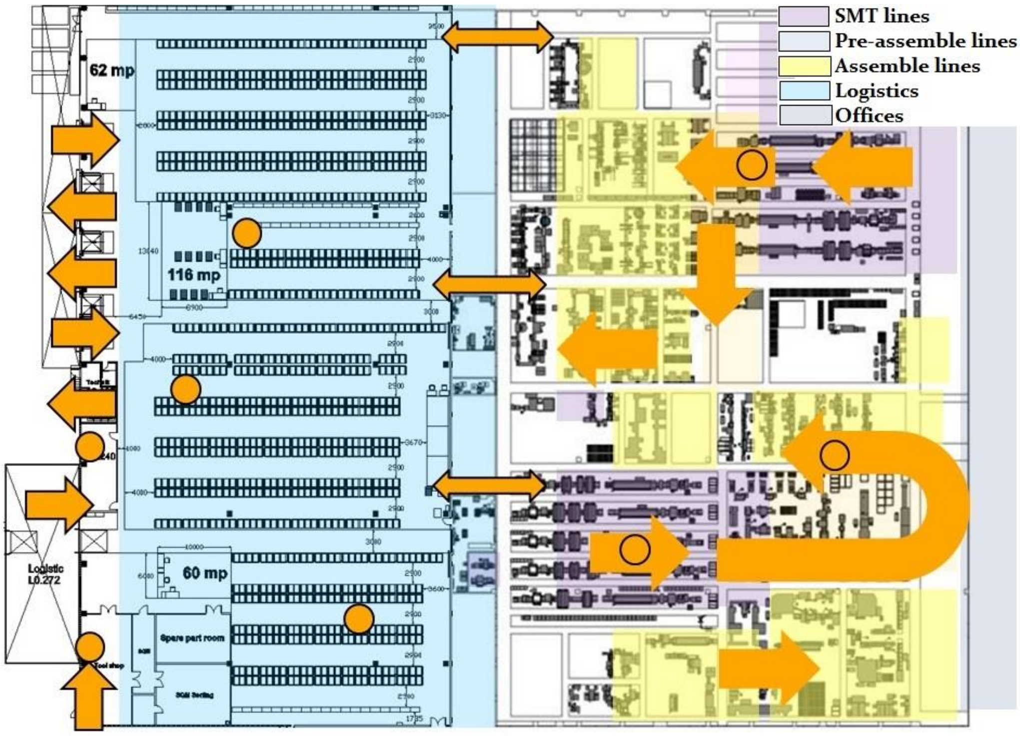

Figure 2.19. Layout before improvement

The layout configuration presented in figure 2.19 has many operational and functional problems ranging from mixed areas, where multiple tasks and processes are carried out, to flow issues and inventory (through buffers), adding to the burden of management of these activities.

Remarks:

- Mixed surface-mount device (SMD) area with important work in progress (WIP)
- Not really constant and systematic area in logistics for reception, storage and delivery activities (mixed reception and delivery material flow areas, not optimized)
- Incorrect material flow (in production and different from one FF (focus factory) to the other, not optimized)
- Buffers everywhere (after SMT, before preassembly, after preassembly, before assembly, buffers for materials)
- Some free areas were planned for additional lines

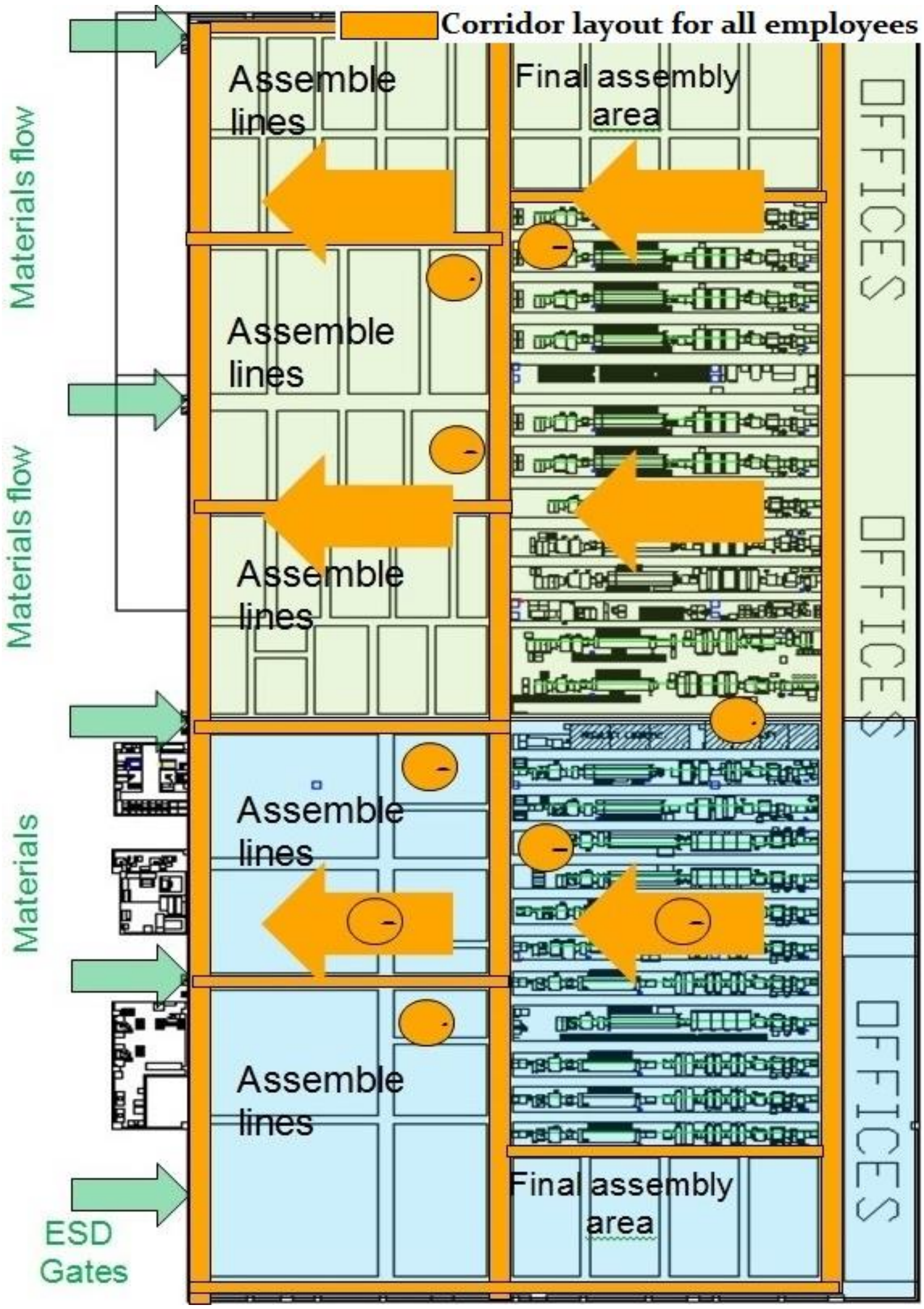

Figure 2.20. New standard elements in production for defining ideal plant layout

Table 2.1. Overview of corridor descriptions

Type	Width	Description
Main corridor (type 1)	2.5m	Special large equipment go through/main SMT material distribution/ nearby office wall/ between different SMT are and Backend are
Main corridor (type 2)	2.0m	Main material distribution/ nearby logistics wall and the 2 lateral walls / between FF big areas
Internal corridor	1.5m	General equipment go through/ internal material distribution
Line separation	0.8-1.0m	Replenish material with manual in internal
SMT line separation	1.3m	For SMED between SMT line
Inside width of U-shape cell	0.8-1.0m	One operator, no big tool for changeover requirements, small product handling, etc.
	1.2-1.4m	Two operators with cross operation
	≥1.4m	For special changeover requirements, special buffer storage, special machine width, etc.

The main goals of the improvement process were to simplify all processes of the plant and to reduce waste to a minimum in order to improve effectiveness, increase added value and productivity.

The reorganizational efforts also provided space gains (see figure 2.20 and table 2.1), which were used to redesign process flow and helped increase output figures and impressive efficiency results.

Main target changes:
1) Introduce component storage in production/install mega lift;
2) Change the complete material flow from one production unit.
3) Optimize the product cycle time on the line in order to implement one piece flow for high runners from SMT to the complete assemble line
4) For the high runner product absorbed the preassemble line in the final assemble line
5) Very limited buffers only at the end of SMT line
6) Switch from Push to Pull planning mode
7) Define clear route and timing for the material flow from logistic to production

The improvement plan of the plant was done according to a planned schedule of modifications (see figures 2.21-2.24), starting with the year 2014 when the important reorganizational efforts began as a response to the strategic objective of the plant and the growing trend of the market and the increasing demand from the plant’s customers.

The plan was divided into 4 quarters, each of the actions planned being upheld by the implementation team in order to ensure that the final deadline for all plant modifications was met and that everything would be operational at the end of the project. The main target of all these modifications was to increase productivity, eliminate waste and add value in order to improve overall plant efficiency.

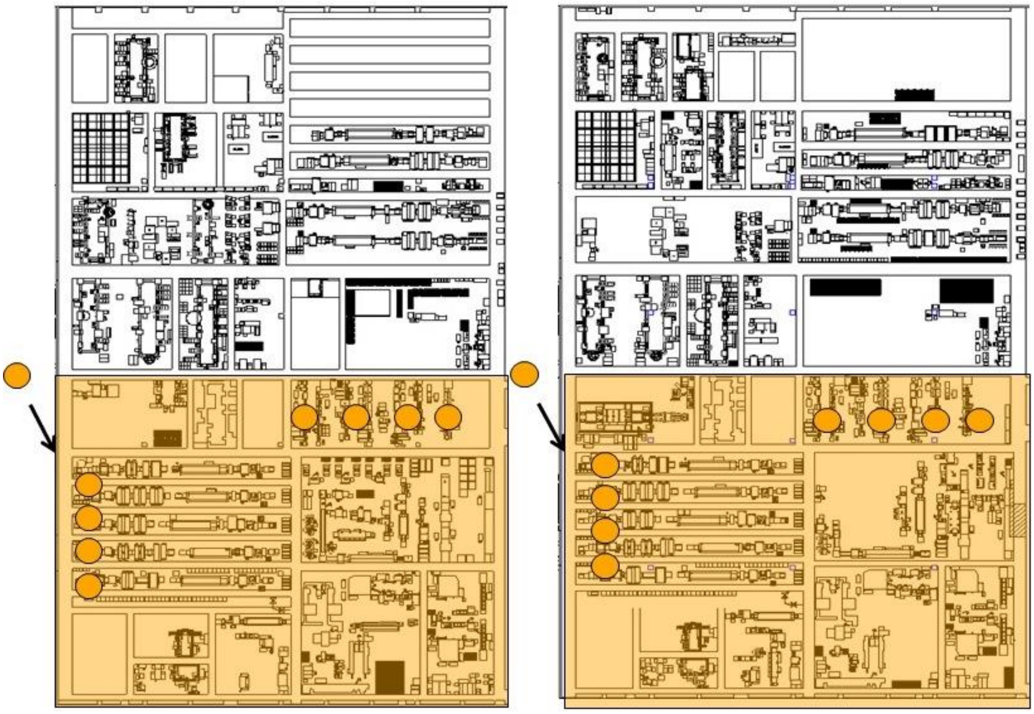

Figure 2.21. Plant layout improvement program (2014). Quarter 1 (left), quarter 2 (right)

The main actions completed within the first quarter (Q_1, 2014):
1) Prepare the complete layout change target for one of the business unit (BU): SMT, preassemble and assemble line;
2) Inform the customers about the layout improvement plant
3) Based on details planning order in advance the material needed in order to make safety stock for the line movement (15 weeks lead time for electronic components)
4) Order the mega lifts
5) Work on the equipment cycle time improvement, prepare high runners line for one piece flow

The main actions completed within the first quarter (Q_2, 2014):
1) Finalize the new layout concept
2) Get approval from customers for the line movements;
3) Prepare the safety stock for stop of the line during the move. Produce in advance on SMT line and also on specific assemble line
4) Improve the cycle time for high runners, balance the line for one piece flow
5) Prepare the needed infrastructure for the new layout

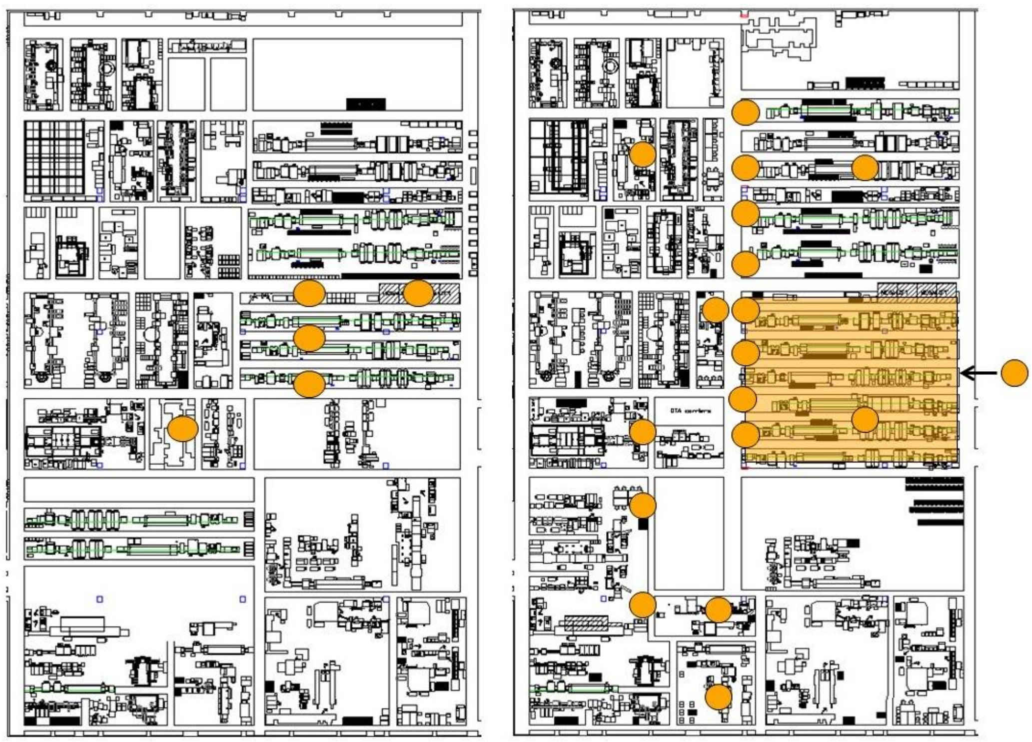

Figure 2.22. Plant layout improvement program (2014). Quarter 3 (left), quarter 4 (right)

The main actions completed within the first quarter (Q_3, 2014):
1) Prepare in the advance the installations for the SMT line in the new position
2) Move 3 SMT lines (step1)
3) Lessons from lean meeting and actions after each move (first SMT line move needed 4 days, second 3 days, third 2 days)
4) Prepare the assemble line for the move and move some of them (where space was available)
5) Install mega lift in production

The main actions completed within the first quarter (Q_4, 2014):
1) Finalize the movement of all planned SMT lines
2) Finalize the new material flow from Mega lift to SMT lines (for all SMT lines)
3) Reduce the material buffers on SMT lines
4) Introduce preassemble cell in the assemble line or very close with assemble lines

The plant layout changes continued in the following years as well, as a proactive and continuous challenge to keep in line with increasing demand within the automotive industry from the plant's customers.

Increasing capacity was first done on existing plant facilities by trying to maximize space utilization through layout and process redesigning as well as introducing new organization concepts in order to improve process flow, productivity and overall activity efficiency. Figure 2.23 highlights these changes, providing an overview of the extent of the improvement process carried out by the plant.

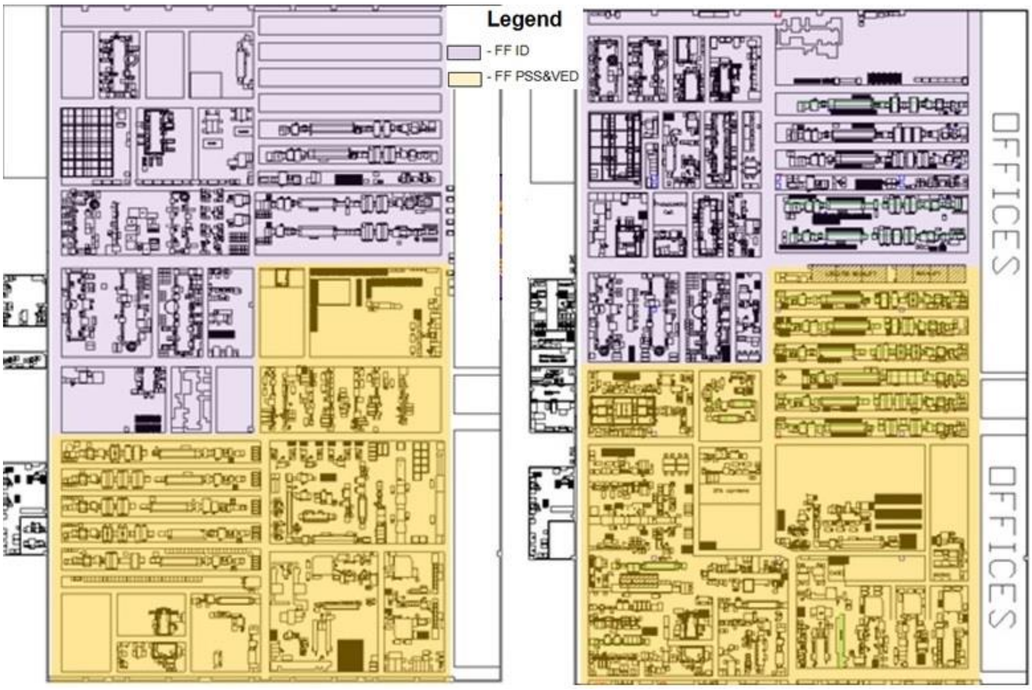

Figure 2.23. Plant layout progress. Quarter 1, 2014 (left) and quarter 2, 2015 (right)

The high level of demand, constant increase in volumes have made plant extension and space utilization the most important target for all management levels in an attempt to source high effectiveness and consistent efficiency rates for the plant.

The changes brought to the plant by the second quarter of 2015 sourced a saving of 800 m^2, with a share of 33% being gained in the improved area.

The modifications within the plant helped increase the plant volume by around 60% within the year 2015, compared to the beginning of the previous year (2014).

This impressive progress continued and by the first quarter of the year 2016 the actual production layout reached a 100% capacity increase compared to the same first quarter of the year 2014, practically doubling the output level of the plant within only 2 years.

Figure 2.24 outlines the newly set up layout as of 2016 with its associated functional areas (see legend from figure 2.24).

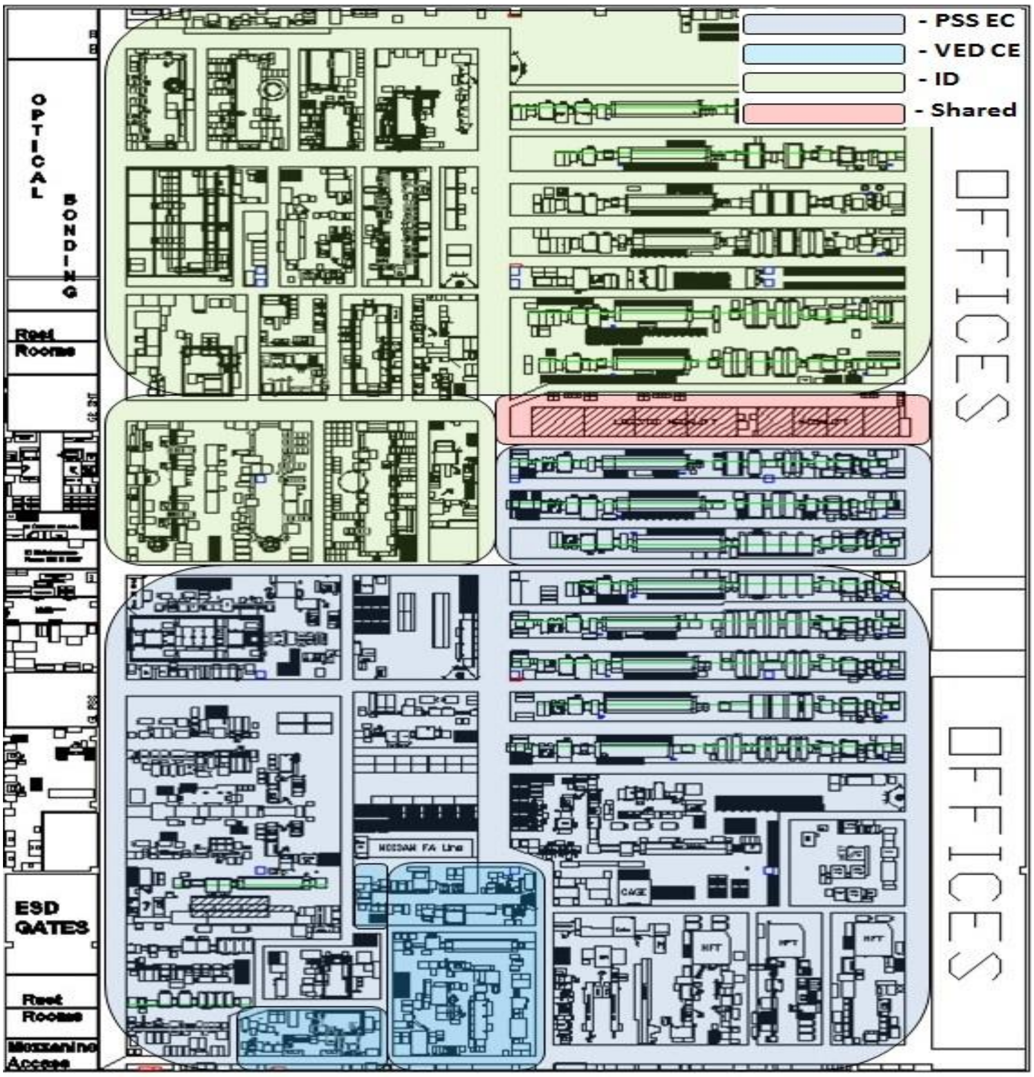

Figure 2.24. Plant layout improvements within the first quarter of 2016

The layout changes and modifications sourced higher productivity for all areas affected by the changeover process: PSS EC (Passive Safety & Sensorics/ Electronic Components), VED CE (Vehicle Dynamics/ Continental Electronic), ID (Identification) and the shared equipment are as well.

The new layout is also represented in figure 2.25, where the ID (brown), PSS EC (blue) and VED CE (green) areas can be seen from a different angle.

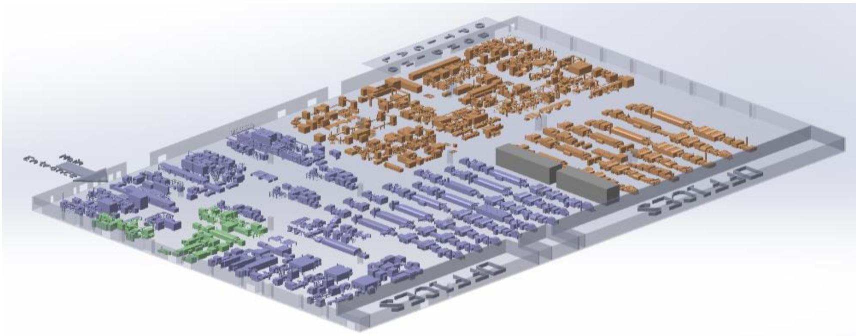

Figure 2.25. New layout representation (as of Q_1, 2016)

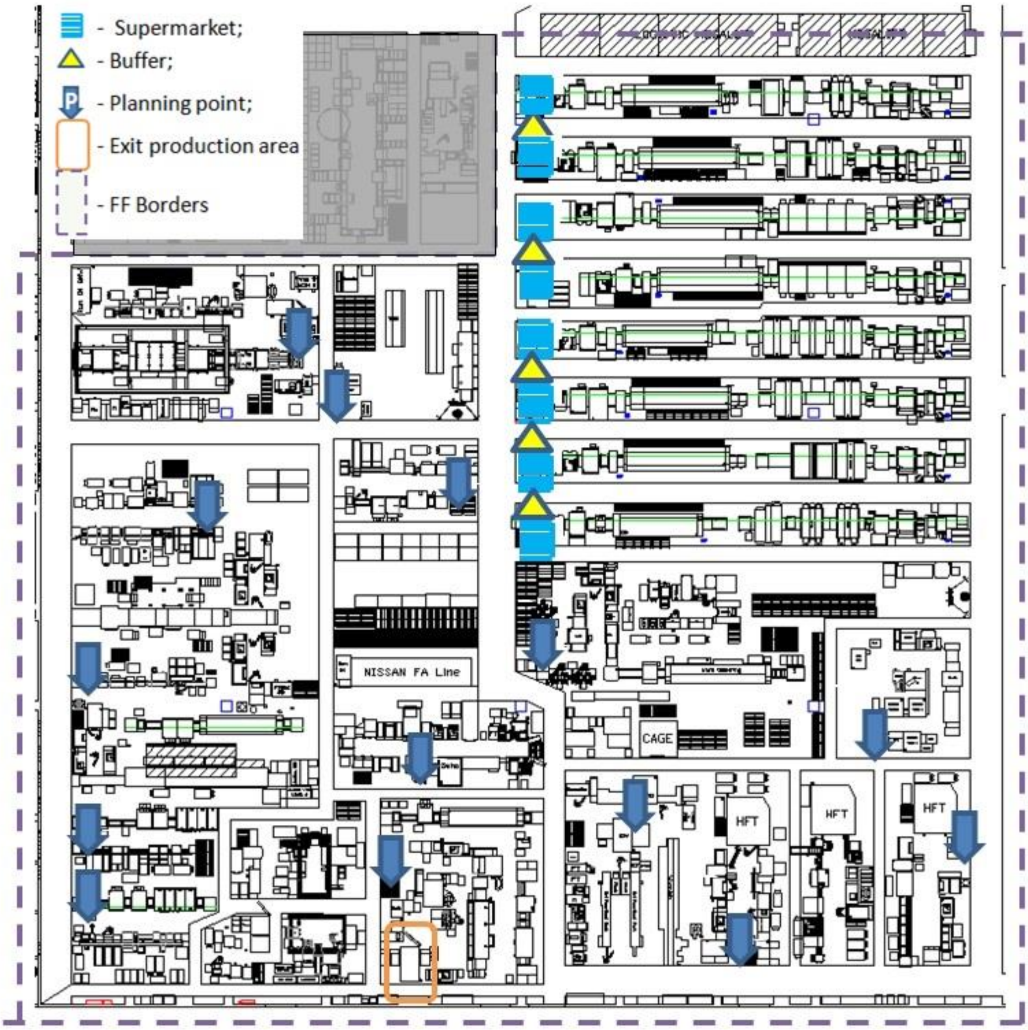

Figure 2.26. Plant layout before improvement (2015)

Before the plant layout was further changed in 2015, there were some issues hindering performance improvement and a high effectiveness rate of delivering the maximum output sourced mainly by the problems in the design of the workplaces. The layout was however changed from a more "Push" style layout to a more "Pull and Flow" type of layout as is shown in figures 2.26 and 2.27. At the beginning of the process the actual layout was not being very efficient and it also sourced some extra work and activities which were not adding value, being unnecessary within the overall process. The changes made did however source better productivity, as is highlighted in figure 2.27.

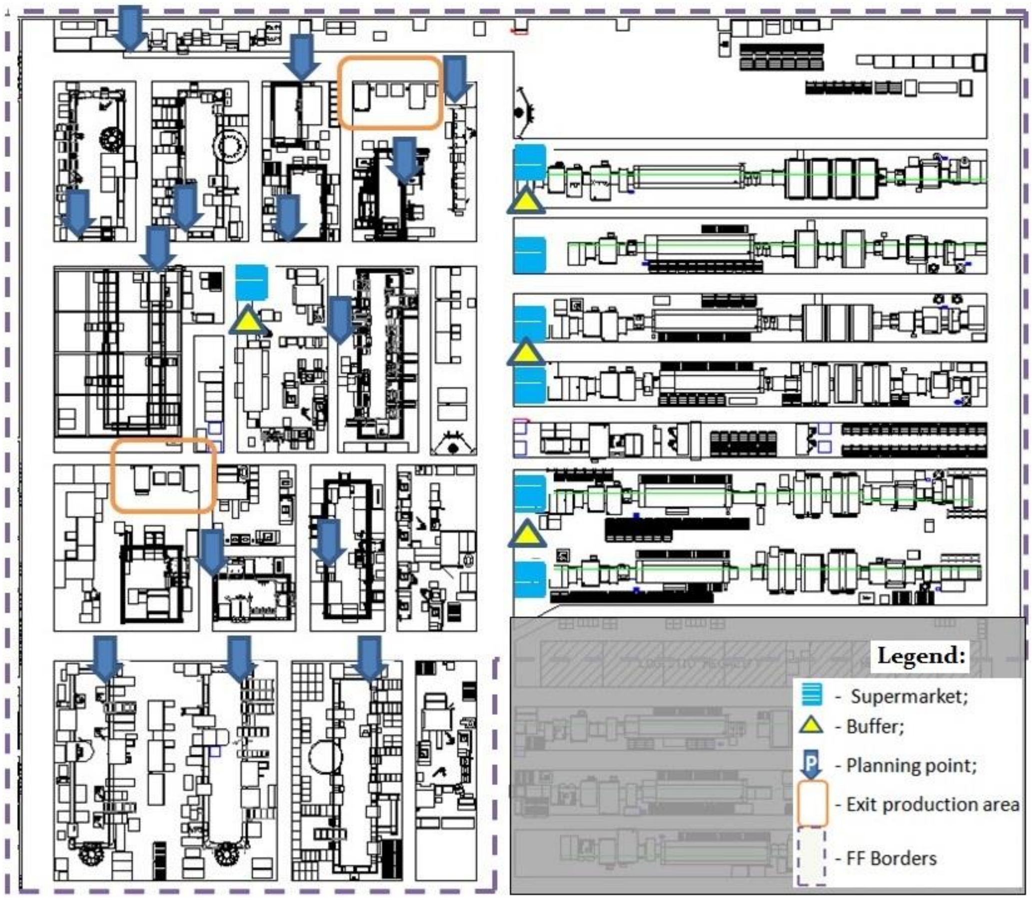

Figure 2.27. Plant layout after improvement (2015)

Improvements at the end of the layout changeover included the following:
• Planning points were only in assembly line (no need of the "push" principle in the SMT area, no need of buffers in the assemble or preassemble lines)
• Some older projects (where volume was reduced) were already being reorganized
• Based on the layout reorganization 7 big projects were introduced basically in the same space for improved space utilization (5 big new projects introduced in the period 2014-2015)
• Introduction of "one pierce flow" principle for high runners (PSS EC and ID) as shown in figures 2.28 and 2.29

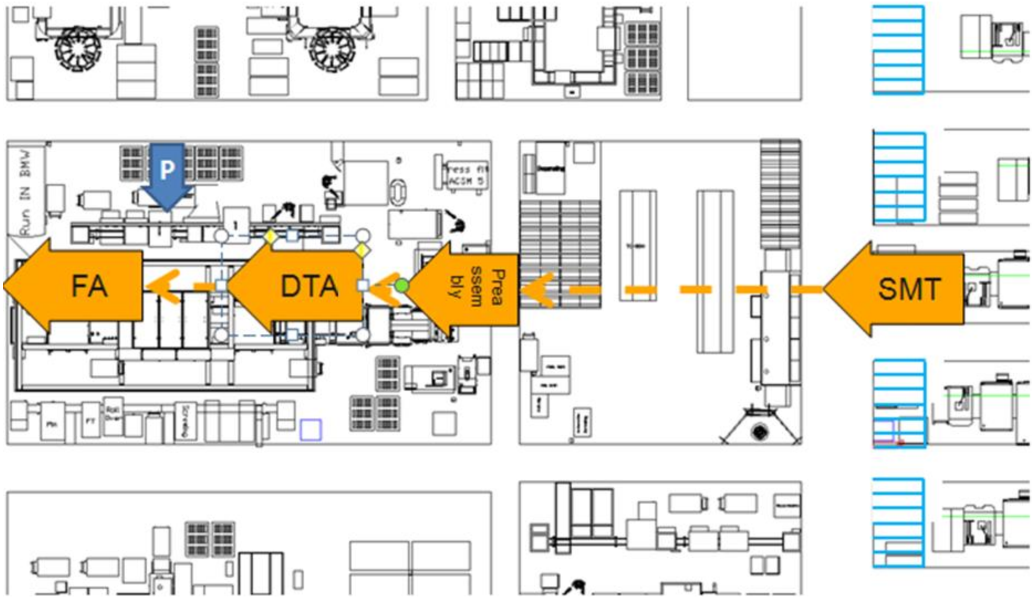

Figure 2.28. PSS flow chart for backend high runner

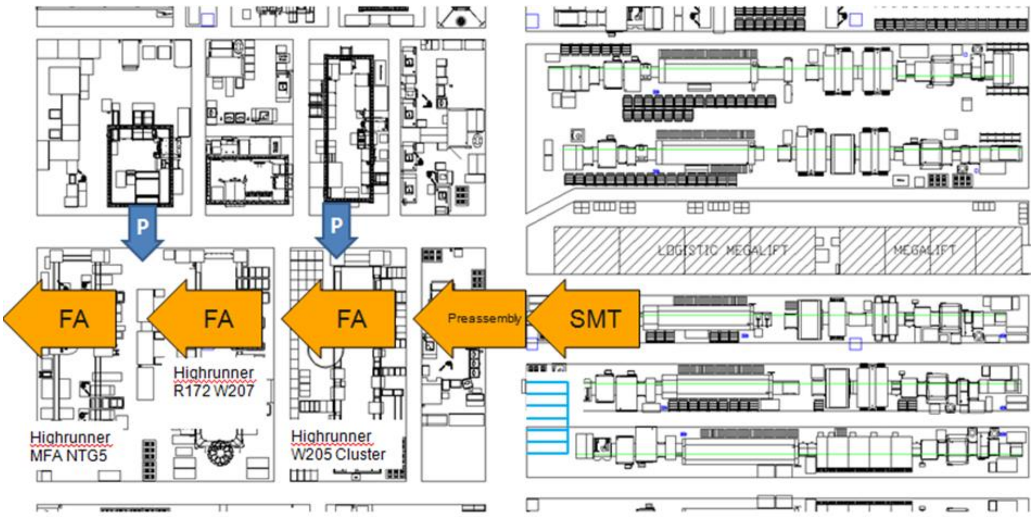

Figure 2.29. ID flow chart for backend high runner

When the flow is clear it is easy to understand where blocking points are that need improvement and also how to set up the organization in order to support the process flow. When the value chain is easy, the organization must be setup according the stream value flow. This means that, after the layout changes, we must optimize the organization to support and improve the activities in order to reduce stoppages in the production flow. The planned layout for the last part of 2016 was also implemented successfully and increased the space of the plant for improved productivity. This was very necessary in view of the fast growth of the plant and its operations, brought about by the high quality products, the best cost asset and the high customer value, all as a result of the impressive productivity figures and effectiveness rate of the employees. The layout changes for 2016 are represented in figure 2.30.

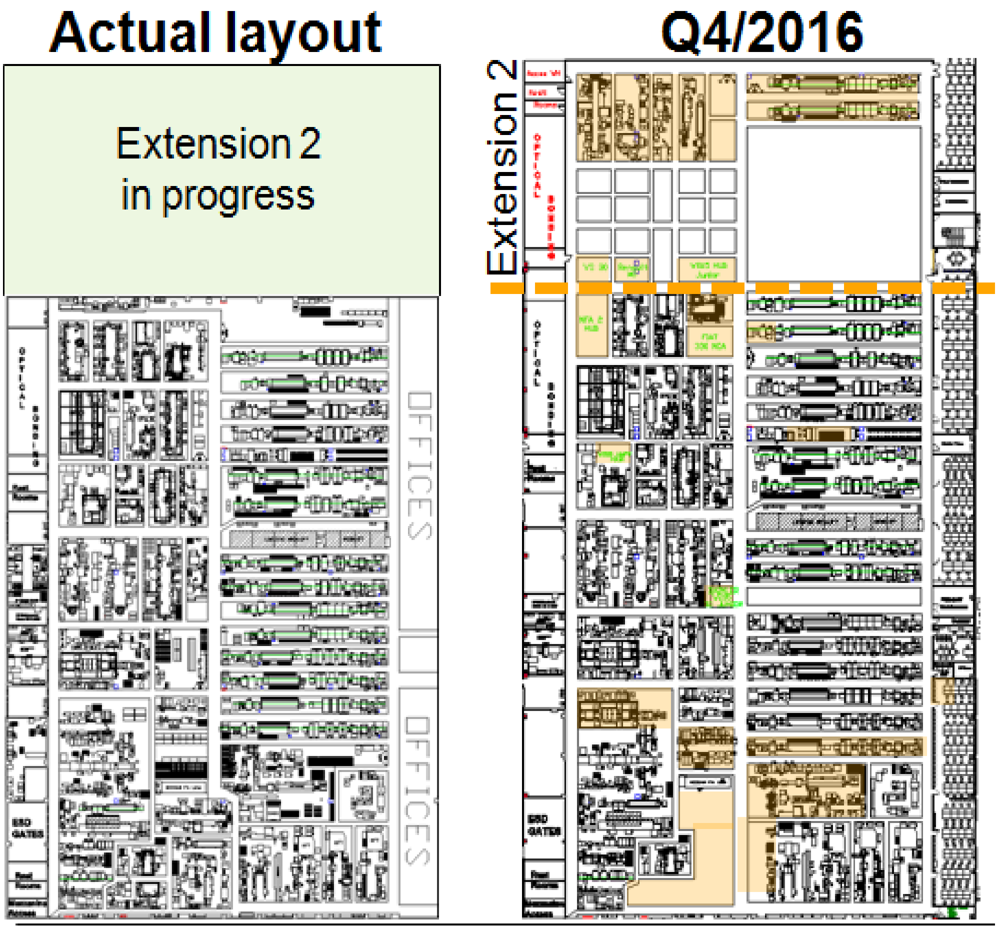

Figure 2.30. Plant extension and layout update (Q_4, 2016)

The results achieved by the new modification to the plant were the following:
1) Organizational culture: employees acknowledge the fact that the layout improvement has to be a continuous process (change management)
2) Impressive results achieved after the improvement process and all layout changeovers:

- Space reduction (30%)
- Material flow optimization and WIP reduction (30%)
- Productivity improvement (20%)

3) FFs (focus factories) will rearrange strategically assuring development potential for next year;
4) Layout project will involve all plant teams and more that 50% of personnel

2.5.2. Visual management: monitoring performance, relevant KPIs and output levels

When the layout is optimized and the right organization is in place, then it`s necessary to visualize all the relevant KPIs and control the production process in real time [87]. Visual Management is a Web Tool that helps us see what happens in the production area for Front End and Back End – all this in real time.

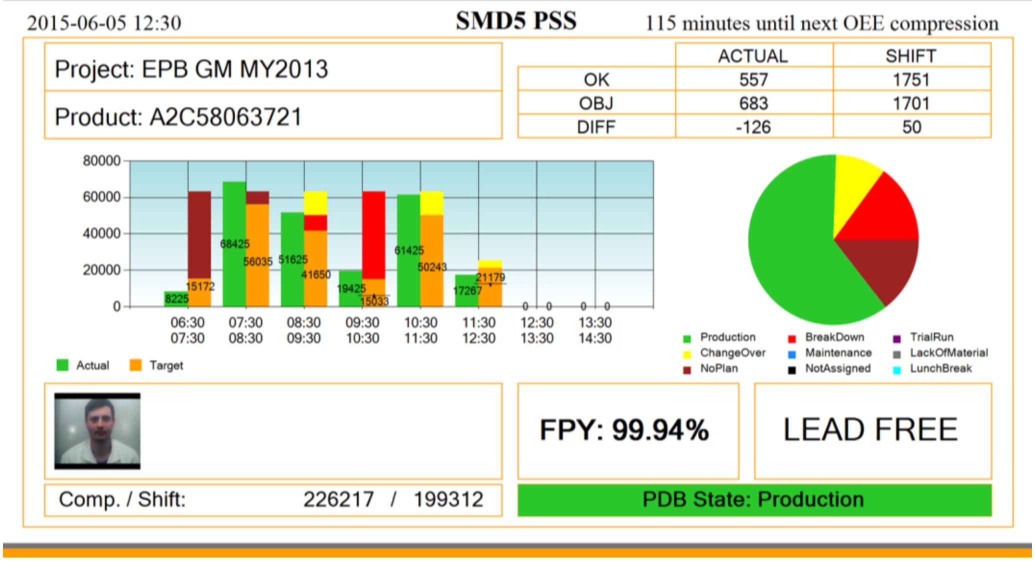

Figure 2.31. Front End view

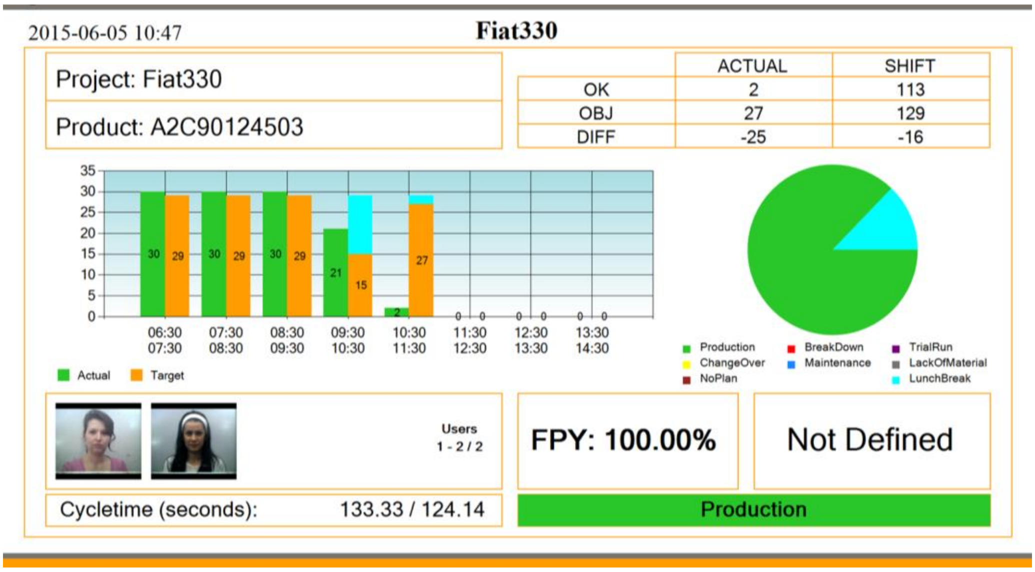

Figure 2.32. Back End view

The visual management tool used within the plant and its main features and performance indicators is presented in figures 2.31 and 2.32, from which relevant data and information can easily be extracted to source for a thorough analysis upon employee productivity and differences in shift output levels.

This tool allows us to see all production parameters on a certain selected line. The layout contains the following informational zones:

- Line name and date/time (top)
- Project and product (top-left)
- Parts output and targets for current interval and whole shift (top-right)
- Outputs and targets bar chart for shift intervals (components for Front End and parts for Back End)
- Line statuses (in the form of pie charts for the whole shift)
- Working users – on multiple pages if the count is greater than 4 – and output components / cycle time (bottom-left)
- First Pass Yield (FPY): current line status and paste type / time spent in current status (bottom-right)

For each shift interval, the bar chart shows actual line output (green bar) and real / virtual target (orange and colored bar). Real target is shown in orange and indicates the actual part count that can be produced in current interval, depending on how long the line was in production status. If there are any colored bars on top of real target bar, those represent virtual target and how many parts cannot be produced because the line was in non-productive status (each color indicates corresponding status). For each project we have an A2C (company code numbering system), this is the material number that is produced on the line. We can see the target that we can produce for a specific A2C number, per hour and also per shift, also the actual quantity produced per hour and per shift for this A2C number. We can also see the difference between these two to inform the line operators how many parts they need to produce, for that A2C number to achieve the set target.

On this interface we can see a chart which is represented on each time slot for the placed components quantities on produced parts. There is another pie type graphic chart where we can see the state of the line in current shift, any modification of the line state will be reflected in this pie chart (see figures 2.31 and 2.32). Every operator that works in the line will log in to work and their pictures will be seen on Visual Management Tool interface, in the down-left corner. On the bottom of the page we can see the number of placed components from the beginning of the shift till actual time, the placed components on FAIL part and also the placed components on PASS parts. In the first textbox we will see the number of placed components of produced parts and in the second one the number of components that should be placed (number of components that should be placed on target).

Also on the bottom of the page we can see the current state of the line, signaled by color and by a specific name state: "Production", "Break Down", "Change Over", "Trial Run", "Maintenance", "Lack of material", "No Plan", "Lunch Break". "Lack of PCB" status is only available for Back End. For ID SMD lines it displays also the paste type that is applied on PSB (ex: LEAD FREE). When the line is in Maintenance status, in the paste type frame/div a counter will be displayed that shows the time that has passed since the line entered that state. Right beside the frame/div where the photos of the working operators are displayed, in another frame/div there is the FPY (First Pass Yield) value.

For each line, the productivity is given by these parameters:

- Output in units & components
- FPY
- Line statuses
- Working users

The calculation algorithm takes each production line with current shift, divides it into 1 hour intervals and for each interval it calculates outputs, line statuses and targets. The technical approach is supposed to provide effective results without too much effort from the computational part. Thus the web tool has to show line parameters as close to real time as possible, without the annoying page refresh flickering and without putting much work load on the SQL server. In the previous solution, the calculations were done inside each web page, at each refresh. That approach puts stress on the SQL server with each new client window opened and resulted in many shutdowns of IIS Application Pools.

The current solution uses a background service to crunch the numbers from data sources and compact them into some easily to read format. This service also renders the line image in PNG format and saves it into database in ImageLast field. The web sites for Front End and Back End only take this image and show it into web pages, with a JavaScript refresh interval. In this way, no stress is put onto the SQL server, no matter how many customer windows are opened, because the picture is rendered only once by the Calculation service. The flickering at page refresh is gone because the whole line image is loaded at each reload. There is no delay between page components being shown, because all of them are rendered in the same time. The page reload is triggered in JavaScript, so each customer has to have JavaScript enabled.

The formulas for First Pass Yield (FPY) and target calculation are the following:

$$FPY = \frac{Output}{Input} = \frac{first\_time\_pass}{first\_time\_runs}\,[\%] = \frac{sum(pass\ units)}{sum(all\ units)}\ x\ 100\ [\%]$$

$$Target = \frac{3600\ s - nonproductive\ statuses\ duration}{Cycle\ Time\ Product} = \frac{productive\ status\ duration}{Cycle\ Time\ Product}$$

Data sources and data provided by the real-time visual management tool focus upon the most relevant and easy to understand KPIs such as output levels, FPY rates, cycle times and components count for each part (to calculate targets and component outputs), targets for each line (depends on number of logged users) and per number of operators for each line, line statuses, current operators working on each line as well as all logins and logouts of each operator on all lines.

In addition there is an authentication software (LineLoginApp VM) for operators working on the production line and which allows and registers changes made to the status of the line by the operators based upon their personal badge. The areas of interest in the program window are: the division and the current line, the date and hour of the system, the button for the operators to be identified, the button for changing the line status, the name of the program and current version. When we have an update, the program will restart automatically without the operator's intervention and show the new version.

The system also controls access and limits the possibility to enter certain areas or make changes to the lines without having the proper authorization encrypted on the personal badge as to better control credentials and to avoid issues, being very easily traceable through the constant monitoring of the activity of every employee.

Thus, by clicking on any button, the program will step on "Authentication" module, and you need to touch the card reader with the badge. After your identification, you will have access to the next section. If you cannot pass the identification step or you receive and error message, you need to ask the supervisor to inform the technician in order to authorize the card into the base system.

The next step implies being logged in (or logged out upon departure) into the production line in order for personal work to be registered within the system and to quantity it at the end of each day to see if targets are met or not and to trace performance. After being logged in, operators can change the status of the production line according to the current situation and thus avoid quantifying time when the equipment is having problems for example.

Only authorized personnel have access to this status and may select of the following status possibilities for each line in case of an event: breakdown, trial run, changeover, maintenance, lack of material, no plan or lunch break. After selecting the new status, a window will appear where to insert a comment on this change (i.e. the reason the material is missing for the "Lack Of Material" status or the description of the fault for the "Breakdown" status).

For some changed statuses, this comment is required – see the presence of the word "Required" and that the button "Save" is disabled. The new status of the line and comment can be saved only when the "Save" button is active. This way there is a very rapid, real-time and efficient documentation of any events for every line, making analyses and reports really practical to analyze the performance of each line, operator or machine.

The visual management real-time KPIs are also visible for the operators working on a specific production line and for all employees who are in the area, therefore there is a very high level of visibility of the current performance of al lines and of all employees.

The KPIs are visually represented and are easily understandable as they provide only the most important performance metrics for the specific production line and focus only on the most relevant areas of interest as is shown in figure 2.33.

Besides having all the main KPIs represented, the graphical part is equally important as the choice of colors makes it easy to rapidly understand the status of the line or the extent to which the performance metrics and targets are aligned within the current working shift.

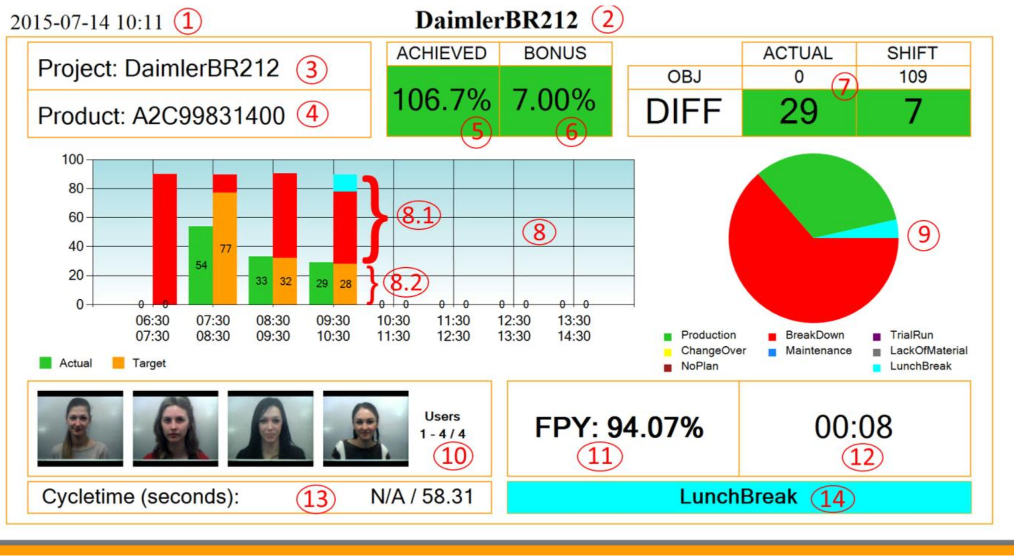

Figure 2.33. Visual management performance metrics for a specific production line

The most important parts of the interface are summed up below, being the focus areas for operators. The visual management tool thus contains the following relevant performance metrics and data:

1) Date and time of last update (year, month, day and time);
2) Name the production line (may be dedicated to a specific customer);
3) Name the current project;
4) Product name (part number or reference) currently being assembled;
5) Achieved output (compared to standard output): the achieved target percentage provides the ratio between the output of the whole shift until a given time (real time) and the target value until then on the same shift, all multiplied by 100 to obtain a percentage value:

$$T_{Achieved} = \frac{Output}{Target} * 100$$

6) Bonus percentage achieved for all shifts: it is based on the achieved target (pt. 5) and varies between 0% and 7% as follows:

$$Bonus = \begin{cases} 0\%, & T_{Achieved} < 95\% \\ 3\%, & T_{Achieved} = 95\% \\ between\ 3\%\ și\ 7\%, & T_{Achieved} > 95\%\ și\ T_{Atins} \leq 100\%, linear\ interpolation \\ 7\%, & T_{Achieved} > 100\% \end{cases}$$

7) The parts target objective means the target number of parts on the current timeframe (ACTUAL) and on all the SHIFT, and DIFF is the difference between this target and the number of part-time interval's current products and all returns. If the difference is negative (production lagging behind), the background color changes from green to yellow
8) The graph of outputs and line targets. The output target is green and orange is the target (8.2). The difference between the virtual target (which could be achieved if the line was performing full range production) and the real one (with the reduced length of time when the line was unproductive) is filled proportionally with unproductive timespans (8.1);
9) Graph with proportional duration of line status. Current status of the line can change the application VM. This area there are legend colors and names of all possible states of the line;
10) The photos of operators currently working on the line, as well as the total number of operators which are assigned to work on the line;
11) FPY: First Pass Yield for all changes calculated for the station to collect the output;
12) When the line is unproductive, then you will see a timer in the format [hours:minutes] that will display the time elapsed since the change of status. If the line is in the state "Production", the Front End displays the type of solder paste used
13) Cycle time for virtual target and real target;
14) Line current status (one of the following: breakdown, trial run, changeover, maintenance, lack of material, no plan or lunch break)

When everything is applied production becomes simple and easy to plan and is achieving the expected results. The organization becomes an improvement and learning organization, because the organization's purpose is to keep the production flowing without any stoppages: everything is clear, visible and simple to manage.

In the end, the results have been to avoid the complexity of the process by keeping the production flow constant. In this process the organization is clearly defined as an improvement organization.

2.5.3. Operational efficiency: reducing waste, adding value and improving effectiveness

Besides layout effectiveness to improve productivity and visual management to monitor performance, operational efficiency is the basis for reducing waste, adding value and sourcing high quality products for the plant's worldwide customers.

In order for the operational process to be reliable it is important to assure that several areas of the production zone are working properly as well as their associated workplaces. In this sense there could be changes required to areas such as: production line and process changes, operational changes in the workplace, improving layout and space utilization, ergonomic changes and common space improvements, logistics, employee careers and development perspectives.

All these changes and improvements are detailed in the following tables (tables 2.2-2.8) and figures (2.34-2.50) below and highlight the range of activities and relevant areas where changes have been made in order to source increased efficiency and improved effectiveness for the plant in order for it to become a highly competitive plant both at group and international level.

Table 2.2. Logistics organization changes

issue	before	after
Delivery numbers (DNs)	No identification type for DNs opened in the SAP system	Priority type for each DN opened in the system
Delivery priority	No clear overview of delivery priority at plant level	Clear overview of standard and special transports at plant level
Special transportation	A lot of time consuming related to calls, e-mails for special transports	Less time consuming for customers and warehouse colleagues
Order processing	Missing order of DNs processing in the dispatch area	DNs processing is done based upon priority type, stock and leaving hour (classification is also visible via Picking list)

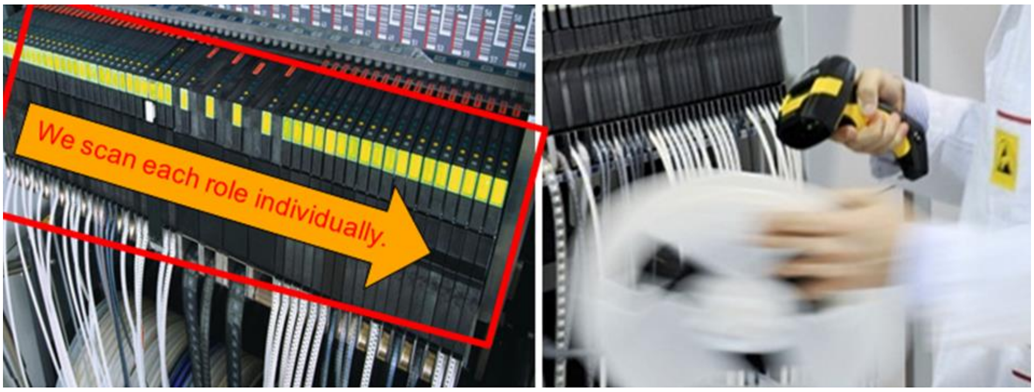

Figure 2.34. Scanning operation (before)

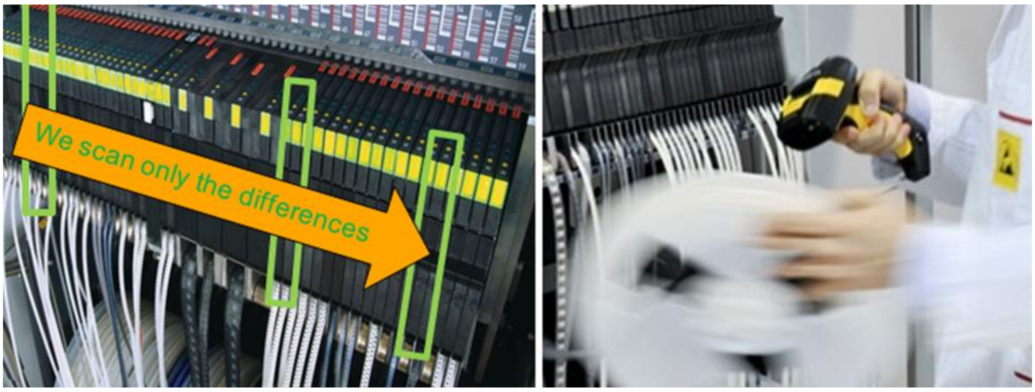

Figure 2.35. Scanning operation (after)

Table 2.3. Process organization changes

issue	before	after
Changeover (SMT ID)	For every changeover we scan all the setup roles (see figure 2.34)	Priority type for each DN opened in the system (see figure 2.35)
Trial checklist and report	Trial time around 8h per complex product or 2 simple products; in average 6 trials per week for new PN implementation	Trial time reduced to around 6h per complex product or 2 simple products; in average 6 trials per week for new PN implementation
Time consumption	In 1 month an average of 192h are used for new product implementation	In 1 month an average of 144h are used for new product implementation (saving of 48h per month)
Work flow (Ford CD4)	Fixed shift profile (each operator works at the same working place)	Dynamic shift profile (operators rotate based on light signals between station to reduce nonproductive time); cycle time optimized
Process flow organization	Buzzer check towards the end of the process and precise parking position for screwdriver	Optimization by elimination of redundant test and easy magnetic fixation of screwdriver
Output level	Output: 40 parts per hour with 3 operators	Output: 45 parts per hour with 3 operators

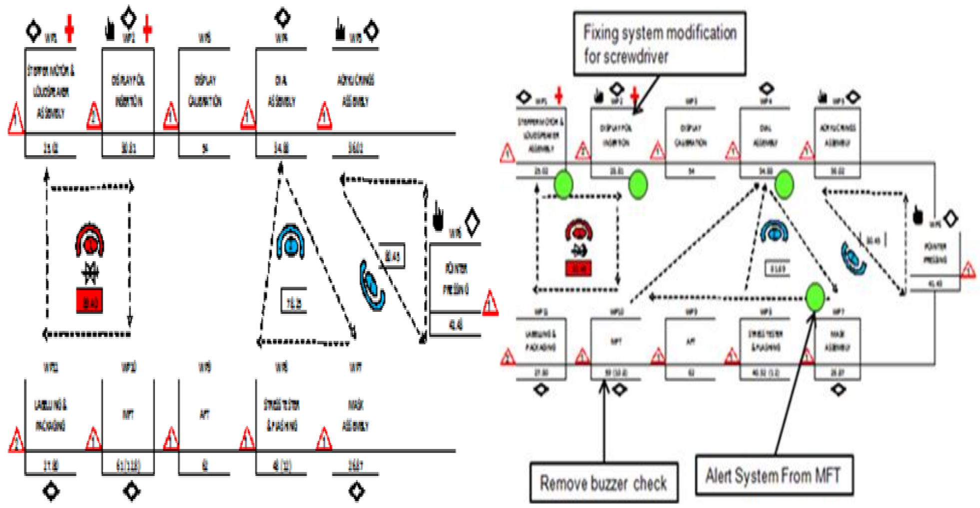

Figure 2.36. Before (left) and after (right) process flow organization improvements

Table 2.4. Production line organization changes

issue	before	after
Everyday inspection	There is no daily check of the production lines status	Introduction of daily visits on the production lines, done by QMPP (Quality Management Program for Procurement) once per day and by each supervisor per shift
Real time overview	Not regularly followed situations regarding Jidoka, maintenance, ESD check and calibration, 5S, conduct code, KPIs update on the line board, registrations, correct zone delimitation	Daily checklist available on the line board, with daily checking registration of OK or NOK, according to the check results
Checking for issues	Missing PQM (Process Quality Management) involvement in daily line following	Fast feedback at the big problems on the lines
Quality inspections	Missing regular Quality	Responsibility given to the supervisors to verify and optimize the line
Stencil inspection	The stencil verification was done in the room they were cleaned	Each desk on the SMT lines is equipped with optical check system on the stencil (see figure 2.37)
Quality impact	In case of defects, the impact in the production area was very high	Fast access and elimination of the transportation time to the wash to check the stencil
Waste	There was the possibility that the paste would not be used	Easy to use and if it is not used, it can be used on another SMT line

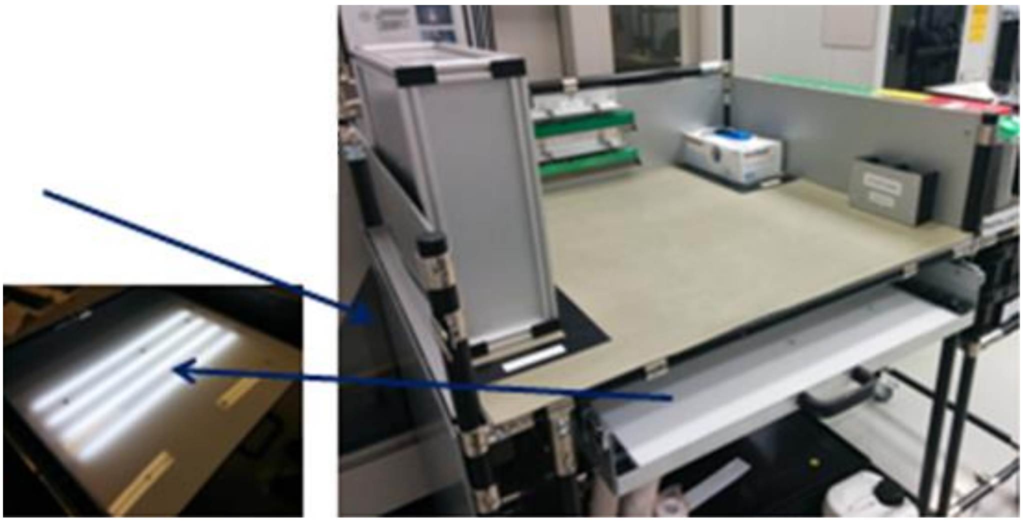

Figure 2.37. Desk equipped with optical check system

Table 2.5. Operational changes in the workplace

issue	before	after
Separator difference	There was the risk regarding dimensions change and that the operator cannot therefore introduce the PCBA in the separator	The separators are marked with the name of the products they should be used for
Introduction order	The separators were not marked clearly with the insertion order of the PCBA and the steps between it	The introduction order of the PCBA in the separators is shown
Separator composition	There was the risk to destroy the electronic components by hitting the PCBA with the margins of the separators	The separators are build out of a more flexible plastic and easy to introduce in the ESD boxes (figure 2.38)
Storage	The lead and free lead solder paste was held on a single place for all SMT lines	Each table on the SMT line is equipped with two types of solder paste without lead
Changeover of the solder paste	High time for changing the product from one type of solder paste to another	Quick access to the solder paste and elimination of the way to the former centralized storage where the solder paste was kept
Confusion	There is the possibility that the two solder paste models could get mixed	Elimination of the possibility of mixing the different types of solder paste when working (see figure 2.38)

Figure 2.38. Adjustable separators (left), solder paste storage and quick identification: before (middle) and after (right)

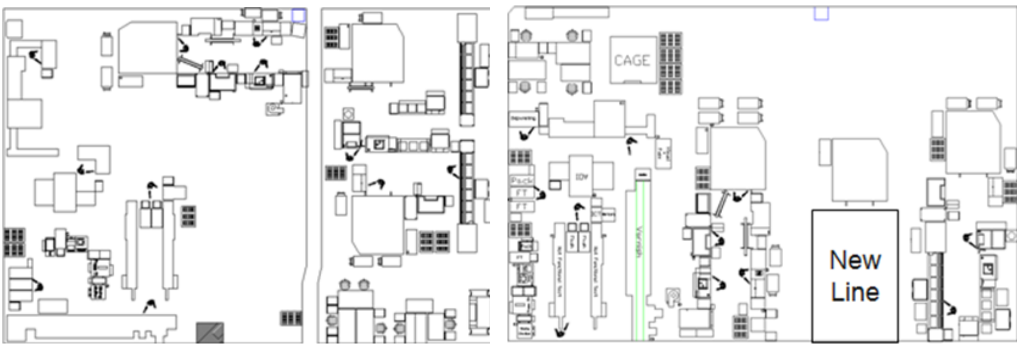

Figure 2.39. Layout improvement for PSS EC (before and after)

Table 2.6. Employee careers and development perspectives

issue	before	after
Internal skills	The career plans of the employees were not known and considered when open positions appeared	Increased number of internal promotions
Internal movements	The number of internal movements between the departments was low	Since the beginning of the GROW program, 46 employees changed their working place within the company according to their career plans
Career perspectives	The employees had no clear perspective about the internal opportunities regarding their professional development plan	The career plans of the employees are checked on a n annual basis
HR Team promotion	The employees knew the HR team member only by direct collaboration	The employees can find information about the HR team members from the HR Info Board and ConNext community
HR consultancy	The employees were asking for a discussion with the HR representative dedicated to their department, but there was no general frame for these requests	The employees are encouraged to ask for a discussion with their HR consultant in order to improve motivation, internal development or work relations. Each employee meeting a HR consultant receives a coffee cup, coffee included
Developing an internal training program	No centralization at location level for the internal trainings	Developing a Master program with already 6 sessions of internal trainings: MFEA and IQ-RM, Communication skills, MS Excel, Time Management
Communication	The internal trainings were communicated and organized only on team level or department level	Scheduling of further internal trainings within the following months: Presentation skills and negotiation skills
Overview of training history	No overview of all the internal trainings, no complete history and report for the employee level	More than 15 more employees are scheduled for the Train the Training session

Figure 2.40. Ceiling plates' replacement

Figure 2.41. Before wall plating with stainless steel

Table 2.7. Improving layout and space utilization

issue	before	after
Unused equipment	The equipment used was kept in the production area and took up unnecessary space	Removal from the production area of the unused equipment
Layout improvement (PSS EC)	The layout does not allow the integration of new production lines	Rearrangement of the production lines (savings of 141 m^2)
Line improvement	No line optimization for equipment in EPB2	Line optimization for equipment in EPB2 (see figure 2.39)
Working environment	Large deposits of particles in the environment of the production hall, from old coffered ceilings	It reduced the number of particles generated by coffered ceilings due to the composition of the new ceilings
Appearance	Visual appearance unpleasant (dirty tiles, stained)	The visual appearance became very clean and bright, everything seemed new (see figure 2.40)
Maintenance costs	Corrective maintenance and related costs due to the age and yellowing plates	Maintenance and relative cost were significantly reduced and became low
Wall plating with stainless steel	The walls were frequently beaten and dirty (see figure 2.41)	The bumps and dirt do not destroy the metal walls (see figure 2.42)
Maintaining lean aspect	High frequency corrective maintenance and repair costs	Corrective maintenance and associated costs were reduced
Plant image	Negative image for the plant	Good image for the plant
Labeling	The electrical circuit and HVAV were difficult to be localized	The electrical circuit and HVAV utilities are identified and labeled (see figure 2.43)
Safety information	Safety information was not marked	The valves and elements are labeled and marked
Repair time	Long time for interventions (waiting time) and additional installations	Short time for interventions and additional installations

Figure 2.42. After wall plating with stainless steel

Figure 2.43. After electrical circuit and HVAV labeling

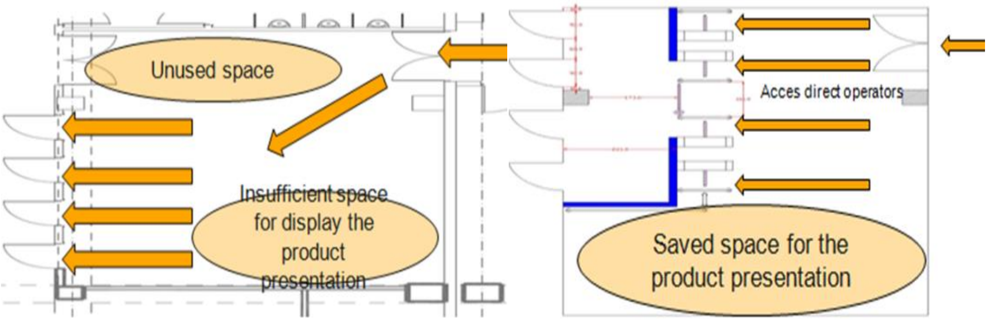

Figure 2.44. Factory entrance space organization, before (left) and after (right)

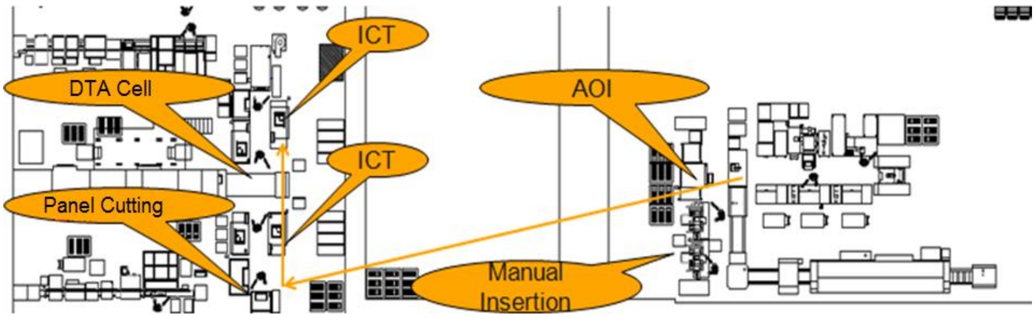

Figure 2.45. Process configuration (before)

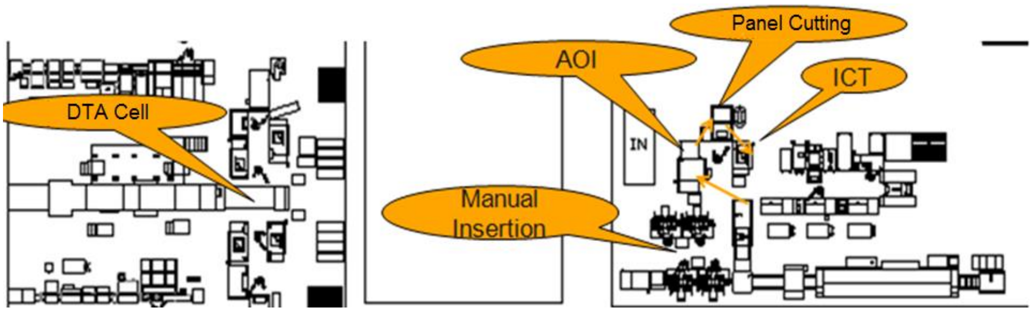

Figure 2.46. Process configuration (after)


Figure 2.47. Meeting room appearance (before)


Figure 2.48. Meeting room appearance (after)


Figure 2.49. Dining room renovation in the factory (after)

Figure 2.50. Lighting in production hall after changes

Table 2.8. Ergonomic changes and common space improvements

issue	before	after
ESD gates	Unused space in front of the door, the door being used	Space optimization flows used for personnel entering and leaving the production hall
Space for product presentation	Insufficient space to display boards with valuable information for the factory's product presentation	Increased space for panels showcasing information and reference products of the factory (see figure 2.44)
Installation of doors and turnstiles	Intersection of in and out employees and in and out visitors	Separation of in and out employees from in and out visitors
Insertion area	Complicated production flow for existing products	One piece flow for old products
Work in progress (WIP)	Processed products in buffer (WIP) between manual insertion stations, panel cutting and ICT (figure 2.45)	Inventory reduction between processes (see changes made in figure 2.46)
Planning	Production planning was complex for products involved in the DTA cell area	Simplifying planning for the manual insertion products and products from the DTA cells planning
Office wall protections	The walls were frequently damaged and dirty	Bumps and dirt do not destroy the protections on walls
Space maintenance	High corrective maintenance and high repair	Corrective maintenance and reduced costs
Appearance	No esthetic visual aspect (figure 2.47)	Visual appearance impeccable (figure 2.48)
Dining room	The walls were dirty and there was unused furniture	Walls were painted and furniture refurbished; efficient organization (figure 2.49)
Dining room furniture	The tables moved and created discomfort	Reorganization and fixing of the tables, as well as replaced seats
Coffee machines	The coffee machine (and sandwiches) were moving, were not working and were old	Replacement of the old machines, with new ones, relocations
Switch accessibility	There were very few switches for lighting and they were inaccessible	Switches were made accessible and included remote controls for supervisors
Functionality	Many lamps were turned off from a single switch	Lighting was separated into 24 independent sectors (figure 2.50)
Lighting features	Lighting could not adjust to operate lights and was not working properly where needed	Lighting can turn off in areas where it is not needed

All the members in the organization have defined visible KPIs to improve the process and avoid any distortion in the production flow.

Starting with the planning and the materials availability, the process starts with the customer demand, making the plan schedule to deliver the requested product request on time. In production there are several points that can block the continuity of the process: quality problems, break downs or difficult changeovers.

The organization has been developing and improving its effectiveness to avoid any blocking points in production. Maintenance must avoid the quality and breakdown problems and the supervisors must do their best and constantly achieve the production target.

Everybody in the organization knows their roles and responsibilities and the results are visible and easy to follow and improve. The organization has become a learning and improvement organization. All the structural and repetitive problems have been identified. The important amount of changes has made an important impact in the plant.

3. CHALLENGES AND ASSETS IN AUTOMOTIVE INDUSTRY PRODUCTION

3.1. Automotive industry production's main goal: best quality at the best cost

One of the most impressive quality statements comes from the Korean automotive industry, where Kia and Hyundai offer a standard 7 year warranty for their cars, twice the average warranty other more renowned car manufacturers provide. Research on the Korean automotive industry and its performance has been conducted for more than a decade now and hints upon its success are to be found in existing literature. For example Park, Hartley and Wilson conducted a study to explore quality management practices in the Korean automotive industry and their relationship to ratings received by suppliers from their upstream buyers. Interestingly they found no significant differences based on conformance quality amongst suppliers, but when considering the overall rating, evidence showed that the highest rated suppliers emphasized process management and employee satisfaction more than the lower rated suppliers [88]. The fact that quality compliance has become only a qualifying factor and not a winner of supply contract is supported by other authors as well and is becoming more of a constraint than an asset [58].

One main reason for understanding the relevance of these findings is that competitive advantage can only be achieved by having an effective focus on value added activities and on process efficiency within the factory. In the case of the Korean automotive industry as is also the case for today's picture, it is important to understand the difference between an order qualifier and an order winner. An order qualifier implies the supplier meeting a set of minimum requirements to first even be considered as a possible and viable competitor in the marketplace. Based on each company's policy and criteria, the standard requirements may refer to price, quality, delivery and other specific standards, which provide a range of eligible suppliers for the company for a specific component or part. Winning the order or being selected as a supplier however implies additional features, which are called order winners. Thus, to win orders a supplier must have certain characteristics or a combination of characteristics that encourage customers to choose its products and services over those of its competitors [5]. Order winners usually mean the supplier achieves a competitive advantage within the marketplace for its specific products and services. The importance of having reliable suppliers is essential for a proper working automotive supply chain, where Just in Time practices are currently an industry standard and on-time delivery is one of the most important KPIs for car manufacturers and are high-priority performance targets for all-tier suppliers.

In fact the key areas of process management which enabled the effectiveness of the Korean automotive industry were the fact that suppliers used different stage process performance charts to monitor progress and employee efficiency, the focus on reducing cycle time and having an overall approach to achieve continuous improvement within the factory. Employee satisfaction was also highlighted as an important component as the quality of the human resources, both their technical skills and mindset as well, is essential for achieving every day goals and overall objectives. This was even more important at the time as there have been a large number of labor disputes during the 1980s and 1990s in Korea and employee satisfaction and motivation were not easy to achieve or maintain by the local automotive industry. The people within a company must be implicated and contribute to improving their specific activity in order to make their work easier and achieve better results with less waste as to enable them to be more productive and increase the degree of value added activities.

By improving the process flow and reducing waiting times, the proportion of activities and processes which add value will increase and more customer value will be created as a source for competitive advantage (see figure 3.1).

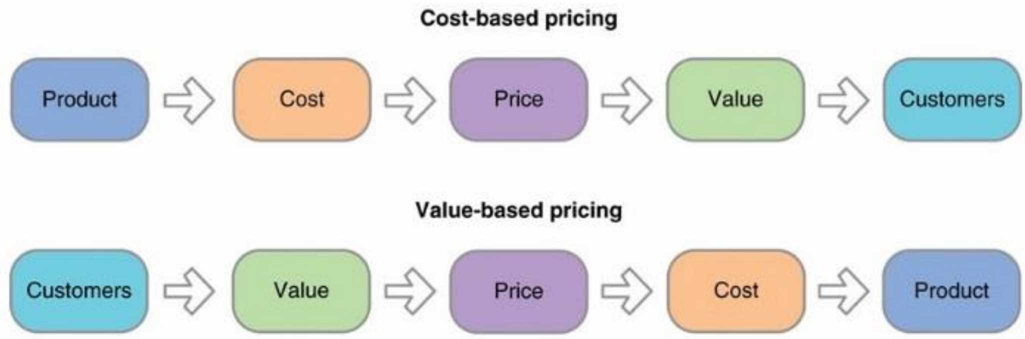

Figure 3.1. Pricing strategy differences

The automotive industry today is more dynamic than ever: changes, innovations and new technologies are constantly entering the market and adding new features to the cars as well as to the complexity of the processes and their coordination within the supply chain links. Integrating all these new concepts and features to their models as well as finding the right suppliers or adapting the technology used by current suppliers is an important challenge for carmakers to be able to maintain a competitive position on the market and be in line with car industry trends.

Flexibility is thus a characteristic of utter importance in today's automotive industry background as a manufacturing capability with the potential to impact the internal performance, competitive position and its entire supply chain effectiveness [62].

The importance of flexibility has been proven in similar internal organization challenges by Japanese manufacturers through the Just in Time production philosophy which made Toyota one of the most competitive car manufacturers in the world towards the final quarter of the 20th century. One of the main reasons was the fact that Toyota and later other Japanese carmakers had worked on improving their own processes and emphasized the role of flexibility more than the traditional North American or European manufacturers, which lead to a competitive advantage for those who successfully applied the Just in Time system.

By reducing inventory, setup times and improving productivity and quality, the Japanese carmakers could provide a very reliable car, with a better price and faster delivery than its better rated European or American competitors, achieving a remarkable competitive advantage.

Today Just in Time is applied by almost all companies that are part of the automotive supply chain and has become a reference for assessing suppliers by their customers, being one of the most representative concepts of automotive industry evolution in the last century.

The challenges of today are different as the time needed to recover investments in technology changes and devices fitted to cars has been reduced to only a couple of years, which puts an immense amount of pressure on carmakers to try to balance out these costs and keep an effective production flow with as little distortions as possible into the production process, layout and equipment necessary to support manufacturing these products and delivering them to customers according to their requirements.

Skinner was one of the first authors to identify this issue and noted the importance of the company recognizing the need for flexibility in order to justify investments, costs, benefits, but also certain trade-offs.

Flexibility in order to produce many products implies using different manufacturing policies than for handling severe volume fluctuations and it is important to acknowledge that prioritizing the global effectiveness of the company is a better target rather than rendering individual activities and processes more efficient, as only the whole set of linkages can provide value to the customer [109].

There are 5 important dimensions of flexibility in the automotive industry, which are also recognized by the specialty literature: machine flexibility, labor flexibility, mix flexibility, new product flexibility and modification flexibility [62] and are summarized in table 3.1 below.

The first two types of flexibility are clearly important in order to achieve efficient added value processes within automotive industry, whilst the latter are the more recent challenges.

The relevance of having a mix of models was demonstrated by the competition between Ford and General Motors, which lead to the end of the iconic Model T's domination and meant a change in the car industry rankings as GM overtook Ford thanks to a policy of different models which could better cover the needs of the market.

Today most of the car manufacturing companies have a large variety of models in order to address the different needs customers have when choosing to buy a car for several reasons (mobility, business, family, leisure, prestige, etc.).

New product flexibility implies being aligned with innovation and market trends, which have had a spectacular development in the last decade.

Table 3.1. Flexibility comparison between American and Japanese car manufacturers (adapted after [62])

Flexibility dimension	**Range-Number**		**Range-Heterogeneity**		**Mobility**		**Uniformity**	
	American	Japanese	American	Japanese	American	Japanese	American	Japanese
Machine flexibility (stamping press)	limited	high	zero	zero	long setup times: 8-24h	SMED: less than 5 min)	moderate (lower quality)	high
Labor flexibility	limited rotation of employees	high rotation of emplo-yees	low (more specia-lization and job classes)	high (less speciali-zation and job classes)	low (harder to switch)	high (easier to switch)	moderate (low): less than 48h training	high (standardized methods): more than 380h training
Mix flexibility	mode-rate (45 models)	high (85 models)	Mode-rate	high	low (3 times a year)	high (12 times a year)	mode-rate	moderate
New product flexibility	low (1 per year)	high (5 per year)	high (includes cars, vans, pick-ups)	low	low (60 months)	high (46 months)	low (50% delayed, 6-11 months quality/ productivity delay)	high (only 16% delayed, 1-4 months quality/ producti-vity delay)
Modifica-tion flexibility	high	mode-rate	high	high	high	high	moderate (some variation)	moderate (some variation)

Currently there are many ambitious projects already under way and soon these innovative technologies will be part of the cars driven tomorrow and in a short horizon will probably be fitted as standard to most car brands (multiple driver-aid features, autonomous drive, smart windscreen displays, interconnected vehicles, etc.).

These changes however impose modifications for both the car manufacturers (modification flexibility) as well as for their suppliers at all different levels within the supply chain.

Koste and Malhotra's research showed interesting results as American producers achieved a higher level of modification flexibility than the Japanese car manufacturers.

However Japanese carmakers had achieved significantly better results in machine, labor, mix and new product flexibility [62].

This comes to prove the fact that Japanese companies may not be at the peak of innovative features or new car models, but they have a very good capability of creating a highly efficient internal process and providing added value as well as integrating their Japanese supply chain partners from the automotive industry within this approach.

Without having a strong organizational culture oriented towards performance and customer value, the links of the automotive supply chain will not be able to provide competitive products and support these technological advancements in a highly complex and harshly dynamic car market.

3.2. The challenges of agile manufacturing in automotive industry production

In automotive industry as well as for any other manufacturing facility one of the main performance indicators is productivity or the output volume the factory manages to produce and is of importance for generating economies of scale and lower unit costs. Depending upon the product mix and their respective customer demand a company may select to either have assembly lines dedicated to one specific product with no changeovers throughout the process (thus keeping a continuous flow) or to have a multi-purpose assembly line where multiple products can be produced after changing certain machine settings (thus achieving a dynamic product variation according to customer demand).

Both of these line designs have their advantages and disadvantages, for example a one product only assembly line requires dedicated equipment and settings for only one product and should the project be dramatically changed or the customer lost, the machine could well not be used for producing other similar components.

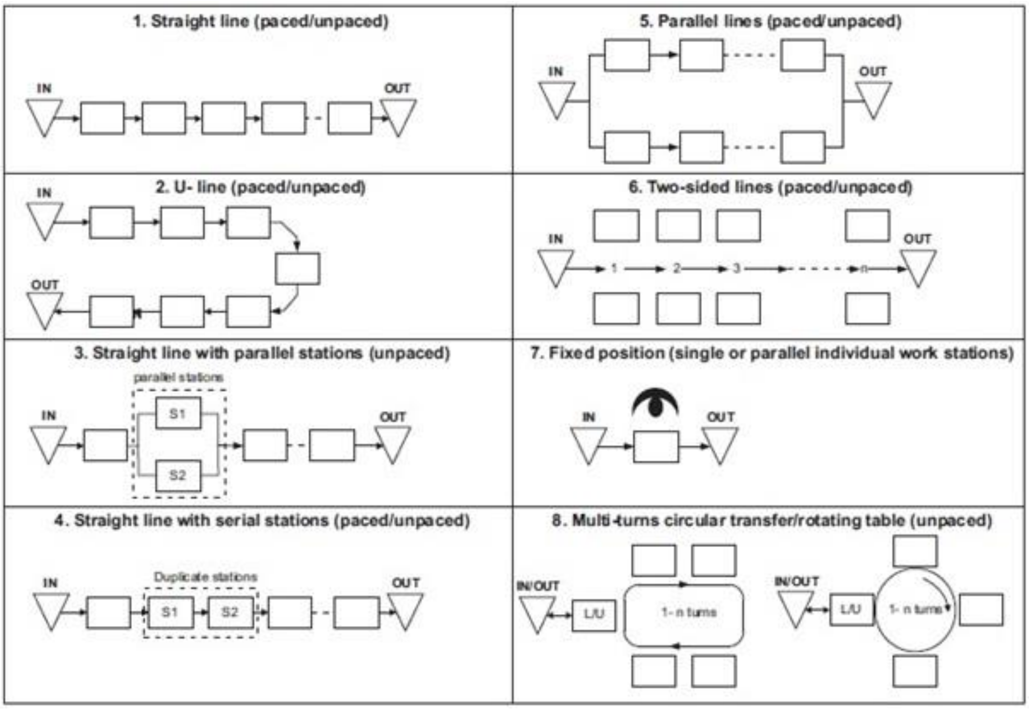

Figure 3.2. Alternative assembly layout configurations (adapted from [13])

On the other hand when employing multi-purpose equipment which requires change-over for different components or projects, this may lead to human errors, or sometimes inadequate planning may generate delays in production not only for one product, but for the entire product range, as stopping the machine immediately affects all other planned work. Having multi-purpose equipment within a multi-product assembly line also implies the operators having the necessary skills to keep the process flow and planning schedule running properly.

In order to achieve desired results (in both product quality and productivity) it is important to have a good relationship between assembly configuration layout and operator ergonomics when choosing the functional organization alternative (see figure 3.2).

Good ergonomics reduce the risk associated with low productivity which can be caused by incurring injuries at the workplace leading to absence, medical insurance and rehabilitation. A proper design of the workplace, its associated tasks and their correct working position as well as eliminating unnecessary movements help avoid fatigue and create a decent working environment for the operator, increasing his motivation and his productivity [13].

First-tier suppliers in automotive industry usually have more complex products in their manufacturing process, which requires having a very well organized flow of materials and parts between workplaces and a continuous process flow with no disruptions or bottlenecks. The important aspect is that of having the whole image of the manufacturing process and improving the overall result by properly adjusting the component workstations.

One of the main manufacturing philosophies used in automotive industry is lean production, an approach which tends to achieve an efficient overall manufacturing process, by using less input, creating added value for an improved output and reducing any activity or process which is considered wasteful and does not create customer value. In order to achieve this leanness certain specific manufacturing principles are applied such as Just in Time (JIT) or Kaizen in order to achieve a high quality product at the end of the process which is competitive on the market.

One of the best definitions of Toyota's lean production system is provided by Bayou [14] who also points out the main advantages of the Japanese concept. He outlines that the lean manufacturing philosophy helps companies shorten their lead times and reduce costs by eliminating and avoiding further production of wasteful activities, thus also improving employee performance and their skills and ultimately providing value added products for high customer satisfaction. This approach helps the company achieve a combined efficiency-effectiveness result which is the source of sustainable competitive advantage, as shown in figure 3.3.

The lean production philosophy also helps in implementing continuous flow production, preventive maintenance, total quality management (TQM), focused-factory production (the concept of "flow"), cycle-time reduction and bottleneck removal for a smooth production flow. These elements also support the reliability of the set planning objectives and a source of competitive advantage for the company. This approach is successful if all the people in the company have the right and common mindset of focusing on customer value and work together as a team to achieve results and improve overall activity where it is possible.

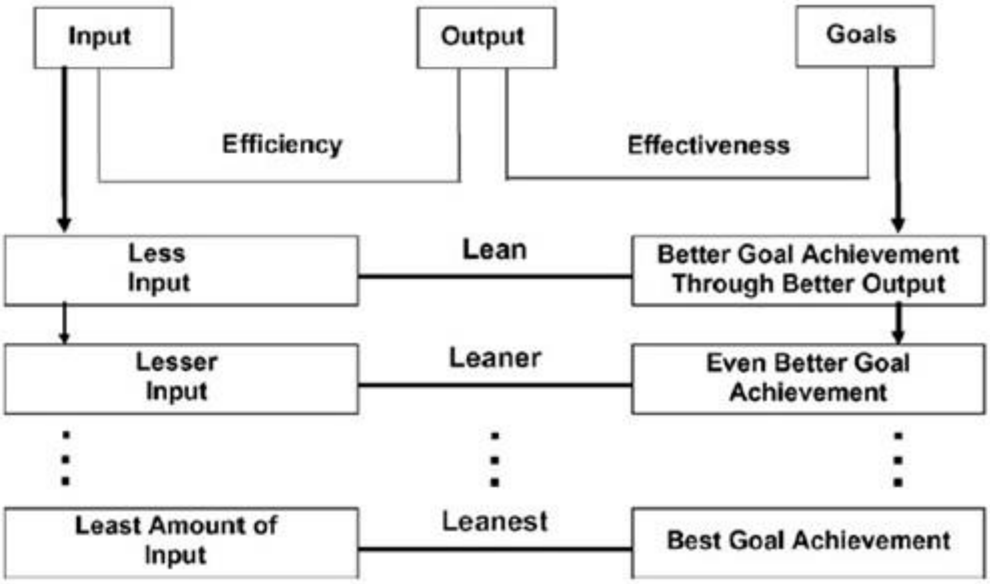

Figure 3.3. Continuous improvement process within the lean management philosophy (adapted from [14])

The benchmarks in this area are the Japanese manufacturing companies, where Toyota is the leading car brand. American car manufacturing companies have tried focusing on solely applying the Toyota Production System (TPS) concepts in the past without the expected results, because they did not understand the importance of the whole philosophy of lean, which is a lot more than its mere component concepts. More recently studies indicate that progress has been made by the American carmakers, as Ford is applying lean manufacturing better than General Motors, but sill behind Japanese car manufacturers as is Honda, for example [14].

In order to achieve good productivity figures and increase the output-input ratio (the rate at which input quantities are transformed into output quantities) it is necessary to fully understand the process, individually, in its links with other upstream or downstream processes and in its whole. This allows for a complete overview of the manufacturing process and provides the needed understanding to know where improvements or even redesigning workstations are possible and may lead to increased efficiency [104].

Achieving productivity is not easy however as automotive industry is faced with very dynamic technological and product changes throughout the entire supply chain. Suppliers and carmakers need to have the ability to react on time and implement all these changes within their processes and have skilled people to be able to sustain the constant product modifications that have arisen in recent years in the automotive industry. Several manufacturers employ specific practices in order to increase their ability to respond to changes in customer demand as quickly as possible. Supplier responsiveness has become an order qualifier for most of the automotive supply chain, but having a superior responsiveness capability than the market average has become an asset to gain competitive advantage and an important incentive for companies to become more agile [54].

The basic concepts that need a high level of effectiveness to achieve agile manufacturing come from the lean philosophy and are: Just in Time (JIT), Total Quality Management (TQM), Total Preventive Maintenance (TPM) and Human Resource Management (HRM) [107]. Although there is extensive research in the specialty literature about the differences [119] and implications [43] of lean and agile manufacturing, the advantages and goals of each of these approaches should be combined in order to achieve best results. Basically agile manufacturing focuses on certain features as are as speed, flexibility and responsiveness to changes in order to achieve a high customer service rate [125], but these are also the effects when properly applying the lean manufacturing philosophy. In addition there is also evidence which supports these two manufacturing systems being commonly used as to enhance effectiveness of results, especially within supply chains as complex and demanding as is the case in the automotive industry [64].

Judging by the main features of both lean management and agile manufacturing, both are essential to face current automotive challenges in terms of cost pressure, customer value and flexibility as the target of achieving agility first presumes a certain degree of leanness, however leanness does not require the prior presence of agility [77].

The harsh competitive nature of the automotive industry, the pressures on high reliability of the automotive supply chain deadlines towards car manufacturers and the dynamic new technological changes in product complexity are the drivers of performance improvement throughout the industry, and only by properly combining all the available manufacturing tools, principles and concepts can best results be achieved on short-, medium- and long-term.

3.3. The importance of customer focus and a value-oriented approach

The issue of inventory is also a sensible matter, as ideally a company will have little or no inventory as it is a source of cost and requires additional space and handling, is not adding value and does not provide customer value. However it allows for production to keep its continuous flow in case there are supplier shortages, problems in production caused by breakdowns or planned stoppages and are an important buffer to support proper operational performance [25]. Therefore it is the task of the production and logistics department to assess the right level of inventory needed throughout the different stages of the manufacturing process in order to both meet the physical needs in production as well as the financial constraints of carrying excessive inventory.

The manufacturing strategy in automotive industry has to be very flexible and ready to adapt to dynamic modifications and have a good balance of the main expected features: cost, quality and delivery accuracy as well as a high level of effectiveness. Volume flexibility was the first challenge associated with flexibility as it assessed the capability to change the output volume of a manufacturing process according to customer orders which reflected actual demand fluctuations [97].

Currently however volume is only one part of flexibility as technological advancements are also imposing product, equipment and skills adaptability upon suppliers, which sometimes need additional investments and have only short timespans of orders, which make it difficult to have a sustainable return on investment for smaller companies without support from its downstream more stable financial partners. The level on which business collaboration is being performed often is decisive as high-tier suppliers often get a premium price and firm multiple-year contracts to supply these parts in exchange for high reliability order deliveries from their customers.

Value stream mapping (VSM) is one of the most important tools to source customer value and competitive advantage within the lean manufacturing philosophy. VSM focuses on cost reduction by eliminating non-value adding activities which are considered wasteful and its ultimate goal is to create a flow of customer value adding processes that are to be performed as efficiently as possible as to obtain best possible results. As is the case with other lean management tools as well, when used appropriately the VSM approach can help significantly reduce and even eliminate waste, maintain a much better control and overview on inventory, improve product quality and ultimately obtain better overall operational processes control and financial results for the company [1].

Basically the value stream concept is a collection of all activities and processes (whether they add value or not) that are necessary in order to pass a certain product through all stages of the manufacturing process of the company from the input of raw materials until the delivery phase to the customer. As is the case with lean, the VSM approach also means emphasizing the overall result of all processes and not just looking and improving the individual component processes.

The main idea is also to work on the linkages between processes and assure they are working in a continuous flow without disruptions and produce added value. The VSM concept is similar to the PDCA cycle or Deming cycle, as it first requires understanding the way the processes work and are interlinked in the current layout, then designing the future layout and the new linkages between the improved more value adding processes and finally implementing the solution and monitoring its progress and results according to objectives and expectations.

Obtaining an effective VSM throughout the company implies having no disruptions in production, which can only be achieved through preventive maintenance (TPM). Total productive maintenance should also ideally be planned in such a way that shortages and waiting time created by this regularly planned activity result in minimal disruption of flow within the facility. TPM’s main advantages are the reduction of random machine breakdowns, necessary carried inventory and planned lead times which usually translate into an increase in overall equipment effectiveness (OEE).

The results of applying TPM were also documented at the Volvo factory in Gent, Belgium, where prior reports showed OEE figures in the company ranged between 66% and 69% before implementing TPM and then went up by 30-35% to 90% after TPM was implemented. This impressive result in efficiency was possible as a result of eliminating machine breakdowns and other random minor stoppages [69].

Applying the VSM approach should be done within the lean philosophy to combine both the focus on added value activities and elimination of waste and achieve best results. VSM within a lean management type approach should start from identifying the value of processes, then the process value stream, the process flow, the pull factor specifications and leaning towards process perfection through continuous improvement [78].

VSM is one of lean management's most effective and simple tools and can be summed up in a three-step method. First, producing a diagram showing the actual material and information flows (current layout/state) giving a clear overview the way the actual process operates. This first step is normally created while actively walking down the production line to have a proper assessment of the real situation.

Secondly, a desired future projection of the layout is proposed (future layout/state) highlighting the root causes of current waste. In addition the future layout would already integrate process improvements with financial impact (cost reduction) to the process flow and its interlinkages. And last there is the implementation plan (new layout/state implementation) which is then carried out in order to meet the established project objectives, but is always ready to be adapted through a continuous improvement (Kaizen) approach [38]. Assessing results can be done by comparing output per man hours and/or backlog quantity on daily basis prior and after implementation of the new layout.

A simplified overview of the key elements within the Value Stream approach is provided in the following sequence:

1) customer and his requirements (e.g. delivery frequency)
2) main process steps (in the right order, including undocumented work)
3) process metrics (process time, waiting time, first time quality pass ratio)
4) supplier with specific material flows (using a value stream walk-through)
5) information & physical flows (how each process prioritizes work)
6) overall performance of the value stream (e.g. total lead time) [118]

This approach helps in understanding several key aspects of the manufacturing facility's performance figures as is the takt time for example. Takt time refers to the frequency of a part (or component) that is produced by the facility. In other words it is the average time between the start of production of one unit and the start of production of the next unit, usually set in order to meet customer demand.

VSM also help remove or "feed" bottlenecks, which can appear within a process (from a chain of processes) and have limited capacity, therefore reducing the capacity of the whole chain. Other important information VSM can provide relates to certain manufacturing or layout constraints, inventory or queue times and can help managers identify where flow and process continuity can be improved to maximize current or future layout's effectiveness [28].

3.4. Changes and challenges in automotive industry today

Today the automotive electronic factories have to adapt to the following main challenges:

- Production in automotive is focused on cost reduction and internationalization, but without quality compromise;
- Product Life Cycle reduction (PLC) from 3 years to 1.5 years;
- Infotainment & communication devices are in big grow;
- Consumer electronic products extend presence in automotive market;
- The modern car is more an electronic and software product than a mechanical one

Cost pressure in automotive and internationalization comes not only from direct and indirect customers pressure, but it is also amplified by the fact that more and more typical non-automotive products are integrated in the car and also non-automotive electronics and related software products enter the automotive market (for example infotainment suppliers). So, the automotive factories are forced to produce with automotive standards of high quality and reliability at the cost of consumer electronic market. This means that continuous optimization of internal processes, 5S, Lean manufacturing and 6 Sigma are mandatory parts of the daily life not only in today's but also in the future factories that strive to achieve competitiveness [89].

Faster Product Life Cycle imposes factories to rapidly introduce new products and variants with reasonable start-up cost and short implementation time in the production. The problem is actually not so much the PLC reduction time, but the rate at which it is reduced, which sometimes reaches 50%, which is considerable. This means a huge pressure on the technical and organizational part of the factories to not only reorganize their schedule and focus upon effective implementation, but to also uphold the imposed quality standards at the same level as before, which enables a massive overall challenge. A possible solution for the mentioned PLC reduction cycle is to focus on clever automation, multiproduct line concepts with easy and efficient change management and visual management processes [114].

Future cars have an increased **use of electronic equipment**, from additional features to safety and control devices as the cars become electronic and related software products. Usually more than 60 electronic units are connected and communicate between them. Even more, the new development goes in the direction of car to car communication, internet communication and semiautomatic/ automatic software update, video stream processing and gradually semiautomatic/ automatic driving will become usual in the following years. Under this condition the future factory production equipment has to deal with high complexity electronic units, production test equipment has to simulate the real car environment and to manage a lot of product software variants and changes. The testing of electronic units is changing from classical in-circuit test (ICT)/ test point access to boundary test and complex hardware/ software self-testing using design for test approach from the start of the product development.

Consumer electronic companies have entered more and more in the automotive market, based mainly on new communication, infotainment and aftermarket solutions. Considering that customer electronic usually focus on pragmatic approach regarding production process and cost reduction the automotive production will be focus more and more upon simplification, improvement and people knowledge in order to keep the competitive advantage and to adapt to the new environment.

The range of electronic and software products of today's modern cars have made the mechanical features secondary in the development efforts of the manufacturers. The emphasis upon this new equipment and the tendency to develop the use of electronics in several important car mechanic features also means adapting manufacturing characteristics. Fast production line reconfiguration, automatic product variant management, production line adaptation and complete product traceability database combined with high degree of automatic solutions are mandatory elements for the future factories.

The future automotive factory has to be an intelligent system with a very strong IT/ software structure that supports not only the technical needs related to production processes, but also integrate decision making software solutions for all the factory values stream.

Considering the mentioned challenges in automotive industry it becomes more obvious that future company assets and efforts of management will concentrate on:

- How to make improvement and adaptation part of everyday work of organization;
- How to develop and utilize the capability of everyone in the organization to repeatedly work towards the common goals and achieve new levels of performance;
- How to enable an organization to have the power of handling dynamic, unpredictable situations and keep satisfying customers.

3.5. Production flow principles and systems in automotive industry

The analysis of added value in the production process will provide a valuable conclusion of the effectiveness and productivity of the internal processes and will support the "system concept of production".

This concept will support the interlinked activities and help reduce production costs, increase the quality, increase the process flexibility and finally improve the overall performance of the plant [110].

One of the main elements of efficiency within a manufacturing facility is for production to work in continuous flow, within a system that allows detecting all the constraints and improving capacity of the bottlenecks.

This process is very important because if the complexity of the process is too high then it is not possible to make the right decisions regarding the production process as a whole.

Another important element is the emphasis on strong fundaments in the production realities where the need of process simplification and constraints reduction is mainly represented by a couple of organization techniques:

• **the concept of flow**: this enables one of the most important features of a high performing and productive manufacturing plant, the uninterrupted flow of production ranging from material, process, product all the way to the information flow; this concept also allows for further improvement of the flow of production, helps creating a clear production concept per product family and has only one point of planning;
• **no inventory in the line**: one of the advantages of the concept of flow is the fact that there is no need for inventory at intermediate stages of production, which translates into savings in required space, handling operations, multiple additional control areas and also financial burdens
• **clear visualization** of all the process deviations: introducing and having an effective process flow within the production area requires having reliable, on time and real time information and data about the actual state of the production targets (output, quality, status information, etc.); this enables monitoring the progress of production and assessing the extent to which all important productivity indicators are met within each step of the production process
• **improving material flow and plant layout**: the dynamics of a manufacturing plant, especially in automotive industry, is very high, therefore new projects are always under way, creating the need to improve current performance as well as sometimes adapt or even change the plant layout in order to render the activity more efficient; the focus on continuously improving flow is a proactive approach which will in time lead to increased productivity and source better cost structures through economies of scale
• **no buffers or bottlenecks**: the reliability of the flow principle and its performance is related to an easy and very compressible production flow without buffers and without bottlenecks; this is important because buffers would request extra time (for processing, handling, waiting, etc.) which is unproductive and wasteful and therefore a target for being eliminated; on the other hand a bottleneck will provide the flow rhythm of the production line, therefore it needs to be constantly "fed" in order to have the maximum possible output and not reduce the productivity of the line and create inventory

The automotive industry established in the Eastern countries is becoming quite important (Skoda in the Czech Republic, Mercedes and Audi in Hungary, Volkswagen and PSA in Slovakia, etc.). There are three other important factors to be considered which enable a specific setting for an automotive industry manufacturing plant in Romania: competitive average salary, high educated workforce and dynamics of the national automotive industry. The common approach for many companies that invest in East Europe was to reduce investment and compensate this with labor, because it is cheaper in these countries. This concept is adopted by most of automotive industry companies located in Romania, but the situation is not the optimal, because machine operations cannot be substituted with people [85].

Often the plants located in Romania are trying to optimize the equipment utilization and are not focusing on having room for extra capacity, because of unexpected problems such as lack of materials, breakdowns or even quality issues. In this situation a lot of resources are necessary to compensate the lack of capacity and ultimately this leads the plant to be in a "firefighting" mode. These everyday problem-solving occurrences will shift focus away from further development towards ongoing operational issues and will limit the capability of the facility, not allowing it to focus on reducing costs, improving quality or becoming an excellent plant [95].

Romania is a best cost country as the overall level of salaries on the workforce market is still below the EU-average and represents a competitive cost for companies willing to open or extend production facilities in the country. Besides the cost factor, the average workforce is highly qualified and has a very good level of education which is also important for the associated jobs in the industry. Nevertheless competition is also fierce and the low unemployment rate makes it difficult for companies to sometimes hire additional workforce of maintain their best employees. This dynamic of the workforce is also related to the high concentration of the investments in automotive industry in certain areas of the country, as is the Western Region, where several multinational companies have opened or extended their businesses. The presence of two car manufacturers (Dacia and Ford) in the country is also important in supporting a network of several suppliers and the associated jobs created and supported by their complex supply chains. Despite certain setbacks and specifics of the Romanian market, with the right set up and organizational culture, any automotive plant in Romania can become the best worldwide.

Considering the importance of automotive production activities, more production systems were analyzed in detail during the last century, taken as a reference and become reference model for further improvement of the production system. For example starting with Henry Ford pioneered manufacturing transfer flow system and with Fredrick Taylor that make the scientific analyze and leanings the world began to change by bringing high-tech consumer product into the lives of common person and to focus on continuous improvement.

Back in the beginning of the industrial revolution, Henry Ford doubled his workers' wages while cutting the cost of his automobile in half. This was possible through the economies of scale and the economic growth the country experienced at the time. Ford's visionary thinking would also enable a new production philosophy that became for many years a standard approach and a reference in automotive industry. Due to Ford's production system and its effects in the industry the United States was the world leader in automobile production for almost a century until the Japanese production system from Toyota introduced new concepts that significantly improved production efficiency [105]. The two production philosophies emerged in different contexts, as the Ford production system was developed during the recovery of the American economy and would be supported by its growth trend at the time.

On the other hand the Toyota production system had been developed in Japan as the manufacturer had less financial means and thought of several means to reduce costs throughout the factory that would not need heavy investments. Although the Japanese production system had a different approach, its main features were inspired from the Ford production system as the concepts basically adapted the mass production philosophy to the changing market dynamics. Most of the Japanese principles promoted by Taiichi Ohno, Shigeo Shingo or Kaoru Ishikawa were focused upon having a better management of the internal flow of goods, implementing a continuous improvement policy and eliminating all unproductive activities that generated waste [30]. Besides individually solving different problems at specific areas in manufacturing, the concepts had to be integrated within the lean management production philosophy in order to increase their overall effectiveness and to be an important part of the organizational culture of the company [102]. This change in work organization helped Toyota and other carmakers that applied the lean management philosophy better face the challenges of increased product complexity and shorter product life cycle.

The huge pressure in the automotive industry is also shown by the number of collaborations and alliances established in order to share costs and increase mutual benefits and are also a cause for the reduction of the number of independent car suppliers (almost 10 times less than 50 years ago) as well as the number of direct car suppliers which were also reduced accordingly. The "octopus" relationships, alliances and business partnerships within the automotive industry of the car manufacturers are depicted in figure 3.4. The figure provides an extensive overview upon the ownership status (more or less than 50% control) and collaboration extent (joint venture or sharing of production facilities, certain models and engines) for the most important car brands in the world.

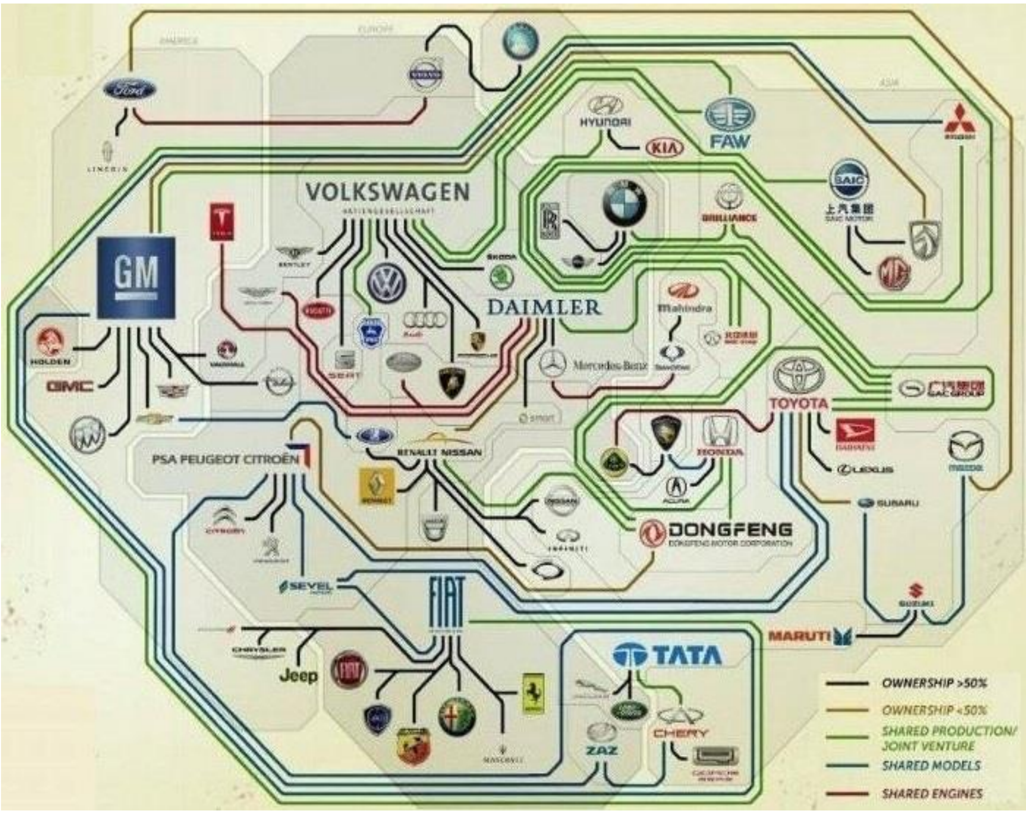

Figure 3.4. World map of automotive industry (adapted after [Teknikens värld])

These ownership schemes, alliances and collaborations have extended their reach around the entire world and today several brands are selling a very wide range and variety of cars (from small and economic models to premium and high class very expensive supercars).

Only 14 carmakers own nearly all major car brands (54 important brands), according to a report of Business Insider, which gives a very clear sign of the automotive industry's recent consolidation and concentration as is highlighted by figure 3.5.

Figure 3.5. Brand ownership in automotive industry (adapted after [Business Insider])

The car manufacturers that control the most brands (24 important brands in total) are General Motors, Volkswagen and Fiat Chrysler Automobiles, each having 8 major brands under their command. General Motors from the United States owns brands like Chevrolet, Holden, Vauxhall, Cadillac, GMC, Wulung, Baojun and Buick, the Volkswagen Group from Germany has Audi, Skoda, Seat, Volkswagen, Bugatti, Bentley, Porsche and Lamborghini (very wide range of both economic, average and premium brands), whilst the FCA corporation controls Italian brands Fiat, Lancia, Alfa Romeo and Maserati alongside American brands such as Chrysler, Jeep, Dodge and RAM.

Japan-based car manufacturers are well represented as well as Toyota owns Lexus and Daihatsu, besides manufacturing its own models, Honda makes the Acura as well, Nissan who is in an Alliance with Renault since 1999 owns the Nissan, Infinity and Datsun brands.

Also from the United States the reference Ford carmaker builds Lincolns (The Lincoln Motor Company) and Fords, whereas South Korean company Hyundai own Kia as well, whilst the India-based Tata manufactures the Tata, Jaguar and Land Rover brands. China-based Geely owns Volvo, Geely and The London Taxi Company, which builds the iconic black cabs for the UK capital.

Germany is also represented by Daimler, which controls the Mercedes-Benz and smart car brands, whilst the BMW Group owns Rolls-Royce, BMW models, and the Mini. France is also represented within this section by Renault (who also own Dacia and Renault Samsung Motors) and PSA who manufactures Peugeot, Citroën, DS Automobiles and more recently (since March 2017) Opel. Mazda, Subaru and Tesla do not belong to a large car making conglomerate, whilst Mitsubishi is part of the Renault-Nissan Alliance and Italian premium brand Ferrari is no longer part of FCA since 2016 and filed for share listing on the New York Stock Exchange.

3.6. Six Sigma

To keep the process flow there is the need to increase the skills of the technicians to solve problems in a methodical way. For this reason, a Six Sigma Training has been introduced as systematic way to solve problems. Six Sigma is a data-driven approach and methodology that gives a measure of quality within a company's overall operations.

Six Sigma uses a set of techniques and tools for process improvement (empirical and statistical methods from quality management) focused upon eliminating defects and minimizing variability (six standard deviations between the mean and the nearest specification limit) in any manufacturing process [19].

Six Sigma is basically an improvement project with the goal to enhance manufacturing effectiveness and reduce cost through DMAIC and DMADV processes. The DMAIC process (Define, Measure, Analyze, Improve, Control) is used for improving existing processes that are falling below specification and need incremental improvement. The DMADV process (Define, Measure, Analyze, Design, Verify) is focused upon creating new product or process designs at Six Sigma quality levels.

A detailed analysis at the beginning of 2015 revealed some special deviations regarding several areas in the plant (workplace ergonomics, work instructions, micro logistics, quality, engineering, maintenance and test equipment). In order to address these issues certain specific metrics (KPIs) were used: FPY (First pass yield), PPM (parts per million), unproductive time, labor time overall reduction, machine time reduction, investment reduction and overall cost reduction savings. By adding up these cost reduction along with the labor cost reduction, the total amount and overall estimated savings added up to around 2.5 million euros for 2015.

The DMAIC (an acronym for Define, Measure, Analyze, Improve, Control) is part of the Six Sigma quality initiative process and is used for improving existing processes (stabilizing processes and designs) within a manufacturing company.

Define is the first phase of the process and is focused upon defining an existing problem, improvement activity and/or opportunity (mapping the process flow), project goals (and its boundaries: the stop and start of the process) and/or customer (internal and external) requirements and expectations, which are critical issues for the quality of the plant's processes.

Measure is the second phase of the process and is focused upon establishing a set of metrics and/or KPIs to be able to control the processes and obtain a high degree in meeting customer specifications and expectations. This requires collecting data from specific sources and comparing obtained results with the initial state to see whether significant improvement has been made. An important feature of this phase is the fact that the team working on the projects decides upon what should be measured and how it should be measured, thus being responsible for establishing an appropriate measurement system.

Analyze is the next phase of the process and focuses upon determining the root causes for existing variations, poor performance and/or defects (through collected data and process map). This phase enables identifying gaps between the current and desired performance level, identifying the sources of variation within the processes and prioritizing improvement opportunities according to relevance. Six Sigma often uses complex analysis tools (statistical tests using p-values, histograms, Pareto charts, line plots, etc.), for this phase however it is acceptable to use basic tools if they are appropriate (detailed process maps, fishbone diagram, 5Whys, 5Ws, etc.).

Improve is the fourth phase of the DMAIC process and is oriented towards eliminating the root causes that hinder proper operational performance within the plant. Within this step creative, simple and easy solutions are proposed to fix and prevent existing process problems by applying the PDCA (Plan-Do-Check-Act) cycle and using the FMEA (Failure mode and effects analysis). The improvements may be local or global, in part or in whole depending upon the actual situation and are usually obvious and straightforward.

Control is the end phase of the DMAIC where the effects of the implemented changes are assessed to see if they improved current and future process performance. This is done by monitoring the improvements to make sure they produce the expected and/or desired effects and continue to bring gains or source savings. A control chart is usually used to analyze the stability of the improvements over time, monitors the processes and provides response solutions in case they become unstable [17].

A simplistic representation of the 5 phases or steps of the DMAIC is shown in figure 3.6.

Figure 3.6. The DMAIC process

The DMADV (an acronym for Define, Measure, Analyze, Design, Verify) project methodology [33] is focused upon creating new product or process designs at Six Sigma quality levels and features five phases:

Define is the first phase of the process and is focused upon project goals and customer (both internal and external) deliverables. The goals of this phase should be aligned with customer demands and/or expectations and the enterprise strategy when identifying the purpose of the project, process or service. Other steps include establishing measurable goals, drawing up a schedule and guidelines for the review of the project and the assessment of potential risks.

Measure is the second phase of the process and is focused upon measuring the factors that are critical to quality (CTQs). These factors are aligned with the required customer specifications and include measuring product capabilities, production process capability and measuring risks. Within this phase, after metrics for later evaluation have been assigned to each process, data is collected to test the metrics and apply them as an effective approach to start the production process.

Analyze is the third phase of the process and is based upon developing design alternatives and options after testing of the results (baseline for improvement). This step provides possible areas of adjustment within the processes that can source further improvement in the quality or manufacturing process. Other steps also include identifying the optimal combination of requirements to achieve the best possible customer value within the initial constraints as well as estimating the total life cycle cost of the proposed design.

Design is the fourth phase of the process with the goal of creating an improved and detailed alternative based upon the thorough analysis of the previous step. The chosen alternative is then tested and compared with customer wants and needs again to see whether additional adjustments are needed. Design elements are then prioritized and finally a high level design is developed to be first prototyped (allows identifying of error sources and making necessary modifications) before releasing the final design of the process.

Verify is the last phase of the process and is focused upon comparing the design performance and its ability to meet customer needs to the initial expectations. This step is practically continuous in order to enable adjustments and implement the best possible production process. This ensures that the chosen and implemented alternative is sustainable within its whole, can be maintained through normal operations and provides good results and high customer value.

The DMADV methodology is also known as DFSS ("Design For Six Sigma") and is used when there is the need to develop a new process (or product) within the plant, which does not yet exist, or when an existing one does not meet the set requirements/constraints/specifications, although it has been undergoing the optimization process (without the desired effect).

A simplistic representation of the 5 phases or steps of the DMADV (DFSS) is shown in figure 3.7.

Figure 3.7. The DMADV (DFSS) process

The Six Sigma methods were applied in three different areas of the manufacturing plant with interesting results: in the first area (production and logistics) there were a total of 89 projects under way which sourced savings of 0.8 million euros (average of 8,988 euros per project), in the second area (quality and engineering) there were a total of 63 projects implemented which brought up savings of 0.56 million euros (average of 8,888 euros per project), whereas in the third area (testing), the 12 projects which were introduced had the highest efficiency as savings of 0.6 million were made (average of 50,000 euros per project).

All in all for the three areas where Six Sigma was applied there were a total of 164 projects, which brought about a level of achievement of 64%, 75% and 91% within the targeted areas and savings of 1.95 million euros to the plant.

The results are very good seen as 78.4% of the estimated savings have actually been achieved with the help of the methods implementation in the operational performance of the manufacturing plant.

3.7. The challenges of cultural differences and features of the Romanian work culture

One of the most important challenges in developing a strong organizational culture is gaining the people's involvement in the proper running of the plant. Ideas, plans and tasks are easy to follow, but it is a much more complex challenge to actually involve the people, to make them always feel motivated and to empower them to bring their own valuable contribution to the plant's effectiveness. Every country has a specific manner of working and stereotypes, which need to be considered when dealing with the employees, to understand better how to motivate and to enable them to be more efficient in the long-term.

When referring to the work culture there are differences between countries: the Chinese are perseverant and patient, the Americans have initiative and an entrepreneurial spirit, whereas in Europe the Germans are renowned for their efficiency, organization and punctuality. Understanding the work culture of every country is thus an important asset to achieve competitiveness, as is the case with the Japanese employees, which are considered among the most efficient in the world and considered workaholics by Europeans and Americans. This is because they do not understand how the Japanese acknowledge work, which is for them more important than the actual result of their work [122]. They basically consider work as a form of spiritual discipline and it is more important for them than their individual preoccupations.

In Romania however the work culture is still very poorly developed according to studies conducted by the Romanian Institute of Evaluation and Strategy (IRES), as work is considered fulfilling only if it deeply related to the economic reward [56]. Thus work is important in Romania, but not because they actually cherish it, but because it is a mean in achieving another target. This is also highlighted by the fact that in Romania very few people are involved in voluntary activities, as the overall implication is very scarce due to the absence of the financial factor. On the other hand Romanians work more on average than the Europeans and often work overtime, exceeding the legal hours limit, although 50% of the companies do not pay for these extra hours at the office. Usually companies prefer to reward employees based on either company or individual performance and results (achieving established targets of turnover, profit, projects, specific objectives, etc.). This may seem as a paradox, but it actually is not, because this situation is due to the fact that Romanians are used to merely receiving their pay for the amount of hours spent at work and not necessarily based upon their productivity within those hours. When deadlines, reports and work volume start building up and time gets scarce, in order to meet the required tasks and their level of quality, Romanians usually work overtime, due to a lack of planning in the early stage of those assignments. This lack of organization generates stress and unbalanced working hours as well as a high imbalance of their productivity, causing excessive fatigue and affecting both individual and overall performance as well.

Work inefficiency is also related to a couple of more aspects, besides a proper organization of their work schedule. One of them is the fact that they do not believe in their actual work, they are not motivated by it and its actual outcome.

This is a normal consequence as their main goal is the financial factor and not the actual job in itself, but this is also problematic because they do not have any objective criteria for which they perform their work in an appropriate manner. The main driver is the interpersonal relationship with either the colleagues or the manager, and depending upon these relationships, the employee chooses which tasks are priorities or not and which tasks are to be performed and which are not, which is very unprofessional given the fact that the work relationships are stated in the work contract and not based on the subjective aspect of the working hierarchy within the company. This manner of working is not productive and does not bring full satisfaction, regardless of the financial aspect or its extent. Work can be a part of someone's identity and by changing the way one thinks about what he is doing he can actually achieve a lot of improvements and become successful, because someone who respects himself will also respect his work and its associated results [56].

Another important factor to take into consideration is generalizing the Romanian workforce: people are different and have different working styles, if some general traits are valid throughout most of the people this does not mean that it is an absolute indicator of the potential working performance of someone else. This is actually a simplistic and harmful, sometimes even hurtful, interpretation and should be avoided. Equally important is the concept of balance: excessive work, merely for the winnings, implies losses at more important levels (human relationships, family time and physical and mental health) and should be carefully dosed over time in order to assure a proper, healthy and sustainable lifestyle. On the other hand procrastinating and not assuming one's responsibilities by avoiding to do certain tasks or having a constant lack of consistency at the workplace is also something to avoid. The main idea is to use the working time more efficiently and source the best possible productivity out of the assigned time to do each and every task, based upon an overview of one's schedule. This will allow for a much better time management capability and support a proper lifestyle with balanced working hours and free time to enjoy one's other activities as well [50].

One of the biggest mistakes companies sometimes make is directly or indirectly encouraging competition among its own employees, which is very detrimental to the overall performance of the company: instead of helping each other and working together to get things done properly, they will more likely focus on performing their own tasks well and hindering the other to not do as well, all within a very unwelcoming working environment. The correct organizational culture will always encourage the personality of the employee to perform at his best level and also align with the common goal of the organization and this can only be done through good individual and team work in order to provide best performance. Work needs to be performed according to some general indications, but it is the people who actually add value to processes and activities and they need to be motivated to use their skills and provide quality work which will in turn source customer value and competitiveness for the company in the long-term.

These differences in the Romanian work culture make achieving results more difficult as they are a challenge every day and need to continuously be overcome in order to have good performance within a plant. The amount of working hours is not important, it is the commitment which is generally lacking and this is something which is affecting the performance on the long-term. This limits the possibility to involve the people in the functioning of the plant and implies having to artificially push them to achieve the desired results and performance goals. One of the most important concepts in achieving a strong organizational culture is to have a sustainable mindset of all the people working in the plant, being motivated at their workplace and also having the commitment towards the company values. This cannot be achieved if they have an excuse for every problem or for every time they do not properly perform their tasks, as solutions are needed to make things work better. The proactive behavior is still generally lacking, the motivation to do more and achieve better results for one's own career development as well as for the team and development of the company is pretty low and hinders the plant's opportunity to keep on growing in a dynamic rhythm and be more competitive in the automotive industry and its future challenges. Romanians have good and very good performances individually, in many other domains as well beside work, but as a team there are almost no important results or great performances being achieved within a team. This rather strange paradox has its roots into the recent history of the country, when the communist regime wanted to promote collective work between comrades through a policy of fellowship.

This however was never really the case as except for some isolated cases mainly caused by natural disasters or national holidays, teamwork was really scarce as an acknowledged principle and became an even shallower concept when used in conjunction with forced labor activities after the Second World War. This generated a rather negative feeling associated with teamwork and for good reason at that time, because its application had in reality nothing to do with teamwork, but more likely with using a mass of people for productivity or labor force crisis purposes. This misconception has also been transferred into education by the teachers and passed on to future generations by parents, therefore there is actually little experience associated with the real meaning of "teamwork". In school and even in higher education there are few cases when pupils and students are familiarized with working in teams or together within projects, therefore they have a more individualist oriented behavior and act accordingly throughout most of their time.

This sense of freedom and independence has also brought about a more scarce likelihood of the younger generation to be involved in voluntary activities, associations or in common friendly gatherings for entertainment, shifting further away from the main virtues of teamwork. In essence teamwork is about interacting and working together in order to achieve a common purpose and/or goal by emphasizing the needs and results of the entire group in detriment of one's own personal needs with the clear belief that the positive outcome of the entire group will also translate into a positive result for all the involved team members, thus sourcing greater rewards. This reluctant approach towards one of the most important sources of effectiveness within a plant creates an important and tough challenge to face and overcome for management in the attempt to create strong organizational culture and render a positive working environment focused upon multi-level team performance.

A more commonly developed conception however is the "people-pleaser" aspect, which is again a result of individualism and the promotion perspective, as during the dictatorship of Nicolae Ceausescu one had to pass through certain stages to get to a higher level and this could not be done without the informal and social approval of the higher-ranked superior "fellow". Romanians sometimes really lack a modest and humble behavior regarding teamwork and the individual contributions associated with this activity and its results. Usually they will actually seek to emphasize their own (and important) role in the team through a more direct or indirect approach and outline the fact that without their own contribution the work or task would not have had the same results. Overestimating one's own contribution has however a pragmatic goal and that is what counts sometimes for some people, who do not care how and by what means they obtain what it is they want. This is why Romanians feel the need and are willing to put extra efforts in order for them to be noticed and appreciated by their managers, hoping that through this behavior they will be more likely to succeed in progressing in their careers [39].

Team spirit is a very complex mindset challenge, because it can source motivation, commitment and productivity as well as support developing very good relations between the employees and improve effectiveness. Romania has lots of assets regarding workforce advantages (best cost country, average salary level is competitive, high education level of the people) and some of the capitalist values adopted are actually not bad, but the excessive focus on the financial aspect is a negative trait which makes achieving a proactive commitment and motivation difficult to sustain in the long-term.

The developing economy and the companies established in Romania have raised the overall level of the economic and financial wellbeing of the population in the last years, but in order for their performance to further increase and for the level of salaries of their employees to also increase, effectiveness and productivity need to be sustained. This is only possible if the working staff is committed towards achieving goals and targets, motivated to do the job right from the first time and proactive to support improvements and innovative changes throughout the plant.

The human resource is the most important resource of a company, because it has a high capacity to adapt and solve problems and through efficiency and commitment during working hours the people can provide added value, value to the customer and a competitive product or service on the marketplace thus contributing to a sustainable wellbeing cycle within their community on short-, medium- and long-term.

4. MANAGEMENT OF PRODUCTION IN AUTOMOTIVE INDUSTRY: ISSUES RELATED TO OPERATIONAL EFFECTIVENESS

4.1. Globalization: opportunity, every-day challenges, issues and constraints

Globalization and the opening of the markets have enhanced and widened market opportunities but have also enlarged competition amongst the main economic growth sectors, as is the case with the automotive industry. With competition getting harsher amongst carmakers, the implications of designing a competitive car industry within countries which have automotive supply chains have become more intense.

Automotive industry is of strategic importance for a country's welfare and future development as the nature of the products manufactured throughout the supply chain of any car manufacturer involves creating high added value, generates high employment figures both for the manufacturer and its high and lower-tier suppliers and uses new and innovative technologies with a multiplier effect on the overall technological development of the country.

According to recent research the main pillars in developing a sustainable supply chain for the automotive sector are related to its efficiency. Basically the car industry needs to be very effective and have a very good performance in certain key areas as is the level of quality of its local suppliers (product quality and delivery reliability), capacity to provide and fit cars with the latest technological features (availability of latest technologies) and the overall ability to engage in technological advancements of the companies within the local supply chain (company–level technology absorption) [29].

A company's business orientation has a major effect on its performance and designing a proper strategic approach can often make the difference between the success or failure of the company in a specific market or worldwide. One of the most interesting automotive manufacturer business orientations is the customer-approach the Swedish carmaker Volvo employed throughout different timespans of its business operations. The Swedish carmaker embraced a very unique philosophy of customer orientation between the 1930s and the mid-1960s, facilitated by the technological development at the time, but was in opposition and contradicted the traditional view of business orientation evolution (from production to sales and marketing) [68].

Between the mid-1960s and the 1980s however, Volvo car operations followed the automotive mainstream of the time and shifted towards being more production-driven. The overall performance of the company remained satisfactory, despite the problems associated with mass production and changes on the labor market. Surprisingly the production volumes at Volvo between 1980 and 1986 increased by more than 60% and generated high profitability in Volvo's car operations, but this was only due to the Swedish krone's depreciation [16].

At the end of the 1980's the stable growth of the automotive industry ceased and brought about a massive sales decline and rendered carmakers with the issue of overcapacity. Sales decreased, competition was harsher, customers started becoming more demanding, legislation was starting to impose tougher regulations and the car model range was in need of renewal. The beginning of the 1990s and its new challenges meant the high profitability that Volvo had enjoyed in the 1980s disappeared and for the first time in the Swedish manufacturer's history, Volvo sales fell in all its main markets (cars, buses and trucks), prompting management to reorganize its activity and targets. The goals set were an increased focus on customers, achieving shorter lead times in all processes, more efficient resource utilization within the manufacturing process and a more market-driven process design with the aim to mainly increase profitability. The Swedish car brand became profitable again starting 1994 and was bought by Ford in 1999 for around 6.5 billion USD and just two years later Volvo Cars was covering 100 worldwide markets, with global car sales of 412,000 units, 56% in Europe, 33% in North America and 11% from other parts of the world.

The Volvo case is an example of cyclical adoption of market orientation with different changes and adaptions brought about by market dynamics and economic shifts. At the beginning it is easier to adopt specific strategies, but as business grows production development and the challenges of handling a complex supply chain arise, often leading to neglecting the importance of adapting to certain shifts in market dynamics. Customer demands, regulations and shorter product life cycles add to the challenges carmakers face and the competitive nature of the automotive industry implies a more intense focus of market needs, desires and trends. Nowadays market orientation is an order qualifier and a must for the entire automotive industry supply chain in its pursuit of achieving overall competitiveness [68].

4.2. Motivation and mindset in organizational culture

Having a motivated staff is very important in order to achieve operational goals, but is even more important on the long-term as a high level of motivation will drive employees towards reaching every-day goals and lay the foundation for producing quality and competitive products.

Employees with higher educational levels have increased expectations upon their quality of life and jobs, where working in a dynamic environment with challenges and growth opportunities are considered very important and motivating and assure their commitment towards company goals [3].

A case study in Sweden at Volvo revealed 4 main principles upon which motivation was based: structural decentralization, small autonomous working groups, incentive bonus schemes and a joint approach to towards motivation through common development plans [59].

Structural decentralization mainly refers to having shorter lines of communication in order for certain areas within the company to have a better responsive capacity (e.g. production) and a certain degree of empowerment as well as feedback opportunities for their work quality and results.

Working in groups is very common in Sweden and expands the job content, increasing the ability to learn from other colleagues, enhancing motivation and productivity.

Giving bonuses to employees who attain higher productivity figures than the standard rate is an important motivational factor and generates a committed workforce. It is also important to provide regular feedback regarding performance which may further enhance workforce stability and reduce employee turnover.

Common development plans imply a more large perspective of the employee on the importance of his role within the company and future projects in which he will be involved in order to contribute with his knowledge, skills and experience and further enlarge his career development.

Volvo is also one of the carmakers which emphasizes the importance of good ergonomics within its facilities. The Swedish factory in Uddevalla achieved high productivity and quality through a wider work content (involving less repetitive work tasks than on the traditional assembly line) and better ergonomic conditions for operators working at assembly thanks to having the proper conditions to produce cars in a more "human way" [61]. The high ergonomics standards at the plant enabled the Uddevalla plant to become the Volvo car assembly plant to reach its productivity goals which was mainly due to the operators' high level of competence.

Basically by creating and maintaining appropriate conditions for specific jobs to be done properly by employees, the consequence usually enables a higher product quality ratio. Other advantages include fewer manual and mechanical disruptions as there are no stoppages and processes can run on a continuous flow and productivity ultimately increases. A good overview upon workstations and the required skills to perform operations also increased the chance of employing the right person, thereby reducing recruitment costs, training time and absenteeism rate. Ergonomic stations in turn reduce the chances of occupational injuries incurring and the company spends less on the rehabilitation of its employees. This is important to consider as for example in Sweden, all companies are required by law to implement rehabilitation measures in such situations [76].

Similar preoccupations have been carried out at Ford as well with results confirming the benefits yielded within the automotive industry by other companies as well. Although it is rather difficult to adequately measure the costs and benefits of ergonomics, there are some figures which speak about the effectiveness of these measures at the American carmaker: identifying and solving over 1500 ergonomic issues in US manufacturing plants in the United States, around 30% cost savings through the reduction in workers compensation and the rate of lost time, product quality increase, reduced injury frequency due to improved ergonomic design of workplaces, less required rework and an overall reduction in worker absenteeism [60].

Organizational effectiveness depends on a wide variety of factors, one of the most important being how the business entity in its whole and in its departments is being run by managers. Managers should seek for stability, control and efficiency while being able to be practical, analytical and rational within their approach to achieve predictability and order within their area of responsibility. Top management on the other side needs to focus on implementing value flexibility, innovation and adaptation and need to know to transmit their vision, be creative and know how to motivate and commit their people to the company goals to create strong organizational culture. Both of these qualities are essential when facing the challenges of an organization becoming larger and sometimes even more complex (management) or when the marketplace and its external environment generates changes, become more dynamic and uncertain (leadership). Managing and leading properly are usually interrelated in successful companies and they jointly contribute and/or affect organizational performance [124].

Successful leadership implies the awareness of certain key areas within the organization and looking over their proper functioning. These areas are the processes where added value is created, research and development and the people within the organization. Processes need to be reliable first of all in order to perform the jobs and tasks within specifications and without interruptions in a continuous flow. The process efficiency must be combined with the company's ability to innovate and create competitive advantages and adapt to market demands and desires in order to achieve a high level of customer value. This can only be done with skilled and motivated human resources who have the correct mindset in compliance with the company's vision and mission statement [63].

Implementing company strategy and working towards achieving results however is performed at operational level though the guidance of supervisors and managers, but there are always challenges associated with this activity and all processes need to be running properly in order to achieve desire results. In automotive industry one recent example of good management saw Japanese manufacturer Nissan overcome severe financial problems in the early 21tst century and avoiding bankruptcy. Problems at Nissan were mainly related to excessive costs, an important decrease of sales and an overall weak management. The turnaround at Nissan was due to the successful management policies applied by Carlos Ghosn, whose decisions and actions combined effective leading and managing techniques.

He managed to reduce purchasing costs by 20% by reducing the number of suppliers and supported easing the previously overly exacting specifications imposed on suppliers by Nissan engineers. He also decided to close 5 Nissan factories in Japan which also meant laying off more than 20,000 employees and other Nissan workers became restless, but the strategy was explained and a new more performance-based merit pay plan was introduced to motivate employees. Ghosn also decided to implement design modifications and make Nissan models more appealing, however he also simplified production in the other factories and made them more efficient and after only one year the Japanese manufacturer was once again profitable, after being close to shutting down completely in 1999. The impressive turnaround at Nissan is an example of the importance of situational awareness for the effectiveness of an organization and that internal processes determine what types of strategies and changes are likely to be successful in specific circumstances [40].

Assessing the different aspects of the situation and having an adequate overview upon the overall state of a company requires having a systems thinking which implies understanding the fact that all activities and processes are interlinked and it is the whole functioning or the end result which needs to be effective and not necessarily each individual component process. In order to acquire an intimate understanding of the efficiency in running operations, certain areas must be well-known: cost and productivity of each process, added value by each operation to the end product, effectiveness of each management policy, employee skill distribution, competition and its perceived competitive advantage, customer perception upon own products and services, etc. [123].

The success story of Nissan and its quick revival into becoming profitable again required mutually consistent changes from both management and operations to improve company efficiency, adaptation and human resources willingness to follow and understand the importance of the recovery strategy.

4.3. Logistics and supply chain integration

Within the last decade automotive industry has been facing a constantly changing market demand, with the increasing competition between car manufacturers making accurate forecasting a very difficult task, especially when considering supply chain management for vehicle components and main parts (e.g. engine types, options and equipment). Also building a car to specific customer requirements take time and usually ranges within 2-3 months depending upon car model and brand. Although mass customization and its associated production type (build to order) have helped manufacturers improve synchronization with market demand, the global suppliers of car plants sometimes need up to 2 months to supply certain parts depending upon transportation mode and production process [121].

Coordinating sales on the one hand and the supply chain on the other remains a serious challenge because of numerous differences in terms of associated objectives, responsibilities and management (trade-off between increased flexibility demands from sales and less changing demand requirements from procurement). Globalization and the global automotive supply chain sourcing strategies increase the lead times for supplying parts to carmakers and make the supply chain more vulnerable to demand variability from customers and markets. The supply chain vulnerability and the associated costs must be balance out to create a competitive and sustainable linkage between business partners working within the automotive supply chain [41].

Renault has established vehicle-assembly plants in Eastern Europe, North Africa and South America for its strategic purpose of gaining market share in emerging countries and at the same time to reduce the overall car production costs. The challenge for Renault’s supply chain is that its suppliers are often very far from these regions and require up to 12 weeks to deliver certain parts to the manufacturing facility, whereas the sales dealers are complaining due to the very rigid process to order cars assembled in these plants.

The Renault dealers are asked to send firm orders 9 weeks before assembly without the possibility of making any modifications in the orders later on due to the extended lead times cause by the global supply chain configuration and constraints. The impatient customers however represent a risk of cancellation and the manufacturer may be left with the high cost of having a customer-tailored car on inventory which generates additional costs to the dealership and may not be sold within a decent time horizon or at a fairly similar price to that of its initial retail price. Coordination of sales requirements and industrial constraints in an environment as uncertain as the automotive industry is a common globalization challenge for carmakers around the world and their highly complex supply chains structures and also subjective to intensive research efforts to support effective decision-making [67].

One of the most important management associated challenges for companies is to have an effective value chain process flow throughout the manufacturing facility as to assure providing value to the customer, with high productivity and an efficient linkage of activities to ensure a continuous flow without disruptions. This internal form or organization is more effective if the value chain approach is also applied within the near supply chain at least of the company, therefore enlarging customer value and sourcing competitive advantage for the companies as well as making the supply chain reliable. Integrating the value chain approach within a supply chain requires more coordination from the linkages between business partners and often raises certain additional challenges for its successful implementation as are information sharing to support physical and informational flows and a keen focus on improving business processes [94].

The challenges associated with supply chain integration and enlarging customer value network [115] can be overcome by having a joint approach in undertaking organizational and technological changes together with a common structure alignment, as well as an effective co-alignment of management processes, business strategy and technology requirements. This kind of business partnership extends the added value that is created to further links of the supply chain and strengthens the focus on customer value, which will ensure a sustainable competitive advantage for the involved companies [86].

4.4. The harsh challenges associated with building a reputation of best quality over time

An important enabler for achieving a proper integration of the added value approach on a supply chain basis is information sharing, which needs to be very effective. The goal is to reduce lost time and focus on the value-creating activities within the supply chain business partners to achieve internal performance and supply chain efficiency through quality product delivery to the customer. Collaborative activities between a leading manufacturer, its suppliers and customers are an important asset to achieve sustainable competitive advantage.

Product quality is a very sensible concept as it can be defined as the subjective perception of the customer that the technical specifications of the product and its features will meet his expectations in terms of reliability and functional performance within a certain timespan.

A tight collaboration between the manufacturer and it suppliers is the basis for having an adequate quality design, because engineering the design will later have an impact on quality conformance and customer compliance. Thus supplier integration and customer integration are the fundament of having the requested features of product quality and also the capability to enhance customer value and achieve a competitive advantage [71].

The increased complexity in automotive industry has brought about some discussions of reversing the outsourcing process, which is a widely used technique to focus or core competencies more and delegate certain parts of manufacturing to an external supplier (either within manufacturing facility vicinity in the case of high tier suppliers ranging to overseas for commodity parts) if he can deliver a similar product quality with better overall costs. As in most business related decisions it comes down to some main criteria as are costs, quality, flexibility and reliability of the approach as to ensure that features and quality compliance remain at a requested level.

The harsh competitive nature of the industry as well as the less stable growth experienced within recent years can be made an opportunity to have a better control over manufacturing certain components and extending employee skills and possibly sourcing better customer value and is during harsh times a good mean to avoid laying off staff, as was done by Mercedes-Benz in Sindelfingen and Leoni in Arad in recent years [9].

This strategy also allows for reducing unit costs as more volume is produced within the premises of the facility and can also improve employee motivation and commitment towards the company as well as enhance brand image for customers and is usually only used in times of crisis when underutilized capacity becomes a challenge for efficient company operations [35].

The economic crisis of 2008-2009 has been left behind by most of the car manufacturers, but despite heading towards pre-crisis figures for the automotive industry players, the lessons from the low of that period need to be acknowledged, as a crisis is always an opportunity to learn and to learn how to react. Difficult times make it necessary to know how to articulate proper step as to hinder or reduce the negative effects upon one's organization and already having a good set of measures to balance the harsh challenges of an economic crisis is an important asset to remain competitive despite overall market decrease.

The crisis has taught automotive industry the importance of having a strategy oriented towards customer value, having dedicated employees to contribute to improvements in the company as well as enhancing organizational culture and knowing how to make the crisis an opportunity for the company and seeing it as an occasion to stabilize the company rather than a threat. This is the responsibility of management in more difficult times as is the managing success when the company thrives and has very good results and develops itself [70].

A strategy, no matter how brilliant or great it may well be on paper, does not directly lead to value (or customer value) unless the organization has the proper ability and required discipline to carry it out. This capability is provided by a strong organizational culture and only with employees who are focused on their jobs who have the correct mindset and the needed skills and competencies can a company truly implement such an ambitious plan with the expected and desired results. The principles of the strategy need to be materialized into the company's reality, which implies having a strong focus on product quality and the supporting processes (adding value to the customer is the main idea, as well as reducing cost and improving flow), being able to deliver through a reliable supply chain (being on time is a must in automotive industry) and at the best possible cost for both the customer and the company, within a win-win strategy (see figure 4.1).

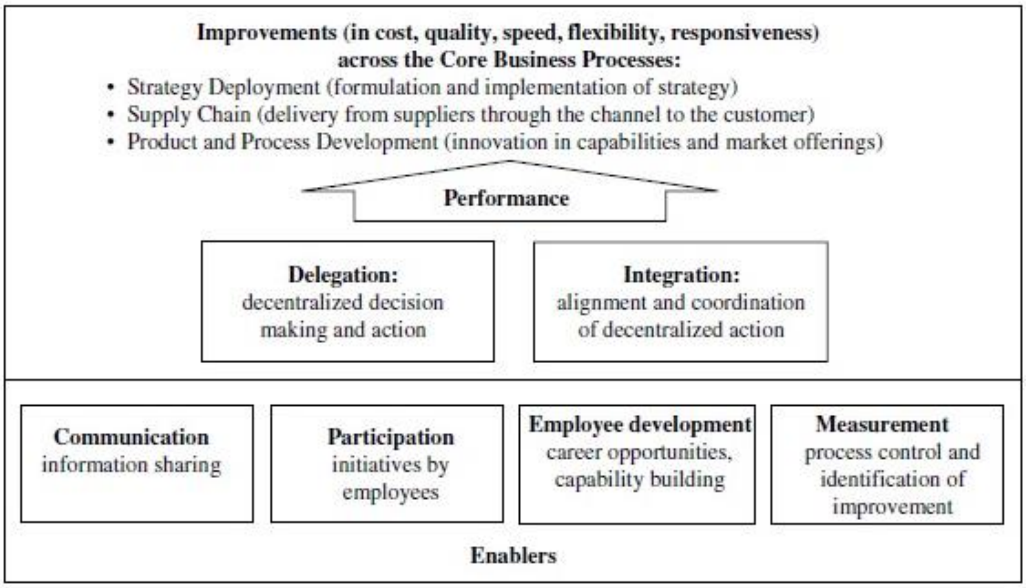

Figure 4.1. Dimensions of management quality (adapted from [70])

Communication is very important for information sharing amongst employees, coordination amongst project members, having all the needed support to make good decisions for the entire company and having the right people to implement changes and improvements which will add value to the customer after being put into place. Participation needs to be an active process of always having the urge to improve where improvement is possible and simplifies work for a certain place or within an area of manufacturing or management. This also implies a certain degree of motivation and commitment from the staff, which need to have a career development plan within the company to see themselves part of the future plans of the business entity and to have a growth perspective within their jobs which will keep them motivated and implicated throughout their current activity.

The perception of one's personal and professional growth through a dynamic and challenging environment and quality people and professionals enables a certain feeling of comfort, proudness and is the drive to further continue doing good work and developing oneself within the company as to cease future career development opportunities. Measurement is however equally important as it provides an objective feedback upon the employee's results. The process of tracking both quantitative and qualitative performance of its staff provides understanding the efforts behind the results as well as the opportunities to put improvements into place where it is the case. This is even more effective if the tracking process is also transparent and done in real-time for certain categories of staff, as are the operators. Honeywell in Germany enables its operators and other workers to have online access to all process indicators and planned work objectives as well as their degree of completion for a complete overview of the operational situation within the company. Other features are shown as well in order to give them a complete assessment based on figures and KPIs of their overall daily, weekly or monthly progress. Operators who understand why properly performing their job can source their further development are more motivated and can focus better on usefully spending their energy within working hours as to become more productive and enables company strategy to become more effective.

Delegation is also highly important as is further enhances responsibility and enhances motivation by empowering employees with important tasks and objectives to achieve within a certain timespan and is a source of productivity increase at the workplace.

Benefits from delegation can range from labor productivity (enabled by strong motivation and implication) to all other types of quantifiable reduced material costs. Best companies and organizations, in addition to cost competitiveness, also achieve certain specific features which create a powerful sense of organizational culture with unique aspects on several levels, contributing to overall company effectiveness.

Integration basically means having the proper coordination to carry out tasks and projects which need to be aligned with corporate strategy and company policy. This is important as in essence the right implementation can source further benefits for the company through drivers of competitive advantage as is differentiation.

Differentiation can be achieved through this approach by innovation, focusing on adding value to the customer and meting his requirements and desires, providing customer support for its products to add confidence to the business relationship and having an overall goal to provide customer value are all elements that can help companies achieve best results and be more competitive with the possibility to reach a best in class or leading position on the market.

Sometimes differentiation can be achieved by focusing on a niche market as well which may be unattractive for certain larger companies who usually favor more mass production adapted products. Assembling obsolete printed circuit boards (design layout requires manual component placing) is uneconomical and does not achieve high manufacturing volumes, therefore margins are very scarce, but there are medium-sized companies, even in Germany, who still make these products. The downside is that production is not standardized, more expensive than an automatic process (economies of scale) and more complicated as is requires a very good quality and productivity from workforce, which is difficult to achieve at a high quality and reliability level [70].

Competitiveness implies productivity as well and implies low-skilled jobs being replaced with automation, a higher-skilled workforce is needed to perform more complex jobs, therefore the need for a better qualified workforce increases. Although there is a loss in low skilled jobs, the newly created ones, which imply a higher degree of competence will be paid better and create competition for the workforce, which is a good motivation factor for the overall labor market. To achieve competitiveness sometimes companies choose offshoring as an alternative to cost reduction, but this strategy can be used also in the case of wanting to achieve an advantage by manufacturing new products and services, for benefiting from new capabilities or expanding business towards new markets. Europe is a high competitive market, with a high skilled labor market, an extensive network of automotive companies and reliable infrastructure, which enable a high degree of competitiveness leaning towards world class in countries as are Germany, UK, France, Switzerland and the Netherlands according to INSEAD-World Global Innovation Index [36].

The globalization and the high cost-pressures have however put pressures on car manufacturers to also reduce costs upon certain production sites which did not average satisfactory levels of productivity of effectiveness and are subject to capacity reduction or even activity relocation (partial or complete). The level of an automotive industry company's competitiveness is highly related to the measure of its overall productivity and is an important indicator for an in-depth comparison in terms of production effectiveness, distribution system reliability, marketing and purchasing skills as well as financial stability with its competition [84].

Eastern European countries have a strong cost advantage in this sense and Slovakia, Hungary and Romania have developed very interesting automotive industry supply chains and supplier networks for some of the most important car manufacturers as are the Volkswagen, Audi, Mercedes-Benz, Opel, the Renault Group (through Dacia) and Ford. In Romania the car market is slowly picking up as Volkswagen, Skoda, Renault, Ford and Opel are the manufacturers who sell best, besides Dacia of course. The Romanian brand sold 550,920 vehicles in 2015, a 7.7% increase in sales with the top models (Sandero, Duster, Logan) each achieving individual sales of over 100,000 units. On foreign markets Dacia sold 513,974 cars, a 6% increase in sales compared to 2014, with France, Spain and Germany being its top-three markets. Interestingly the sales in Morocco still outperform the sales on the national market. The dynamic of the automotive industry is mainly supported by the Western Area's large automotive supplier concentration, where important German, French and Japanese brands have opened up production facilities. This is mainly due to the good linkage with the European infrastructure of the region, as the rest of the country has an underdeveloped motorway network [83].

Knowledge management is based upon three main pillars: people, processes and practice. Having a proper and productive knowledge management approach implies being focused on strategy, planning, execution and improvement. People are the most important resource of the company because the human resource is what makes the company carry out its mission, vision and goals on an every-day basis, as well as on short-, medium- and long-term. The employees are the ones that develop the organizational culture based upon certain company policies and enable the motivation for commitment, career perspective and successful implementation of improvements and changes.

Processes are always subject of improving and they need to improve all the time in order to enhance the degree of added value that they generate for the company and its customers. Processes allow for data to be collected from a quantity and quality point of view and can help build statistics, charts, reports and other tools which may provide valuable support for further improvements. An effective process helps a company develop added value and brings value to its customers in practice and is the result of the combination from right people applying an established process flow through tools such as VSM in order to achieve high productivity and competitive advantage.

4.5. Improving effectiveness through synchronization: from partial to global optimization

Globalization has changed the automotive industry and enabled perhaps the most dynamic and competitive industry sector, where technological advances are applied into modern day's vehicles at affordable cost and where important and complex safety features are becoming standard within all vehicles. The reduction of the product life cycle for cars which concerns the manufacturing companies has an important impact on their every-day activity and strategic management options. The fact that the time allocated from conceiving the project of a new car design and its actual production as well as parts engineering have been reduced in some cases to even less than 2 years have added pressure on the entire supply chain to become more competitive in order to meet this challenge. Depending on the level at which tier-suppliers are integrated within each car manufacturers supply chain will also give an indication upon the complexity of activities it needs to manage in order to provide the required parts at the right quality, best cost and required time.

Car manufacturers sometimes refer to companies in their supply chain as tier one and tier two suppliers (sometimes they may also have further levels). These terms indicate the commercial distance in the relationship between the manufacturer and supplier and are an expression of the technical and organizational level of collaboration between an OEM and its tier suppliers.

An OEM (Original Equipment Manufacturer) is a company that makes a final product for the consumer marketplace, or in the case of the automotive industry, car manufacturers. Tier one companies are direct suppliers to OEMs and refer to major suppliers of parts to OEMs, who are mainly German, Japanese or American companies as the automotive industry has a major importance and tradition within these countries. Tier two suppliers are the key suppliers to tier one suppliers, without actually supplying a product directly to an OEM company. However, the same company may be a tier one supplier to an OEM and at the same time be a tier two supplier to another company, or may be a tier one supplier for one specific product and a tier two supplier for a different product line within the automotive supply chain configuration. The same logic applies to tier three companies, which supply tier two companies. Tier four companies are usually providers of basic raw materials, such as steel and glass, to higher-tier suppliers (either a higher end supplier or even to an OEM). Higher tier suppliers will have to adapt their own supply chain network and render it reliable in meeting higher technological and complexity challenges, shorter implementation and lead times to actually manufacture and deliver products and lower price per part selling prices. The amount of work, technological equipment needed, added value activities and effective management that needs to be performed in order to provide these results implies a very good plant organization. Each company analyzes its capacity and capability and designs its own different automotive production system and model in order to properly deliver components, subassemblies or parts to the higher end supplier or downstream within the supply chain.

The complexity of the automotive industry and its competitiveness means there are different factors that contribute to the production result, quality results and productivity improvement in order to provide customer value at the best possible cost. In order to achieve these results, the companies must have a very good overview of all processes, from incoming of the materials, to all the production processes till the shipping of the finish goods. Only by achieving total optimization is it possible to achieve meaningful and long-term results. This is to be considered as one of the key aspects as the optimization of the whole is much more difficult to achieve than partial or local optimization. Improving and having good indicators for only part of the processes only gives the impression of performance, because individually improving a line, workplace or work cell is a lot easier to achieve than synchronizing an entire complex of activities throughout an entire plant. The latter is much more difficult to achieve as there is a systemic view to be considered, needs, flow, constraints and output capacity from all major points to be calculated and designed in such a way as to maximize results, performance and work load for the workers, but to also integrate this approach so that it can be sustained on a long-term basis without being exhausting, so that employees can be productive without exceeding the average fatigue levels, which would be detrimental to the company.

Although Just in Time principles are widely used in automotive industry and the production system introduced by Toyota is a reference in automotive industry, today's specific automotive industry settings have changed and in order to be competitive on a sustainable basis, companies cannot merely rely on the same principles used and applied almost half a century ago. The rapid technological advances and the pressure to fit modern equipment and gadgets to cars mean simply reducing waste and applying lean principles partially, don't guarantee the total improvement. In order to achieve important positive results the improvement process has to be well-defined and implemented in a continuous manner.

There are basically three important steps that help generate overall improvement, contribution to increased effectiveness and productivity gains throughout the plant: simplification, improvement and people empowerment.

1) **Simplification** is the first part of the process and lays the basis for the plant's production layout, organization and overall efficiency, as it needs to focus on a couple of important principles:

a) Work in flow – is perhaps the essence of a proper functioning plant, as a continuous and uninterrupted flow of materials and information enables transforming products through effective processes and create added value for the customer.

b) Define the needed capacity – one major advantage of simplification is the fact that it helps provide an extensive and easy overview of the layout and functioning of the plant and it enables sourcing locations where there may be room for further production or process capacity in order to better meet and cover the estimated output needs of the company.

c) Avoid bottlenecks – a production plant's output is mainly defined by the number of its bottlenecks. It is practically impossible to achieve identical output levels for different processes and working stations, therefore the end output will always be set by the process with the lowest pace, where there is a high chance of inventory building up as well. The main challenge in this case is to reduce the number of these vulnerable points within the overall layout by either increasing the designed capacity through investment in more productive equipment or more efficient organization that enables time savings and higher productivity. Once the negative effects are sorted, the bottleneck should always be "fed" by the process, in order to not further reduce the maximum possible output levels, which means it has to always be in "flow mode", by running continuously in order not to block the process flow throughout the factory. Bottlenecks are weak points of the company and are a vulnerability in the overall targeted output levels, therefore requiring continuous organization, management and planning effectiveness and efficiency.

2) **Improvement** is the second part of the process and is the source of improving the plant's production layout, organization and overall efficiency, on short, mid and long-term basis.

a) When the process is clear and easy the **waste reduction** process needs to start: there are many sources of waste throughout the plant and they are a target to be eliminated in order to increase the proportion of added value activities throughout the entire plant. This is one of the most important approaches of lean management, as through the Muda principle the employees and workers can significantly increase their effectiveness and efficiency and improve the overall functioning of the company by enabling a continuous flow and sourcing more added value to the customer.

b) Create **improvement culture**, general people habit to have an open mind for improvement: this is one of the most important principles to be acquired by the employees, as the need to improve is constant and so should their overall preoccupation be. Sometimes improvements may only be marginal, but the important fact is to have this reflex and concern in order to further reduce wasteful activities and help contribute to making work easier, faster and with less effort and source customer added value. This will in turn create a strong organizational culture for the company and provide a basis for future competitiveness as well and support further improvement and overall development within the plant.

3) **People empowerment** is the most important part of the process, because the human resource is the most important resource of the company which enables the proper functioning of the plant and is the source of customer value. Recognition is one of the most reliable ways to prove the importance of hard work and efficiency within a plant. This can be done and shown in several ways, the main idea is to prove the fact that the work done has been appreciated, giving the employee a sense of further motivation. If people are motivated they will feel their job is an important part of the company and help further improve activity as they will have a sense of empowerment. Empowerment may also be formal, but it may also be informal, because people having different positions may see things differently and communication can help design the best solutions to existing problems. Empowering people gives them the sense of responsibility and decision making and enables

employees to feel that their contribution is valuable to the company. This principle is the individual basis to sustain a strong and effective organizational culture which will help the plant further improve its effectiveness and provide value to the customer.

Any plant or company has to have a clear focus upon all its system elements in order to manage to properly synchronize them, achieve operational efficiency and provide customer value. A system is composed of a set of parts that relate in a more or less predetermined manner with the aim of obtaining its functionality, going from being a set of spare parts with no practical use to a system through which one could achieve the response to various stimuli or needs (see figure 4.2).

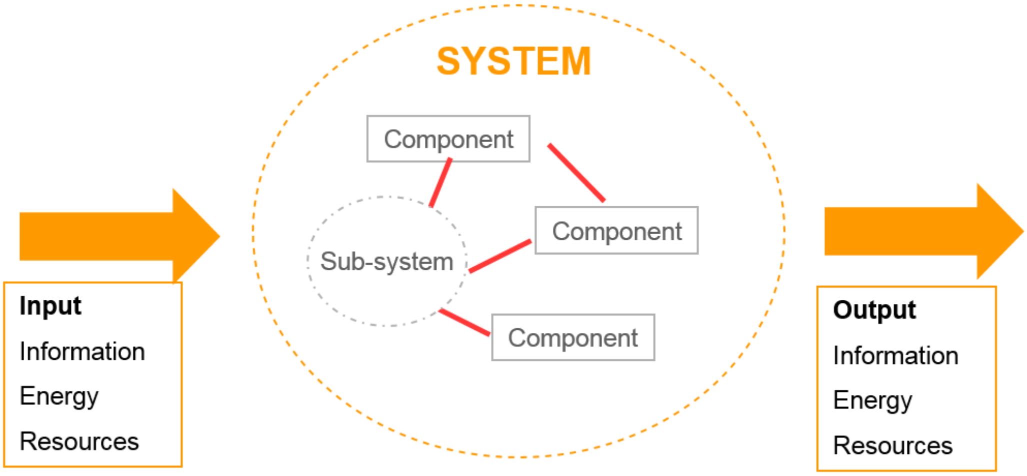

Figure 4.2. Inputs, outputs and linkages of a system

The systems have rules and patterns so that once acknowledged, they can be influenced. In order to be a good manager, one must see the overall concept or "all the system", the parts that complete it and the relationships that make it work. The unique method of knowing how the system is functioning is by seeing the system itself in action as a whole. This is similar to the Gemba (Genchi Genbutsu) concept from the Toyota Production System.

A system can suddenly change if appropriate actions are taken, this is feasible when the system is well understood. This is called leverage and is very simple, because it implies changing either the processes, products, machines or even the people. We often see that the crucial point for the leverage effect in a system stands in the convictions of the people, because the system itself is based on convictions. If the organizational culture is strong, then changing the focus and way of seeing things for people can be done a lot easier. Often we must understand the whole and the relations between the implicated parties in order to improve, as considering just an individual area and its results is not good enough to improve the effectiveness for the entire set of processes and does not work.

The most important point for understanding the problems of running a functional system is when we know that something is happening, because it is the time when we are in a position to do something about it. This is done by having relevant real-time information which enables the ability to take real-time action.

The systemic thinking consists of seeing both the situations and experience as a whole. To do this, you must have a sufficiently broad view, step back and observe the pattern forming correct or build everything from many different angles. When we think we have solved the problem and it comes out again there is no doubt that we are victims of the system structure. If problems are not resolved we must find patterns and promote the change that eliminates the root of the problem.

It is important to understand the necessities in the speed of decisions and actions not to decrease the speed of the organization. The speed of the organization is equal to the speed of the slowest. Our chain reaction is subject to changes of rhythm that we must understand and also must adapt and anticipate the organization accordingly:

- Changes and variations in customer demand
- Product changes
- Design support speed
- Reaction speed from suppliers
- Suppliers' problems
- Internal problems

We must adapt our rhythm to the needs of the moment with anticipation and speed. To synchronize we must observe patterns of behavior, analyze and define those that will repeat. Whatever can happen will happen, therefore anticipation of problems is important in order to find the proper solutions within due time. We must understand the whole system and find the blocking points. Blocking points are problems that appear due to lack of anticipation and a solution will be repeated with many possibilities. This may sometimes be caused by friction, i.e. different working speeds of the departments that cause debilitation, because one must drag the other to perform its activities. Blocking points tend to appear due to the following reasons:

- Lack of shared vision
- Lack of anticipation
- Lack of systems thinking
- Failure to look for patterns of behavior
- Lack of empathy
- Lack of demand; departments that are left pushed by others (wrong), departments that push others (wrong)
- Lack of synchronization

It is equally important to find and fix potential external breaks as well, which may be caused by design, suppliers or even customers, therefore making decisions regarding possible problems will prevent these problems from affecting the company's regular functioning.

Establishing potential internal brakes and their relationship will help avoid perturbations in the internal performance caused by:

- Lack of shared vision
- Lack of communication

- Lack of anticipation
- Lack of resources for accumulation of incidents
- Not having the right equipment
- Lack of preparation
- Blur responsibilities
- Lack of coordination
- Lack of action and resolution of recurring problems
- Lack of overview
- Lack of information
- Lack of ownership

Synchronization is one of the most important factors which improve effectiveness and is a state where everyone is performing their activities without being stopped or pushed by the others. Synchronicity is important for the employees' confidence and means working in a positive state.

This means employees believing in themselves, having the feeling that they can do things very well, having the initiative to seek and find solutions to problems and solving them, enjoying their work and finding new possible ways of performing their tasks better, liking their job and trusting that everything will be fine without a doubt.

A synchronized company will have strong organizational culture which will be the fundament of its operational effectiveness and high overall level of performance and productivity, enabling it to be more competitive on the market, not only in terms of internal group rankings of manufacturing plants, but also on worldwide level for its benchmark of competitors and reference guide on performance.

4.6. Results of optimization process for automotive electronic production in a best-cost country production plant

4.6.1. Automotive industry competitive characteristics and production plant challenges

Automotive market studies indicate that in the last decade the car industry technology and cost improvement pressure was transferred from car producers to the component suppliers. This tendency will continue and will be amplify especially with the introduction of automatic driving, electric cars, new infotainment and car communication solutions. Basically the automotive market suppliers have to introduce new product features, assure the product quality, implement the governmental new regulations, have a dynamic product cycle development, but assure the same product cost.

In this condition the automotive suppliers have the strong need to apply intensively internal improvement programs to become World Class Manufacturing (WCM) sites and to become the best international suppliers. The practical implementation experience indicates that work is under way to start preparing the right team and strategy.

Manufacturers in many industries face worldwide competitive pressures. These manufacturers must provide high-quality products with leading-edge performance capabilities to survive, much less prosper. The automotive industry is no exception. There is intense pressure to produce high-performance at minimum costs [73].

Companies attempting to adopt WCM have developed a statement of corporate philosophy or mission to which operating objectives are closely tied. A general perception is that when an organization is considered as world-class, it is also considered as being the best in the world. But recently, many organizations claim that they are world-class manufacturers. Indeed we can define world class manufacturing as a different production processes and organizational strategies which all have flexibility as their primary concern [106].

So, gradually the worldwide competitive pressures and the globalization forces the companies to improve continuously and to try to become one of the best in the area of their activities (WCM). Additional, financial statistical data also show that actually in the competitive market fields (Communication, Computers, and Automotive) only the first suppliers from the market could have a good profit margin the rest of the suppliers usually do not have enough market share to make consistent profit and need revolutionary ideas and actions to progress.

For example a detailed study of North America Automotive Supplier Industry [73] show that the weighted average cost of components for a standard car remained unchanged between 2001 and 2010. At the end of the decade the typical share of the overall cost of the car that was borne at the supplier was $13.400. Over the decade the supplier industry achieved productivity gains equivalent to $2.900 per car (2.4% per year).

Briefly if the suppliers continue the manufacturing process using the same components the average car price should be decreased to $10.500. The market analyses show that the average car price did not really changed (remains around $13.400 euro).

Basically the cost reduction based on productivity improvement was compensated with increase of:

- Material cost increase (around $1400 per vehicle);
- Additional government regulation add $600 for each vehicle (fuel economy $200 and safety regulations $400);
- Additional car features $800.

For the decade 2010-2020 it is expected to have a similar market trend:

- Average cost car at supplier will remain around $13.400 ;
- Cost reduction programs at suppliers around $2.900;
- Additional implementation for regulations (fuel economy, pollution requirements) increase the cost with $3.200;
- New safety and new features implementation cost additional around $430.

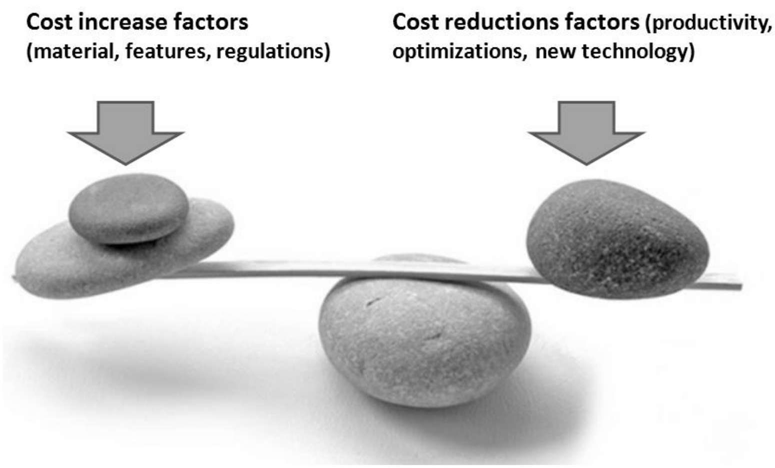

Figure 4.3. Pressure factors in the automotive market

In these conditions it is more important for the companies and organizations to become more agile and try to improve more that the competition, to come with even more revolutionary ideas to be better, faster and more professional than the competition (see figure 4.3).

The following main trends are visible in the automotive market:

- Increasing the complexity of the cars especially in regard to the electronic and software (infotainment, safety additional features, comfort features and the automatic driving features and direction)
- Car producers are focusing on car platform and the reuse concept in order to reduce the development, share part and to globally reduce the price;
- End Customers of the car industry (private persons, but also companies) have a larger expectation in quality aspects and specific customization;
- Generally, the automotive industry has an overproduction capacity in classical producers, strong competition and price pressure. It also deals with the challenges of competing more and more with the computer and communication field;
- Some of the international markets (for example the European one) are looking for complexity and sophistication, while they are also interested in cars for standard daily use and the most cost efficient solution.

Based on these trends especially the western and central parts of Romania have the following main competitive advantages:

- They are reasonably close to large car producers in Europe, resulting in reasonable transport costs and delivery time especially in Western Romania;
- Good workforce and highly educated human resources at low prices;
- Good and very good capability in software development, electronic and mechanic design give the opportunity to create large development centers in Romania to serve the international headquarters.

Using the Romanian competitive advantages, during the last 5 years almost all large automotive companies (Continental, Hella, Takata, Dräxlmaier, TRW) doubled their production capacity in Romania, creating or extending the international development center. This increase was often done using the strategy and method used in Western Europe and sometimes applied different local conditions. For example, production lines were often designed in the west with the target to reduce the investment, to reduce the sometimes exaggerated automatic solution, and to mainly allow manual production and control.

The production of electronic automotive components is challenging because of the following main factors:

- Strong pressure in product cost and also yearly product cost reduction;
- Continuous Product Life Cycle reduction;
- The increase of product complexity combined with the extension of product variants;
- Customer pressure in product quality and quality preventive actions

In order to be better prepared for the challenges of the automotive market, automotive companies prefer to start the production Plant in best-cost countries, reduce the investment and compensate this with extra human resources (because salaries are low) and try to properly manage the activities and the eventual difficulties using additional administrative or process-related human resources.

4.6.2. Applying the WCM principle: The right approach to achieve effective organization within a best-cost country production plant

Based on the mentioned pressure factors most industries would like to find the formula for the ultimate productivity improvement strategy. Industries often suffer from the lack of a systematic and consistent methodology. In particular the manufacturing world has faced many changes throughout the years and as a result, the manufacturing industry is constantly evolving in order to stay ahead of competition [110].

Innovation is a necessary process for the continuous changes in order to contribute to the economic growth in the manufacturing industry, especially to compete in the global market in order to make products of the highest quality eliminating losses in all the factory fields an improvement of work standards [102].

When Schonberger [106] first introduced the concept of "World Class Manufacturing", the term was seen to embrace the techniques and factors as listed in Figure 4.4. The tools and methods used in the companies increased immortally and can be related in part to the growing influence of the manufacturing philosophies and economic success of Japanese manufacturers from the 1960s onwards. What is particularly interesting from a review of the literature is that while there is a degree of overlap in some of the techniques, it is clear that relative to the elements that were seen as constituting WCM in 1986, the term has evolved considerably.

It is visible in the theoretical model (figure 4.4 and figure 4.5) of WCM that "Just in Time", "Total Productive Maintenance" and "Total Quality Management" are the base and starting elements in order to transform a company in the direction of World Class Manufacturing [106].

After the WCM implementation base is solid the next natural phase is to focus in the simplification of all the processes. In order to have a sustainable WCM company focusing on people development, people involvement and empowerment are mandatory elements.

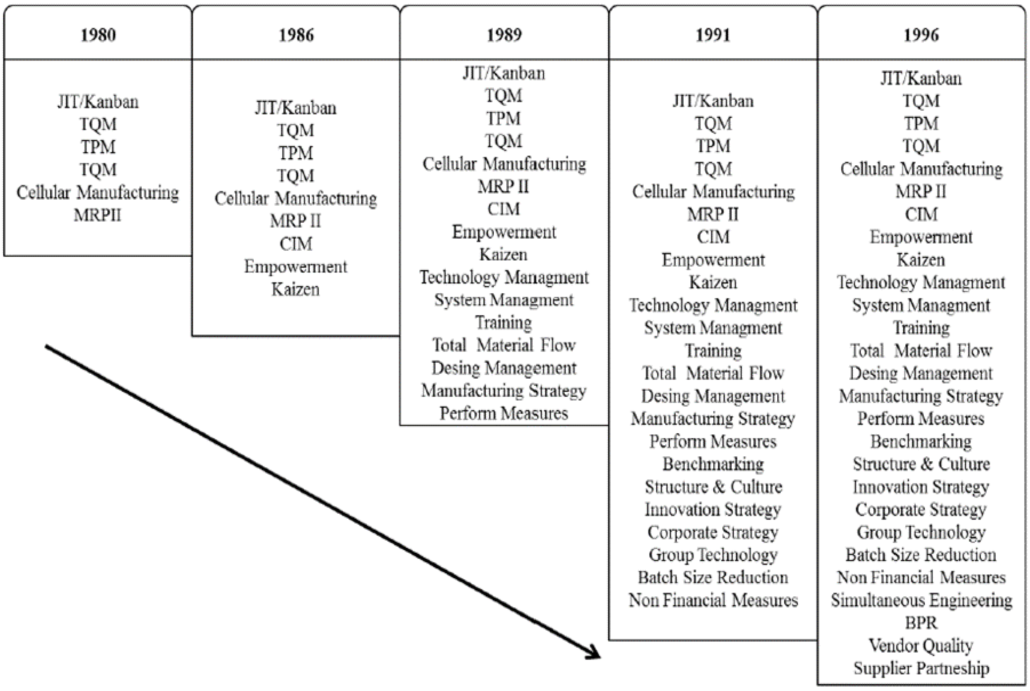

Figure 4.4. The growth of techniques associated with the WCM concept (adapted after [32])

In the Schonberger growth model (Figure 4.5) it is visible that advanced WCM companies have introduced gradually additional tools and procedures in order to simplify and increase more and more the activities' efficiency. In general the theoretical model show that the activities of WCM companies are based on easy and clear procedures and tools that bring efficiency and predictability [102].

One of the first steps for one organization in the direction of World Class Manufacturing is to define the criteria for the level of competitiveness of a plant. To support the systematic and the more precise analysis of competeveness it is necessary to cluster the plant activities in order to come to similar categories. The possible comparison is between plants that are doing the same or similar process [30, 110].

The main WCM competences for an automotive plant are the following:
1) Supplier management
2) Ordering, receiving, storage of raw materials
3) Deliver materials to assembly
4) Assembly and test, packaging
5) Storage of finished goods
6) Shipping to the final customer

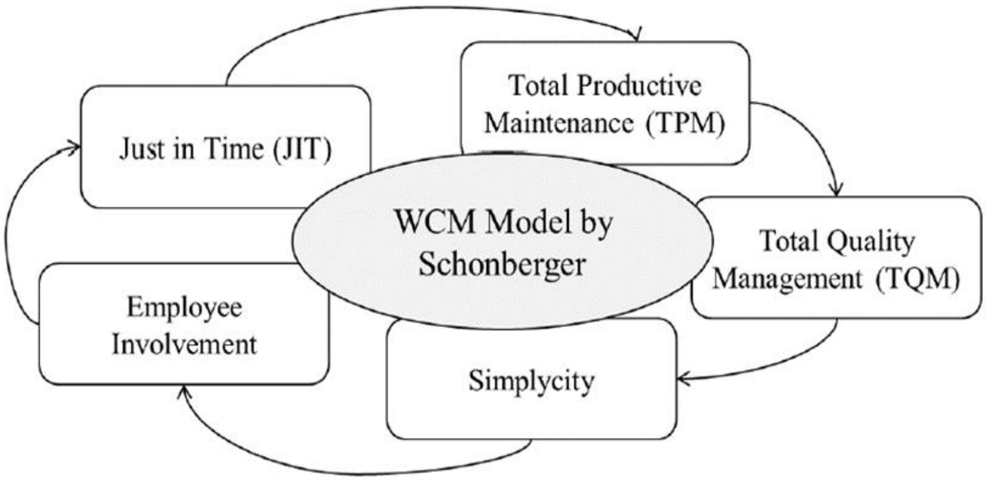

Figure 4.5. WCM model by Schonberger (adapted after [32])

All the assembly plants can use the mentioned comparison process as a way to know the level of competitiveness and also establish the possibility to benchmark and analyses the results.

In the next step is necessary define the way to compare different production plants in different locations of the world in order to benchmark and see the level of competitiveness, comparing one against the other.

Next step for WCM Company is to define the main KPI (key performance indicator) that describe the main competence:

1. Added value as a concept of time that the product is transforming and the time that is in process. This is the criteria of value stream analysis (VSM). How many time of the total time is production, the product is on transformation, due the man or machine process, versus the time total time in production [110]
2. The level of inventory versus the lead time
3. The quality criteria, defining how many times the product fail in each process and the level of quality cost, these means all the quality associated cost, scrap, guaranties etc.

When properly defining those 3 criteria it is possible to compare the level of competitiveness of a plant versus another.

In the next step based on Toyota philosophy it is important to define what the real waste is and what the value in the production flow is. This analysis is not so easy for teams without experience and is recommended to use a more experienced one to create a proper mindset in the team and to assure the proper stat-up [30, 110].

Companies which use optimum investment in equipment have the following main challenges and waste drawbacks:

- Working intensively to optimize the use of production equipment and production planning;
- Managing dynamic bottlenecks in process;
- Production planning is strongly affected by any issue in the logistic or production chain.

The end results of the fixed cost reduction are visible in the inventory, but also in the difficulties for planning and scheduling the process and the complex situation in managing the plant [30]. This is shown in figure 4.6.

Usually, the production company focuses in investment reduction, but the delivery pressure and quality requirement force hiring additional people and lead to the use of additional components and product inventory. Having more people and more inventory will result in more work in planning process, although in the end, this will increase the inside company's complexity and waste. Gradually, more production facilities employ the spiral model and the surprise is that the larger human and material resources do not bring better results.

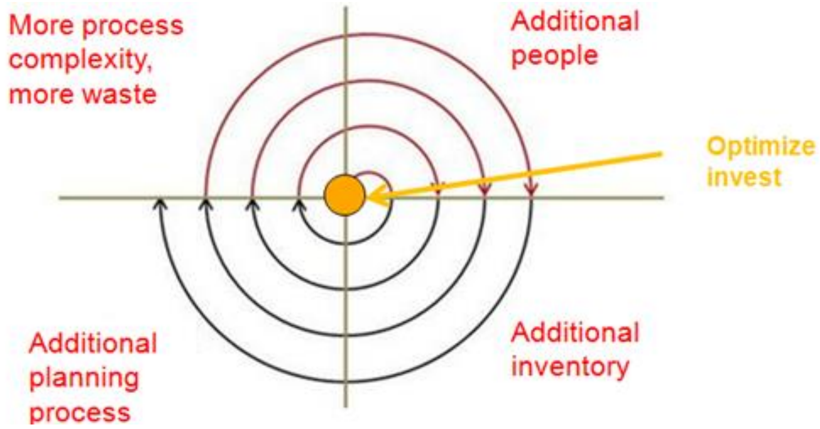

Figure 4.6. Reduce investment spiral escalation model

For the complete picture of a company performance there is the need to compare the efficiency of a plant and not only the financial results. Sometimes the financial results are the results of marked advantage, price positioning and other points that influence importantly the results, but are in general high volatile and depend to temporary or local conditions [32].

Normally the comparison between plants is done by mainly using the following relevant KPI:

- Gross margin;
- EBIT (Earnings Before Interest);
- EVA (Economic value added).

It is important to consider that using only the analysis of financial results is not possible to benchmark production activities, because the products are different, the market situation can be different and due to this the comparison can be wrong.

It is clear that in the global market, all the analysis companies look for the financial performance, but this is not the right way to analyze the competitiveness of a plant or company. Because by using those criteria, depending upon their interpretation as well, they see the results but not how much better or worse the operations are managed.

There are two ways to consider the results:

- Based on product competitive situation
- Based on production competitive situation

If the product is good and the process is optimum then is possible to achieve the maximum. If the product is good and the process is not optimum, the companies will achieve only good results till the product become not more innovative or other competitors achieve the maturity level enough to compete. In those moments the company can suffer the problems of lack of competitiveness and agility and can pass from the good results to bad results, easily.

World Class Manufacturing does not consider the product, only the process and defines how many times the product is being transformed in the total lead time of production. How much are the quality ratios, and how much inventory is necessary to use in order to produce and deliver just in time.

In this case study, a production company set up in January 2014 was considered using the minimal inventory model, therefore the focus lied on using share equipment with many process constraints, many people waiting or "firefighting", but not adding value. Additionally, the fluctuation of human resources is high in best-cost salary countries and people leave fast if they receive higher salaries in another company. Having a complex system of production, with large waste and a high fluctuation rate, the plant did not achieve the results expected by headquarters and the local defined targets in costs, quality, and turn rate.

Under these circumstances, more actions to applying the Lean principles were implemented in order to avoid waste, but the complexity was so large that the expected results were still not achieved. After the first unsuccessful attempt, it was evident that more action was needed at the foundation of the production system and that the company subculture had to adapt to the new system [110].

Based on the Lean manufacturing principles, the plant team defined a practical approach with several activities in the following main directions to transform a local production site (see figure 4.7):

1) **Simplification** of the overall process: define the correct material flow, and the perfect layout to produce in time, without material in the plant

2) **Organization and tools** to achieve the right competitiveness level: work in one piece flow, not in batches

3) **Employee empowerment** and mindset motivation: involvement and growth of the people in other to sustain and improve constantly

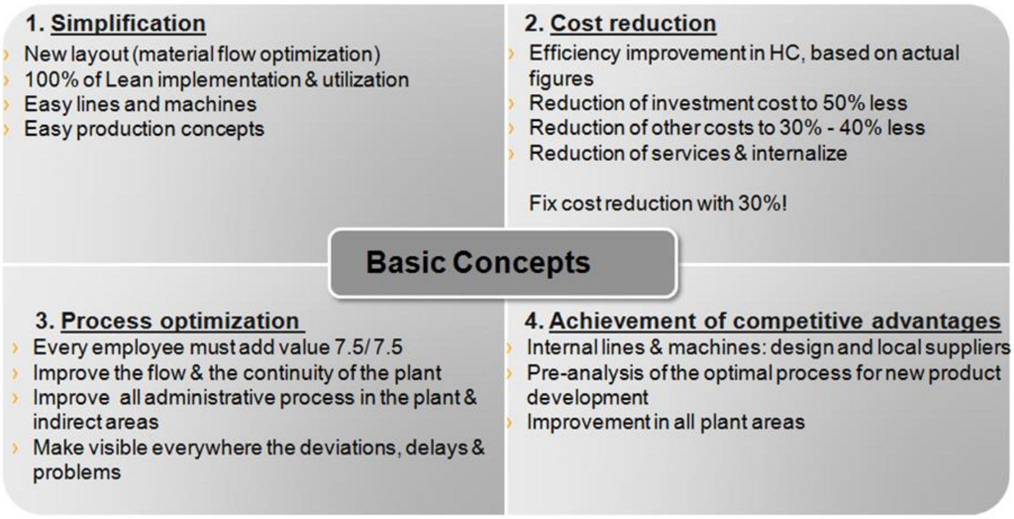

Figure 4.7. Basic concept chart of lean principles

In order to achieve the targeted results the layout of the plant, the processes and the needed capacity were fully redefined. It was important to achieve one piece flow in order to have the same capacity everywhere (no differences in output, avoiding bottlenecks), therefore the tube concept was defined as shown in figure 4.8.

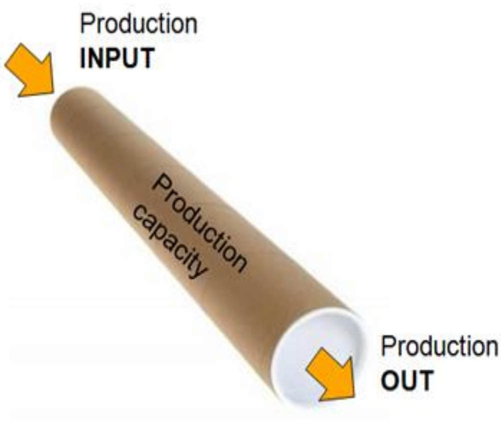

Figure 4.7. The tube concept

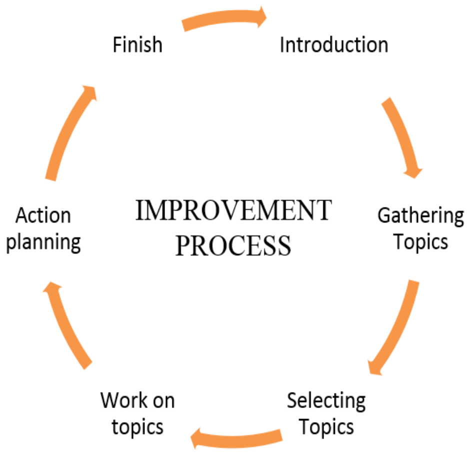

Figure 4.8. Structured improvement loops

After checking in detail the different cycle times of production machines, actions meant to improve the bottlenecks were initiated, most of the time by improving the machine concepts, but sometimes also the ergonomics, and by reducing the test time.

The next phase was the complete modification of the plant layout, in order to improve the flow, to reduce the occupied space and to add additional production lines.

Generally, the process of completely reworking the layout, updating from the route the production planning concept, removing the share processes/lines for more products was a challenging task which needed systematic actions and close monitoring (see figure 4.9).

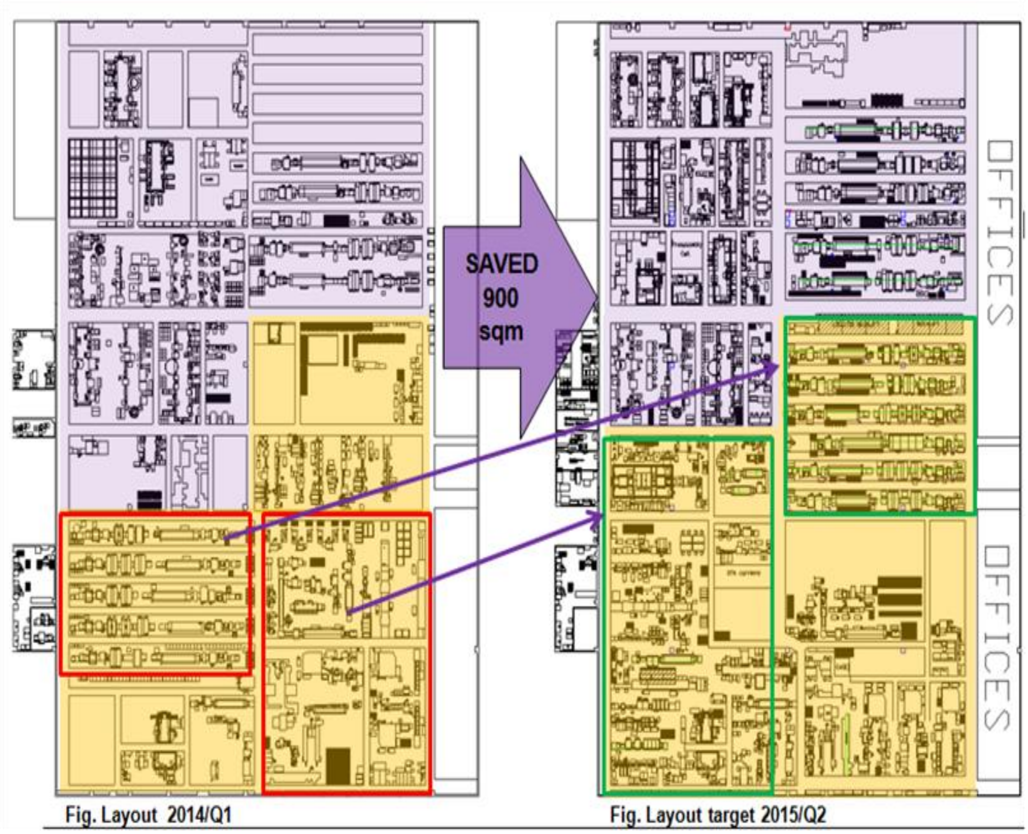

Figure 4.9. Plant layout

Figure 4.10 shows the production plant layout before and after running the improvement program. It is visible that more complex areas were optimized, additional lines were installed and 25% of space in optimization focus was saved. The final layout the production and material flow is easy and logical to follow.

Additional to the layout improvement, high runner dedicated lines were defined, while the low runners share equipment lines with the same capacity. With this concept we fully changed the plant from working in batches to a plan working in one piece flow and we managed to reduce the complexity of the workshop and planning (see figure 4.11).

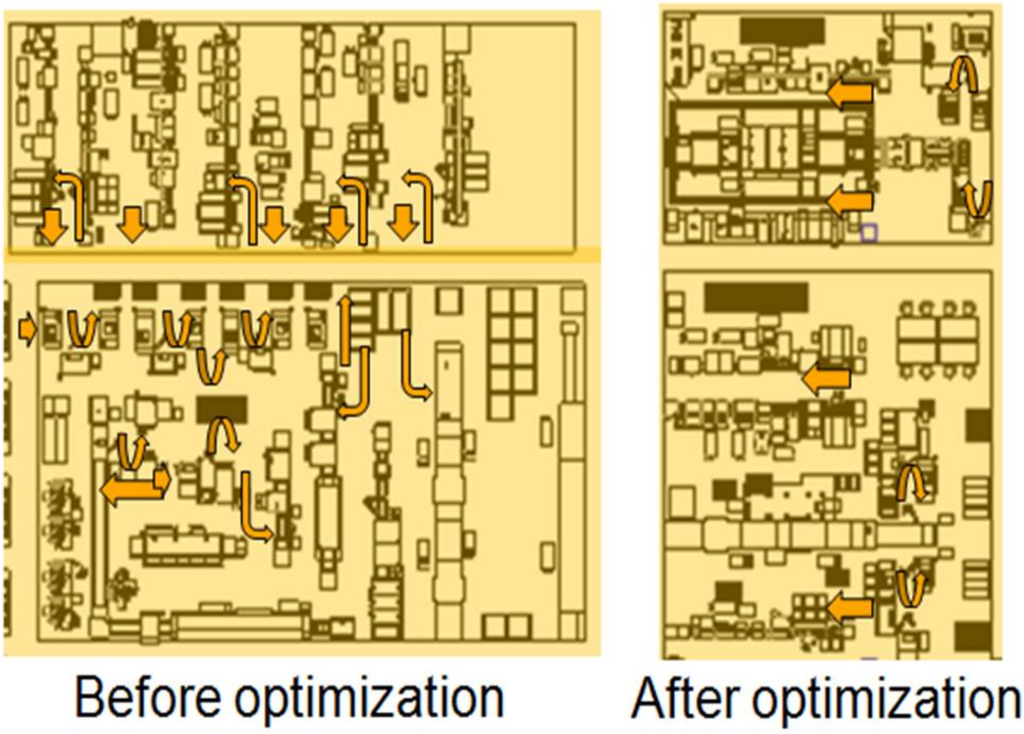

Figure 4.10. Comparison of spaghetti chart (before optimization) and flow chart (after)

4.6.3. The WCM organizational culture: The key focus areas to enable a performance-based mindset for a motivated team

The following set of principles was applied gradually in order to source one of the most important underlying principles of organizational performance within a WCM plant:

1) **SUSTAINABILITY PRINCIPLE**
• We consider the entire value stream in all activities and decisions;
• We transfer problem solutions and best practice into standards;
• We foster through training the competence and flexibility of all employees;
• We ensure a healthy work rhythm through leveled work flow.

2) **INVOLVEMENT PRINCIPLE**
• We empower our employees by demonstrating trust in their capabilities;
• We involve our employees early on and use the power of cross-functional and diverse teams;
• We communicate failures and near- misses openly, and use them as lessons learned for continuous improvement;
• We encourage life-long learning and personal and professional development;
• We set a positive example with everything we do.

3) **RELIABILITY PRINCIPLE**
• We provide quality solutions for our customers;
• We strive to do everything right from the first time;
• We solve problems immediately in a structured way;
• We deliver on our commitments;
• We always have value creation for our stakeholders in mind.

4) **SIMPLICITY PRINCIPLE**
• We develop robust products;
• We design lean, clever equipment and processes;
• We define transparent workflows with short lead times;
• We apply standards for all processes.

5) **FLOW PRINCIPLE**
• We establish a continuous flow by avoiding all kinds of waste in all business processes;
• We reduce waiting times, stocks, unprocessed orders and work packages;
• We create a flow by minimizing the number of interfaces and hierarchy levels;
• We actively involve customers and suppliers to achieve a continuous flow along the entire value stream.

6) **PULL PRINCIPLE**
• We fully understand external and internal customer expectations in terms of content, time and quality;
• We follow the pull signals indicating the demand of products, information and services;
• We adapt our pace to match the speed of the market.

7) **VALUE PRINCIPLE**
In addition, in order to get the right improvement for the plant in the direction of WCM the following methods were used to implement high added value:
a) **Behavior Value**
• Establish improvement culture, constant learning and sustainable problem solving
• All employees recognize constant improvement as a necessary part of their daily work
b) **Quality Value**
• Ensure zero defects in products, processes, services and information management
c) **Resource Value**
• Focus on the overall benefit of the plant
• Consider entire value stream in all activities and decisions
• All employees focus on identifying and eliminating waste in all processes
d) **Customer Value**
• Ensure high customer satisfaction based on close collaboration
• Provide products, solutions and services that add value to our customers
e) **Supply Chain Value**
• Deliver on our commitments
• Ensure delivery of products, services and information on demand in all internal and external business areas
f) **Process Value**
• Maintain reliable, stable and robust manufacturing and administrative processes
• Fulfill market requirements concerning time, quality and cost

The results achieved by applying the WCM principle for only two years within an automotive plant in order to source high organizational effectiveness and performance are presented below:

1) **SUSTAINABILITY PRINCIPLE**
Based on value stream analysis and by applying the specific measures, the productivity of the assembly lines were improved between 20-40%. Eliminating all types of waste from production flow had a contribution of around 40%, nearly 30% come from using better technical solutions and developing them into company standards, 15% from production leveling and around 15% from increasing capabilities, competences and flexibility of all employees.

2) **INVOLVEMENT PRINCIPLE**
Extending the responsibilities of the employees and using a trust culture boosted the employee involvement and communication inside the entire organization and extended the personal and professional development. Within the first half year of the WCM program the focus was in creating the right subculture with the right leaders and continued with the extension of the responsibilities and gradually the involvement was extended in all the levels of the organization. One of the important elements was to set a positive example with everything that was being done.

3) **RELIABILITY PRINCIPLE**
In the current dynamic automotive market assuring the customer trust was proved to be a mandatory element to allow the implementation of new concepts. For example the layout improvement program was considered by most of the customers a risk especially in the first months of the WCM program. Initial layout discussions were difficult mainly due to closed and very formal communication. Gradually, based on keeping promises and planning practice, customers' trust increased and a more win-win relationship was eventually developed.

4) **SIMPLICITY PRINCIPLE**
Using clever, simple and better design production equipment reduced the breakdowns with an average of 25% and improved the maintenance cost by around 30%. Simplification of the production workflow assured a transparent view upon the production performance and enabled a clear overview of real problems.

5) **FLOW PRINCIPLE**
Improvement of the production layout was a key element in reducing all kinds of waste, reduced the work in progress stock and introduced simplicity. The main steps applied for the layout improvement were:

- Define the ideal plant layout based on product portfolio, existing infrastructure, production specific requirements and needs of supporting functions;
- Define the layout strategy and the steps in order to implement the best layout for the plant needs (4 years visibility, main actions in first 2 years);
- Define the local layout standards (corridors size, assemble cell dimensions, local material handling standard, visual management standard and automatic performance reporting for each area);
- Create the detail layout improvement plant;
- Inform the customers about the improvement program and apply the layout rearrangement program.

The main layout changes were done in the first year of the WCM program application and results were impressive. The space improvement of the existing line was on average reduced with 35% and based on the volume increase and new introduced line design the sales per used space KPI was increased with 63% only in the first year.

6) **PULL PRINCIPLE**
Based on the new plant layout and introduced simplicity, the introduction of the pull principle in the production flow and the single planning point became natural and effective. The direct results were a very easy planning and following of production based on customer demand and the work in progress and stock level were reduced impressively.

7) **VALUE PRINCIPLE**
Maybe one of the most important elements to create a Work Class Manufacturing factory is the development of the proper subculture and the constant focus on people development and performance. During last two years a lot of new leaders were formed, many internal and external training programs were developed and applied. Focusing on improvement, innovations and generally open-mindedness became part of daily activity.

4.6.4. Implementing the correct organization principles within a best-cost country production plant and achieving results

The next actions needed to be taken in order to complete the best-cost production plant were to orient all plant activities to work in one piece flow. Consequently, this required the modification of the organization to avoid problems in production.

The one piece flow production system needed resources to solve problems in real time and needed to reinforce the organization that supports production (more resources in maintenance) and to apply the total productive maintenance. Furthermore, it was also necessary to introduce "Jidoka" as a way to improve quality and reduce scrap with all the technicians analyzing problems in real time.

The layout was modified gradually, resulting in the simplification of the operation and in the placement of the organization to support all possible problems during production. It was also necessary to monitor all the problems encountered, in order to achieve the daily production standard. Several teams were assigned to improve the situation:

- One team in charge of reducing break downs: using TPM methodology;
- One team in charge of assuring the planning achievement;
- One team meant to improve the quality and reduce scrap;
- One team assigned to reduce lack of materials.

After the one piece flow production concept was defined and work started to be done in time, we concentrated on keeping the flow, thus working without stoppages and without cutting the production flow. A basis was created for more activities concentrated on continuously running the production. When this level was achieved, all waste was visible and easy to avoid [49].

Following flow improvement, the activities were concentrated on analyzing how waiting time for operators and machines can be reduced. Based on the new production concept and simplification, waste became visible and actions needed to reduce this waste become clear. Afterwards the simplification process on, the actions employed to improve labor productivity and machine time started (as shown in figures 8 and 9). The improvement was outstanding because in some areas a double output was achieved, with the same resources as before. This is the point where the plant reached a transformation.

Because the production was doubled with the same headcount and also the fluctuation was reduced, the bonus of employees was increased, which led to the decrease of fluctuation to half. Based on the achieved positive results, the moral and the motivation of the people improved resulting in the right moment to start offering more responsibility, empower all the teams, focus on the concept of autonomous teams, and assign clear targets and responsibilities to all teams.

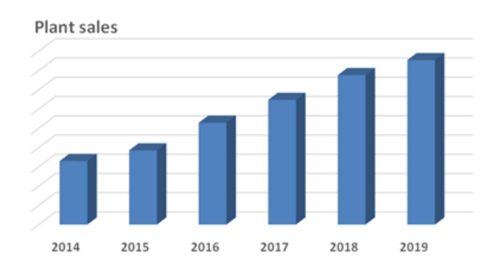

Figure 4.11. Sales dynamics (current and forecast)

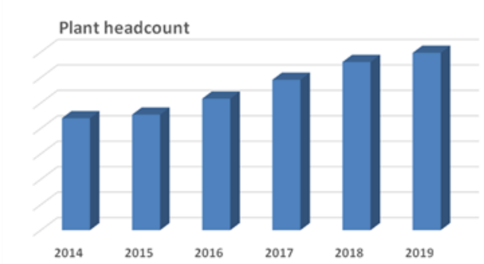

Figure 4.12. Headcount dynamics (current and forecast)

Consequently, people were more involved and the level of responsibility improved a lot. In order to better support these activities, some projects were initiated in the human resources department in order to continue the Grow and Personal Development [102]. Given all these activities and the transformations undergone in 12 months, the plant has become one of the most competitive in the company. This resulted in the fact that the plant in Western Romania is the best plant worldwide in our company today and achieved during this time span the following remarkable results:

• Reducing half of the production costs;
• Reducing 80% of the daily problems in production;
• Reducing non-quality costs by 50%;
• Reducing fluctuation with 80%.

Based on this case study, the following key points should be noted in order to achieve these same results within other similar best-cost countries:

• The most important issue to deal with is to simplifying all processes;
• Work in flow;
• Establish a clear support team with clear targets and responsibilities;
• Reduce waste everywhere and use people to add value, and not to cover other problems from production;
• Involve and empower the people;

• Motivate the people because in best-cost countries, such as Romania, one can achieve better results that in more developed countries, because the people are eager to learn and improve.

The establishments of the basic model of World Class Manufacturing (WCM) and the needed steps to become one of the World Class Manufacturing Company are part of the transformation program which was introduced in one big electronic automotive factory in best cost country in the last two years.

This experience is a real-life case study of a production factory transformation from a standard production best cost country plant to a word class plant, by applying the lean principles, avoiding waste everywhere and optimizing the plant organization structure for the new role. The main focus of the analysis is to provide an example of the optimization potential in any best cost country company by adapting Western automotive technology to the specific local strong points through creative thinking.

Being a competitive company today means at the end to have in place an internal system that boosts the performance of the organization and covers all the functions (purchasing, development, production, engineering, Quality, SQM, HR, IT, Logistic) and gradually transforms the organization philosophy into the WCM.

The analysis also shows that one of the most important elements to be considered for transforming a “normal manufacturing” location into a Work Class Manufacturing location is to develop the people using the proper set of principles and methods and to have a clear and communicated development strategy defined.

4.7. World class concept for a manufacturing plant: operational performance, productivity and adding value capability

4.7.1. Designing an effective workplace with a clear focus on operational performance and reliability

The core success factor for any manufacturing plant is to know what value is for its customers and to focus its processes towards increasing the amount of added value activities within the entire operational performance. This will enable the plant to provide only good products, in the right time and at the best cost for its customers and to improve its competitive position on the market in the long-term.

Basically the price of products which the customers pay is composed of the following elements:

Price = Materials + Added Value + Theoretical Margin

The price is one of the most important decision-making criteria, because it is under constant pressure in automotive industry where competitiveness is very high and efforts are constantly made in order to reduce cost even at a marginal level from both car manufacturers as well as their associated supply chain partner companies. This challenge is even more demanding as there is a high quality standard required as well as meeting very rigorous delivery times in addition to the reduced product life cycles.

The most effective way to source cost reduction is with the inbound materials coming from suppliers. These materials (raw materials, semi-finished goods, other products and services) need to come at the best price and the best quality required by the specific standards of the manufacturing process. The challenge and pressure to reduce cost in automotive industry is so important that there is no margin for waste in the price throughout the industry's network of suppliers.

Adding value is a key factor in automotive industry and the extent to which a plant manages to add value to its products is most often the feature that enables it to be competitive and thrive or struggle on the increasingly globalized market. The process of adding value it very complex, as there is a wide variety of activities within a plant which can contribute to it. The effectiveness and efficiency of the plant are most often a result of the value-adding process and the extent to which the tasks and jobs within the facility are adding value to the customer or not. The higher the extent to which the internal processes and activities are adding value, the higher the customer value is, which will improve the theoretical margin and enable cost reduction throughout the plant.

The theoretical margin is the amount added on to the materials and added value costs which together make up the final selling price. The theoretical margin is an expression of the effectiveness of the suppliers' network which is external to the plant, whereas the added value is the expression of the facility's internal efficiency and management. The theoretical margin is high if both the upstream suppliers and the plant's performance are good and is an expression of the reliability of the plant's operations and the effectiveness of the management's capability to source a competitive suppliers' network. In other words, if adding value is at a good level within the company, then the overall cost of production is low which implies sourcing a high theoretical margin for the plant's operations.

The consistency of the internal performance of the plant depends upon the balance between the activities and processes which are adding value to the customer and those which are not and are therefore considered as wasteful and subject to being eliminated from the process. These unproductive activities and processes within the plant are also a source of improvement if they are properly addressed in order to reduce their effect upon customer value:

- No stock
- No inventories
- No quality controls (extra)
- No internal transport / handling / picking / moving
- No re-works
- No scrap
- No people waiting or not balanced
- No people not adding value
- No extra investment
- No unused machines
- No extra spaces
- No unproductive time

- Not all indirect people (only those that provide the right service at the best cost)
- No low activity
- No absenteeism
- No meetings
- No repair
- No reports

There is a difference to be made between activities which do not add value, as some may be necessary and other not. This is the case with those activities and processes which do not transform the product in any way but are indispensable (for example transportation) as opposed to those activities which can be eliminated or at least reduced (for example administrative work). The goal of the approach is to improve the utility of the entire process and to increase the extent of the value-adding activities within the functioning of the plant as this will bring about customer value and will enable the plant to be competitive on the market.

This can be quantified by the ratio of added value activities within the manufacturing facility based upon certain levels. In a good plant for example only 1 out of 100 activities add value, whereas in a world-class plant 1 out of 25 operations add value (4 times more). In order to achieve these improvements and successfully implement them on the long-term, there needs to be a focus on a couple of key elements.

First of all, the plant needs to increase the personnel efficiency and use less people to perform the jobs and tasks within the designed processes which will enable a higher degree of specialization and productivity level for the employees.

Next, there needs to be a close focus on reducing the non-quality cost, which will generate an increased output of compliant products for both the customer, but which also meets internal quality standards, leading to less cost associated with quality issues.

The last key element to focus upon refers to reducing inventory and assets management which is both a financial and a logistics efficiency indicator. Inventory and assets block the company’s money and if not sized appropriately may cause additional issues and affect the proper flow of the production process.

Thus less investment and inventories mean a reduced amount of financial means blocked and enable increased liquidities for more productive means of improving the plant’s operational performance.

The operational performance of the plant depends upon the amount of added value created by the processes in the various workstations and workplaces throughout the manufacturing facility. This is because value is generated in the transforming operations, which all take place in the actual workplace (any type of workplace).

To increase the added value in a plant, first we must define the proper production concept which needs to have some important features (represented in figure 4.14): simple, visual and easy to understand.

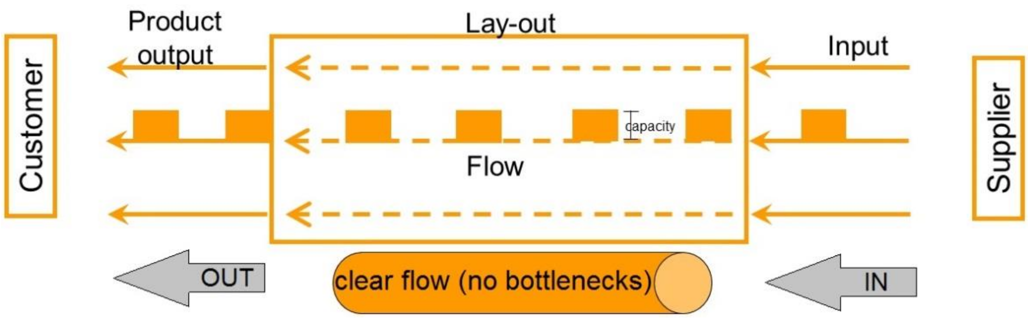

Figure 4.13. The tube concept

The tube concept basically supports the idea of a clear and uninterrupted flow from the input phase, passing through all stages of production, until the output phase, without disruptions or bottlenecks. The operational performance of the employees needs to be designed for 7.5 hours (standard work time is 8 hours) of effective activity at the workplace, which needs to be carried out in a productive manner.

Depending upon the situation the activity can be adjusted to increase the production output by speeding it up with up to 33% (normal activity is supposed to be performed at a speed of 4.8 km/h, whereas high activity is considered when work speed is at 6.4 km/h). The important thing to keep in mind is to maintain a constant working rhythm in the workplace and have a constant speed in the movements, which will make the rhythm easy to achieve and source reliable production output figures.

Maintaining high productivity levels without having to increase the speed at which activity is performed required for the work processes to not cut the rhythm. Any incident in the workplace at the assembly line slows the average speed down, cuts the rhythm and stops the production, therefore it needs to be avoided, eliminated and prevented. The type of incidents which source interruptions in the regular activity flow are caused by breakdowns, lack of materials, difficult changeovers, defective parts or defective process quality (in the production area). These types of issues can occur in production, but also in design or at the office and need a clear output definition in order to prevent them from arising.

The most important incurring issues in design are related to: no clear concepts, not enough knowledge, not considering the product as a business, no team work and no total engagement of all the people. These are important aspects to consider, because a proper design will make a big difference in the effectiveness of the production process and getting it right from the start will save a lot of time and effort in fixing the occasional issues that could occur later on.

Similarly at the office some of the most common sources of incidents that can cut the working rhythm are commonly related to: mistakes, searching for information, no clear flow of information which cause bottlenecks in the functioning and performance of the service and does not provide the support needed to the added value activities. As a result, losses are generated when the rhythm in the production is cut as is highlighted by figure 4.15.

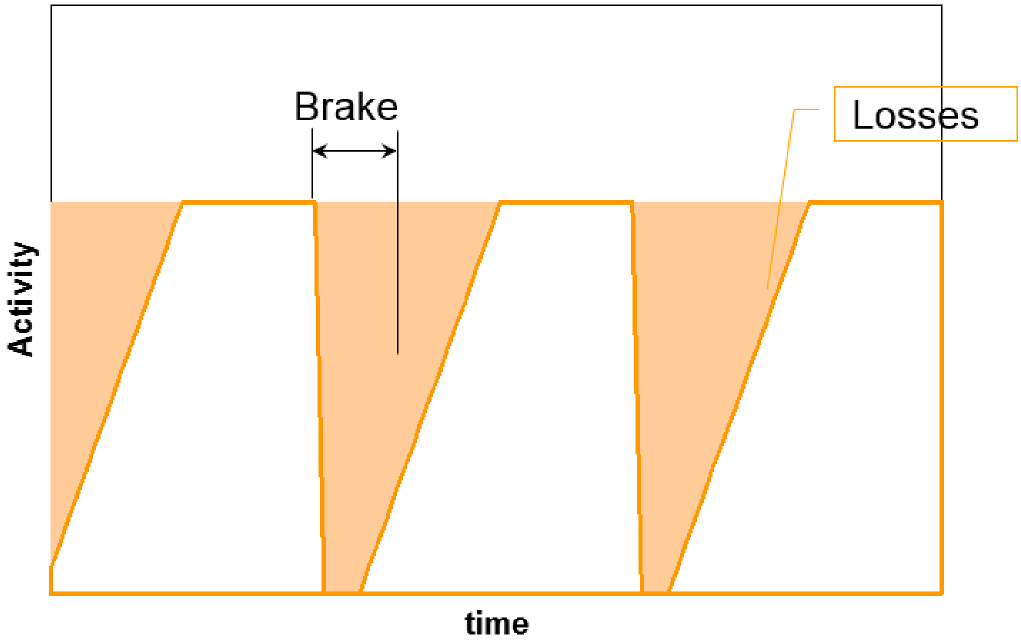

Figure 4.14. Productivity lag by cutting work rhythm

Any time that the process is stopped due to any reason, the operator must put an extra effort to achieve the same activity level after the interruption. It is very similar to the average speed when travelling, as maintaining a constant speed will be more efficient, than having to balance out interruptions caused by slow traffic or by being stationary for a period of time. This means, that the key point it is not the rhythm itself, but it is to avoid any interference in the workplace in order to be able to maintain the rhythm throughout the entire working time (the same anywhere).

The work place concept is thus an important factor in the added value creating process and needs to have special focus in order to keep its performance at an appropriate level (as close as possible to achieving a constant rhythm throughout the 7.5 hours) to support high productivity levels.

The design of an effective workplace needs to focus on the following features:

- **Minimum investment** – Designing a proper workplace from the beginning is much better than constantly having to adjust its characteristics and design
- **Minimum operators** – Better work 3 shifts than 1 because it prevents the loss of speed and ultimately means less problems and incidences
- **Minimum set-ups** – Here it depends upon the case and a decision is to be made on whether it is better to have two dedicated low-cost machines instead of only 1 flexible machine where set-ups per shift or per day would be needed
- **Minimum material** – Better control means less handling, but in order to achieve this you must increase the frequency of the transport

• **Minimum handling** – additional handling increases the risk of damaging the product, therefore it needs to be reduced to a minimum to prevent from such occurrences
• **Minimum space** – a good design of the workplace will source a functional workplace where no unneeded space remains unused
• **Minimum movements** – additional movements are not adding value, therefore every activity the operator needs to do at the workplace needs to be within his reach without having to make extra movements
• **Easy machines** – Less maintenance will increase the overall productive working time of the machines
• **LCA** – Some of the projects within a plant have a higher life cycle, others only up to 1.5 years or even less in some cases, therefore the design of the workplace needs to prioritize these timespans in order to achieve good efficiency levels for all ongoing projects
• **Minimum support** – The employee needs to have very clear instructions and a simple to perform process within the workplace for him to be able to work autonomously and without having to seek support from colleagues or managers
• **Minimum decisions** – Everything needs to be clear at the workplace and no common-occurrence decisions should appear during the process in order not to disrupt the activity rhythm
• **One level decisions** – There should be a clear overview upon the outline of the decision-making process
• **Everything is in the workplace** – The workplace needs to be equipped with all the proper tools in order for the operator to perform his activity successfully

Besides designing and implementing an appropriate workplace layout, there is an equally important aspect of managing the workplace as well in order to assure it is performing within the desired parameters and provides the expected level of output.

A good workplace management which supports productivity should have the following characteristics:
• **Non administrative activities** – The focus should be set on the work at hand and not upon other paperwork or administrative tasks associated to the workplace
• **Automatic control of all KPI** – Visual management is important to have a clear, immediate and real-time overview upon the performance metrics of the processes and their degree of being in line with the set targets
• **Automatic control of planning** – Setting the designed levels for production planning, progress overview and replenishment and enabling an automatic control of the required output increases the reliability of the production process and the accuracy of the planning schedule
• **Automatic control of preventive maintenance** – Preventive maintenance is very important for the proper running of all processes and needs to be done regularly to assure all the machines are running within their designed parameters and producing the expected outputs
• **Minimum dedicated resources to support** – Another important issue is to make the workplace as effective as possible for the operator to not have to need any kind of support during his working hours and to be able to perform the job right from the beginning without any inconveniences or disruptions
• **Material pull-system or Kanban**: The best Kanban is the Box-Kanban (only replace empty boxes, empty spaces), because it makes its implementation much

easier to carry out and supervise in order to obtain a high level of control upon the successful completion of the process

The organization around the workplace is equally important to support its proper functioning in order to attain the expected performance metrics. Lean management implementation enables dealing with a minimum of occurring incidents and thus requires minimum organization for such unexpected problems. In automotive industry it is very important to have a high level of activity without stoppages as ceasing activity for only a couple of minutes in certain plants can cost millions of euros, therefore reliability of machines and their proper maintenance is essential.

The most employed tool in this sense is the total productive maintenance (TPM). TPM focuses on the maintenance of the equipment within a manufacturing facility (machines), but also addresses processes and employees within a system designed to uphold high productivity levels and avoid unexpected stoppages, breakdowns and delays in manufacturing processes. The system helps creating added value to the plant's operations and plays a major role in maintaining a high level of equipment effectiveness and preventing accelerated deterioration with the help of the implicated workforce [42].

Maintenance with TPM implies some obligatory features such as prevention, prediction, involving maintenance and the operators within the overall process. This will help maintain easy lines with easy maintenance and generated the use of less resources [92].

Having an effective TPM system implemented will also support increasing the level of quality of the products the plant manufactures. Not only that but it allows the company to produce better quality with less resources, being an important part of the process. Maintaining high quality standards for both the customers and for the plant's own quality standard policy will empower the support team to introduce serial changes, improve quality, analyze problems and find root causes and introduce new models to increase overall efficiency.

Logistics is the final step in the plant's processes and the people working within this department have a very complex job which deals with a large variety of issues that need to be addressed correctly in order to deliver the products to the customers. The logistics department is in charge of transportation, inventory, handling and storage within the warehouse, where all the products are prepared for delivery towards the customers along with their associated documents and traceability symbols.

Although this part of the activity within the plant requires an important amount of attention to detail, high organization capabilities and problem-solving issues within short timespans, the logistics of the plant does not add value to the products. During these processes no transformation is made upon the products, therefore no added value is created, however there are risks of deteriorating them during handling, loading or unloading which means they require special attention throughout the entire delivery process.

Being a cost-oriented department, the simpler the process is the less people you need to handle these issues. The rhythm of all support people must be higher than the one of workers, otherwise they slow-down the activity, whereas it is good to have the load of the logistic people at a level of 110%, as in most cases it is better to have the issue of some small lack of material than people waiting and disturbing the operators.

Similar to logistics, there are other indirect departments as well which do not add value to the product. So, the target is to reduce at the maximum the indirect people keeping the correct service level. There are 3 main ways to handle this occurrence: first of all, simplifying all the administrative processes means less time and energy lost with unproductive and non value-adding activities. This can be done by having less decision levels and implementing a system for having in line information and KPIs.

Next is reducing all the administrative processes, after having simplified the process, there are always means to reduce those activities which are not absolutely necessary. This can be done quite easily with the implication of the employees and will improve the quality of the information as well as ease the employees' effort through the automation of certain or several administrative processes.

Finally, linking all administrative processes will increase the speed of their completion and will make the flow of documents and information be more understandable and traceable for the implicated members. When some departments are involved in an administrative process the key is to have an automatic system to link, check and alert the people in charge of certain tasks for a better overview upon the jobs needed to perform for the completion of those specific activities.

4.7.2. Workplace effectiveness: Employee productivity and performance-based mindset

One of the most important success factors in a plant is to have a team working together for the same goal. This brings about one of the most sensitive challenges for managers, which is how to motivate their people and inspire them to add value to the company's products and to themselves as professionals. This is both a technique as well as an art, to be able to win the devotion of the employees and make them believe and work for the goals of the company in a proactive manner.

There are a couple of principles involved, which need to be understood when motivating employees to have a long-term productive and added-value based approach, such as:

- **Focus on objectives**: the same that you want as manager in terms of goals and performance metrics, as well as the organizational process, must be wanted by your people, they have to have a common set of values and empathize with the manager's targets in order to bring them to fulfillment successfully
- **Innovative changes**: By making the things in the same way, you will achieve the same results; employees and managers need to understand the

importance of change, innovation and continuous improvement in order to make their jobs easier, more pleasant, more productive and in the end more efficient in order to add value, because the customer only pays for high added-value processes which provide competitive products

- **Empowering people**: one of the most important motivational factors is to give the people responsibility and opportunities to grow professionally; this means investing in training the people to improve, giving them the tools and assigning them projects, which will give them a positive sense of empowerment and dedication to fulfill their tasks and to increase their productivity
- **Relevance of actions**: Change is always received with some form of restraint, especially if the benefits are not absolutely clear and if the changes are not endorsed by those who are effected by the new configuration; in order to help increase the speed of the implementation, the change must be visible to motivate the people and to convince them of the fact that the new modifications are appropriate and will better serve their purpose both on short-, medium- and log-term
- **Responsibility**: One of the most important motivational factors is to have a measurable metric or goal connected to your performance. This is why it is of utter importance to assign all KPIs to all your people, which means that everybody in the organization must be responsible for one or several indicators. Being appointed as the person in charge of fulfilling some kind of KPI will urge you to use all your means in order to achieve the goals set by the higher ranked management level and encourage you to perform at your best level. This will usually source a high degree of goal achievement as well as sometimes exceeding the target levels, which will attract bonuses and different other forms of professional reward for the employees who perform very well at their job.
- **Simplicity**: All the KPIs must be visible and easy to follow, in order to have a straightforward overview upon performance and the real-time status, which will enable for certain measures to be applied in case of progress being behind schedule. This feature will also enable the employees to have a very performance-oriented focus within their jobs and motivate them to achieve high productivity levels.
- **Professional challenges**: Probably the most important feeling needed in order to grow is the sense of being free to choose where you want to improve and challenging your people and making them want more from themselves. This is a key element in a plant, as it gives the people the motivation to continue developing and to invest their energy and know-how into improving not only themselves but also the plant's processes and effectiveness.
- **Freedom**: Not all employees need to be trained in the same fields or on the same levels. This is important to understand, because the mere training session provided unitarily to all employees is not effective. This is because everybody must improve in the proper fields such as leadership, team working, vision and skills and most important they need to have the freedom to do it at their own pace and whey they feel the urge to do so. This is very important for the overall feeling of the employees and their individual process of managing their own professional growth, which will source a productive working environment within the company.

These principles will enable a strong organizational culture focused upon an effective operational process within the plant through continuous improvement, competitive work environment and overall productivity gains which will source customer value. This mindset will be enabled even better should every employee understand the fact that the company's business is his own business, meaning that the interests and results of the company have to be matched by his own interests.

Being aligned with the company's values and goals is important for personal and professional growth and will source the motivation to increase own performance, productivity and achieve ambitious goals. The success of an organization mainly depends upon the quality of the people involved in the everyday activities and their working environment and if the plant knows how to motivate its employees and they are in line with the vision and values of the company then the synergy created will source strong organizational culture leading to a high performance plant with a sustainable competitive position on the market.

This high level of performance is shown within figures 4.16 and 4.17. Figure 4.16 emphasizes the proactive approach towards improvement within different plants, in relationship to the daily operations. The continuous improvement process can source important efficiency and productivity gains, which is why a proportion of 20% of this approach within the operational process will enable best results in the development of the company. The less time a company allocates for improving its processes, the less likely it is to enhance customer value and gain a competitive position on the market.

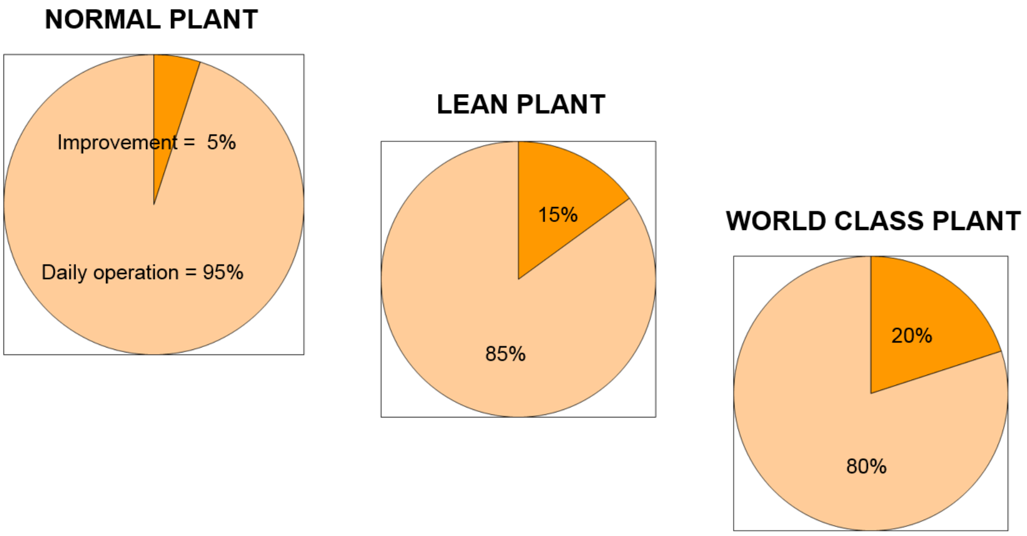

Figure 4.15. Amount of improvement activities within different performance level plants

Figure 4.17 highlights the outcomes of the continuous improvement process preoccupations presented in figure 4.16. The level of improvement achieved will also have an impact upon the employees, as visible improvements will always be perceived as a more relevant change and give a sense of positive dynamics to the company. The term "destructive" is used because constantly achieving high degrees of improvement implementations will almost always significantly change the layout, the process organization or the work flow of the plant and this means that the people need to have a high level of adaptation capability as well as the ability to successfully ensure the effectiveness of the new plant organizational features. This constant improvement process can only be properly performed and applied with the right people, who are in line with the values and vision of the company and its management.

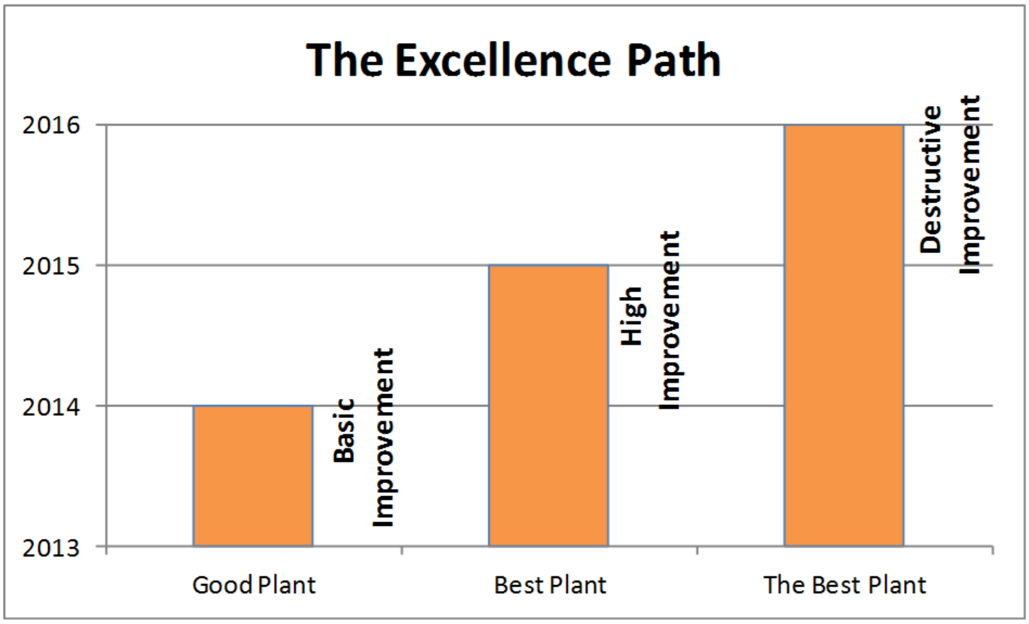

Figure 4.16. The relationship between improvement activities and plant performance

Achieving this high level of performance is a consequence of applying proper management techniques throughout all relevant areas in the plant and having an involved and dedicated team behind to support both ongoing goals as well as future objectives. The target set for the plant in the Western region was to become one of the best plants within its group and to achieve a very high competitiveness level in order to be ranked as world class within only a 3 year timespan (2014-2016).

This meant the plant had to achieve excellent operational performance, to manage new projects and also work on strategic projects and have the proper team to help fulfill these ongoing challenges.

The plant's progress also had to be kept in line with the overall targets for these years to become a world class plant, both within the group, but also on a worldwide level in order to improve its position on the market and to acquire a competitive advantage over its competitors in the long-term.

The year 2015 marked some ambitious targets being met by the company in order to achieve operational excellence and reduce running costs throughout several areas (total savings of 9 million euros):

- achieve 100% production every week, with no backlogs (productivity gains)
- no pending parts – analyze or make decisions (increased effectiveness gains)
- excellent preventive maintenance (reliable equipment outputs)
- perfect 5S (internal organization)
- no overtime => savings of 0.4 million euros (stimulate efficiency)
- no scrap => savings of 1 million euros (quality improvement)
- no claims => savings of 0.4 million euros (high service level)
- no startup cost => savings of 1.1 million euros (reduce unproductive set up and waiting times)
- no urgent freight => savings of 2.1 million euros (reliable planning schedules)
- no obsolete – good ECN application => savings of 0.2 million euros (reduce waste)
- no working during holidays => savings of 0.7 million euros (support time off from work for rest)
- 10% of the departments cost reduction => savings of 3 million euros (stimulate continuous improvement)
- maximum 850 operators => savings of 1 million euros (efficiency gains)
- no defects to customers (high quality and customer satisfaction)
- 30% efficiency improvement in the direct and indirect area (overall target)

In the automotive industry the development of new technologies and changes in product design as well as the diversity of features fitted onto onboard equipment is constantly increasing as is the complexity of the tasks to be able to meet car manufacturer's different requirements. The challenge for any supplier in the automotive industry is to be able to rapidly adapt to these changes and provide the required product with the expected level of performance, quality and reliability.

In order for new product introduction to be effective, the company applied the following methods:

- perfect line and balancing concept (high productivity and no waste)
- bring the line in advance (priority and efficiency)
- involve 100% the design (improved product features)
- check, control, and be 100% sure that the supplier will deliver the right quantity and quality (supply chain reliability)
- full involvement in SOP of launch management, PQM and engineers (overview of all relevant product features and performance levels)
- full involvement in SOP of production and maintenance (overview of all product industrial characteristics and long-term reliability in performance)

Besides being capable of introducing new products, a company must also have a strategic goal of always improving its performance, operations and ability to foresee and adapt to future trends and challenges in automotive industry. Strategic projects are more likely to be successful and provide expected results if there is:

- high quality of the human resource: having the best of the best people, groups, teams and departments (human resource capability)
- plastic suppliers' development (reliable supplier collaboration)

- plant automated information/intelligent plant (real-time overview)
- lines optimization with collaborative robots (supporting effectiveness)
- 100% plant optimization (continuous improvement processes)
- 100% clean plant (high quality working environment)
- 100% 5S plant (high level of internal organization)
- 100% CBS plant (effectiveness)

However, in order to achieve this level of operational performance, new project development and alignment to strategic targets, there must be a very strong organizational culture present within the entire staff and a winning spirit of the team involved in implementing these improvements within the plant.

Having success in these approaches requires having the proper attitude and working hard together to achieve ambitious goals, overcoming difficulties and working as a team throughout all the stages of the project, as is implied by the following actions:

- strong teamwork (working together and helping each other throughout all stages of the project)
- leadership and ownership attitude to all indirect and direct employees (strengthening the team and motivating team members)
- high speed 4 time projects per year (dynamic tasks and challenging goals)
- full involvement of all the people in improvement projects (mindset focused upon achieving common goals)
- passion and winning mindset (inner motivation and implication in projects)
- full morale because nobody win without difficulties (psychologically strong)

One of the most important things to remember is that adaptation and continuous improvement are the basis of career development through listening, learning, working hard, commenting and persisting in one's efforts until achieving goals. Launching new projects with complex tasks is never easy, but by making the proper decisions and working together with the team, the employees will start to believe in themselves and find the way towards successfully completing the project and fulfilling the goals and targets set at the beginning.

A summary of the expected lean results of the plant focuses upon 3 main areas: adding value, productivity and efficiency. The added value concept is based upon the proportion of time in which the direct operators are actually adding value, which needs to be as close to 7.5 effective hours (of 7.5 total hours) as possible to achieve high effectiveness and increase the ratio of time in which customer value is created. The second concept is productivity, which needs to present throughout the entire factory to support superior performance.

Besides the direct value adding processes there are also other activities which may not necessarily add value, but still be required, as is logistics for example. These activities are performed by indirect people, who must have an activity load of 110% (more than the load of the activities which add value) in order to support and uphold the high output levels of the other processes. Sourcing lean results also means reducing all unnecessary activities to the point where they are actually eliminated. This enables the plant to have a high extent of its processes focused upon creating added value for the customers and helps increase its performance and effectiveness. This brings about the third concept, efficiency, which will try to reduce the amount of indirect value adding activities and people to a minimum and lean towards providing appropriate support in the areas where customer value is sourced.

For the plant based in the Western region to become a World Class Plant within 3 years (from 2014 to 2016) the following targets were achieved within the three year timespan:

- increase to 3 times the volume of production per person (triple average individual production)
- keep the same support people producing the double (double the average output of the supporting team)
- keep the same indirect people producing the double (double the average output of the employees indirectly adding value)
- reduce to 2/3 of inventory (33% overall reduction of inventory)
- reduce to 1/2 of investment (50% reduction of investment)
- reduce to 1/2 of space (50% reduction of the space and improved usage)
- reduce to 1/10 of non quality cost (90% reduction of incurred costs and achieving very high levels of quality to avoid future issues and complaints)
- reduce to 1/4 of idle time (75% reduction of idle times)

Becoming a World Class Plant implies having high productivity levels, a very good efficiency in keeping costs as low as possible and having an effective team that is focused upon carrying out ongoing projects and enabling improvements for the upcoming strategic projects and challenges the company will face in the future.

4.7.3. Implementing the World Class Concept: Best results are only possible with the best people

Lean Management is about people. It is about people, because they are the ones that provide the added value, the value to the customer and the ones can continuously seek improvements to make company performance more effective. This is why it is so important to have the right people at the right place.

Finding the best team requires you first to analyze your team: if they are OK, keep them and let them grow in their positions. If they are not OK, move them to other positions in the company and help them perhaps discover another place where they can provide support and add value. This approach is very important within a company, because you cannot achieve the results you desire or expect to obtain with the wrong people.

The Lean Management application and progress within the company is a question of how well your people are growing and are motivated at their workplace. One of the most common mistakes is to merely apply the concepts without having the appropriate work philosophy behind to support these concepts in improving the actual performance of both the company and its employees. Kanban, SMED, VSM, VM, TPM, 5S, Jidoka: these are tools to introduce and follow the production.

So you need people to keep them alive, because all these tools are, are production management techniques and if they are not part of an everyday approach, their effect will be at most marginal. By using the tools without the structure to support them will lead to no results or to an on the spot result, which is only a random consequence.

Every person from every plant must be trained and must have expertise in certain drivers of competitiveness and professional growth. This must be a part of the employees' professional DNA in order for them to grow and build successful careers. These drivers of competitiveness are lean management, innovation and leadership. Somewhere around 40% to 60% of the problems in the plant (Western region business unit/company) are coming from the lack of leadership and ownership of the people.

Leadership and ownership means being an independent employee focused upon the goal of adding value and seeking improvement in the overall activity. This happens when the employee is responsible of his activities, responsible to achieve results and also is responsible of leading any person, department, customer, supplier or whatever to achieve his own goals. This is one of the most important characteristics a high quality employee must have in order to be able to focus on the main jobs and improvements that need to be carried out to achieve good performance within the company.

The key idea here is that the employee should consider the company's business as his own business. Besides performing tasks, every employee should be able to detect waste and improve the process or ask for support to improve the process. Everybody must be able to analyze his own work and ask himself 3 important questions:

- Which is the part of my work that adds value?
- Which is the part of my work that is waste?
- Why do I receive my salary? (Is it because I have a contract or because I add value?)

This self-assessment is very important in order to determine the part of the work which is actually productive and contributes to adding value and the part which is waste and can be eliminated to make way for a more efficient use of working time.

A company will always focus on having two kinds of quality employees: value creators and value applicators, both having very important role in the plant.

The value creators are usually designers and engineers, but also fix and administrative functions. Their goal is to render 80% of their time to create new value.

The value applicators however are the operators and their goal is to have 100% of their time add value. This is because their work is directly related to the end product and they need to be impeccable in order for the products to meet customer requirements and quality specifics, both at the end of the internal process (company quality standards), as well as at the customer where there should be a sense of high customer value and reliable product quality. This is why continuous improvement is good and important, but not enough.

Innovation is necessary in all the areas as a way to achieve competitive advantage and become a World Class Plant (business units/company). This also applies to the people working in the plant, who can come up with some good improvements, but it is innovation which makes the actual difference and the ones that manage to do this will always be one step forward and have a leading role in the company.

The basis of every leader can be summed up in the following 10 points:

1) Believe in your goals and convince the team (inspiring and motivating the team to do their best)
2) Operators add value: blue and white collars need to be productive 7.5 hours / 7.5 hours (added value productivity)
3) Flow concept: no inventory (production effectiveness)
4) Improve and improve and improve (continuous improvement concept of lean management)
5) Easy organization and easy decision making (avoid complexity and complications, always use simplicity)
6) Kill problems: do not accept repetitive problems. You must make a good operation 1 time and a million times (do things right from the beginning and eliminate all potential sources of errors and problems right away)
7) Optimize resources for the daily operation (efficiency)
8) Keep some resources to improve operations: Invest to save more in the future (savings for future investment)
9) Make it visible (real-time visual management helps better control internal operations and performance)
10) Have the passion to be the best (strive to be a successful leader for the team)

5. MEASURING THE DEGREE OF VALUE ADDED ACTIVITIES WITHIN A COMPANY AS A MEANS FOR CONTINOUS IMPROVEMENT TOWARDS WORLD CLASS MANUFACTURING

5.1. Standard times and their key role in a manufacturing plant

In order to assess the extent to which activities, processes and machine working time is actually transforming the products and thus adding value, precise on the spot measurements were made by the industrial engineering team. These measurements are also in line with the standard times that are used for designing and balancing the expected flow and output levels. The standard time is the average time an operator with average skills needs to perform a specific task or set of tasks within a normal working pace at his workplace by using the adequate methods to complete them successfully. Standard times also include additional time for allowance, which may be caused by technical and personal disruptions or unscheduled events, which affect the time needed for the standard work to be completed (personal needs, fatigue, unavoidable delays during the shift).

Calculating the standard time is the product of 3 factors: the observed time (To), performance rating factor (R) and the allowance for personal needs, fatigue and unavoidable delays (PFD).

The necessary time to complete the task is the observed time (To), which is measured while that task is being performed for an average reading. The performance rating factor (R) is the pace at which the operator performs that specific task in accordance to the established standard time. The performance rating factor (R) measures the time he needs to complete an operation by comparing it to the allocated standard time. It should not take the person more than the standard time to complete the operation (working normally at 100%). Should the operator perform the task faster (working at 110%), this implies a gain in productivity, should he perform it slower (working at 90%), this in turn means the person's pace is slower than normal and will slow down overall productivity.

The allowance for personal needs, fatigue and unavoidable delay (PFD) is an average extra amount of time which is added to the standard working time to include lag for unplanned events.

The standard time (Ts) is thus: Ts = To*R*(1+PFD), where:
Ts – the standard time;
To – the observed time;
R – the performance rating factor;
PFD – the allowance for personal needs, fatigue and unavoidable delays;

Standard times are important in industrial engineering for properly designing the production lines, their layout and personnel requirements in order for the process flow to be continuous and provide the expected measured output. It also serves for production planning, assessing the workers' productivity figures and estimating overall reliability of the implemented layout (flow between workstations, processing times, line balancing).

In order to perform the calculation of the employee work time added value factor all the actual times needed at each workplace need to be measured and compared to the standard time. The obtained times need then to be categorized into time which adds customer value and unproductive time, which may be necessary due to certain constraints (indispensable) or unnecessary (dispensable) and subject for elimination (waste).

Any lag at any workstation will slow the overall process down and affect line balancing, workflow and productivity. This unproductive time needs to be eliminated as it causes waste and increases both time and cost where the plant is not producing any transformations upon the product which add value and provide value to the customers.

This is an important business orientation for the plant because even the standard times include lag times where the people are not performing value adding activities due to certain circumstances. The important thing to understand is that the customer only pays for something which brings him value and that is only possible when the products are being transformed, anything else is considered waste and needs to be removed from process flow.

All standard times are measured and a record is kept by the industrial engineering department of the company, however the company did not want to provide these times, nor allow for the individual comparison measurements to be made available as industry standards are quite similar and comparable and would have been a possible source for competing companies to source internal data. The average productive times of both the machines (machine work time added value factor, MWTAVF) and operators (employee work time added value factor, EWTAVF), being a global estimate based upon the complex individual calculations was however allowed for use within this material.

The research method used for compiling the list of individual employee and machine work time added value factors is linear interpolation and by weighing the importance of all individual processes, a reliable average has been sourced for all the associated activities of each category.

Technically speaking, linear interpolation is a method used in mathematics in order to fit linear polynomials within specific graphical curves and construct new data points within the range of a discrete set of known data points. Polynomial is an expression consisting of variables (or indeterminates) and coefficients, that involves only the operations of addition, subtraction, multiplication, and non-negative integer exponents. Linear interpolation is usually performed by fitting one or more points between two known points in order to better match the curve trend and to appropriately represent it.

Linear interpolation is a simple and practical method to obtain values at positions in between a certain range of data points, where these values might not be available or known. The points are simply joined by straight line segments (hence linear interpolation) and have the characteristic that each segment which is bounded by two given data points can be independently linked through interpolation.

The values within the interpolated line range between 0 at the initial or starting point and 1 and the second or end point, being either closer to the starting point or the end point according to their relative distance to or from these fixed and known values [18].

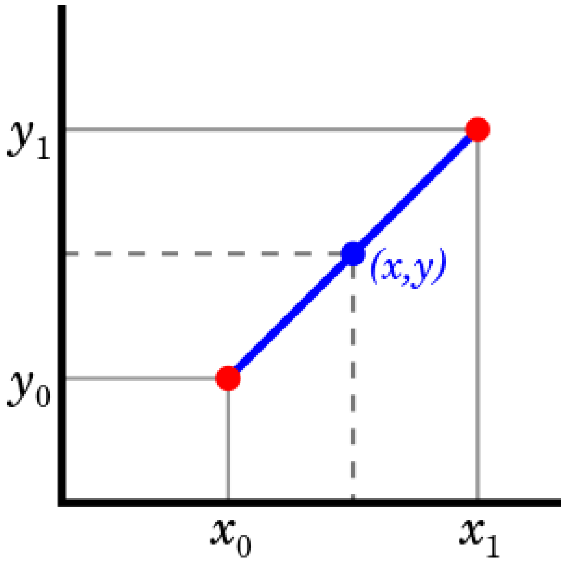

Figure 5.1. Simplistic graphic representation of the linear interpolation method

Basically, if two known points are given by their specific coordinates (x0, y0) and (x1, y1), then the straight line between these points (as is depicted by the figure 5.1) is the linear interpolant. For any value x within the selected interval, the corresponding value y along the straight line is given from equation (1) below:

$$\frac{y-y_0}{x-x_0} = \frac{y_1-y_0}{x_1-x_0} \quad (1)$$

which can also be derived geometrically from figure 5.2. The geometrical representation basically shows that the value at a specific circle multiplied by the distance between the other two circles will always be equal amongst them, regardless of the combination chosen. In essence it is a special case of polynomial interpolation with *n* = 1.

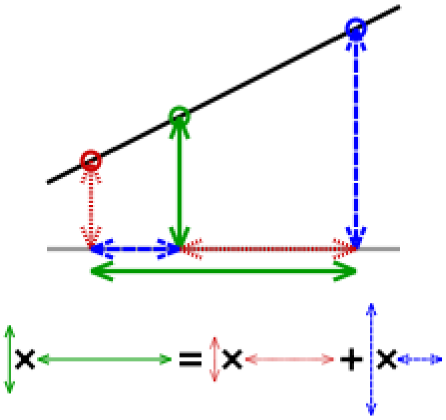

Figure 5.1. Geometric visualization of the linear interpolation method

In order to source the appropriate formula for linear interpolation in this specific interval (x_0, x_1) we must proceed to solve the equation (2) for *y*, which is the unknown value at *x*:

$$y = y_0 + (x - x_0)\frac{y_1 - y_0}{x_1 - x_0} \quad (2)$$

The problem of constructing a continuously defined function from some given discrete data is impending when needing to process or interpret information which may not be provided on hand in the given data. There are a variety of examples where this is to be found in practice and one approach used to solve this problem and fill in the gaps is interpolation which provides the reliable tools to process the original function and source missing values and render them comparable with the help of the given measurement points [74].

The linear interpolation method essentially acts as a weighted average to precisely determine locations of points between two given points of precise coordinates (x_0, y_0) and (x_1, y_1). The distance from the end points of the point in question (the unknown point) determines its precise coordinates between the existing points and helps better estimate the trend and curve shape of the graph. The closer the point is to one of the existing initial given points, the more influence it has than a random farther point upon the allure of the curve through linear interpolation.

The weights are normalized distances between the unknown point and each of the end points and have the following coordinates: $\frac{x - x_0}{x_1 - x_0}$ and $\frac{x_1 - x}{x_1 - x_0}$ which, because they sum up to 100% or 1 as a ratio, provide the formula (3) for linear interpolation below:

$$y = y_0\left(1 - \frac{x - x_0}{x_1 - x_0}\right) + y_1\left(1 - \frac{x_1 - x}{x_1 - x_0}\right) = y_0\left(1 - \frac{x - x_0}{x_1 - x_0}\right) + y_1\left(\frac{x - x_0}{x_1 - x_0}\right) \quad (3)$$

Linear interpolation on a random set of data points (x_0, y_0), (x_1, y_1), ..., (x_n, y_n) can also be performed in order to better fit curve allures and to better match missing data into certain graphs as well as to estimate lack of data within a given range for a better overlap of the data series. This is graphically represented in figure 5.3.

The successive compilation of several linear interpolants between their according pair of data points results in a continuous curve, which generally also has a discontinuous derivative (not always, but in most cases it does appear) and thus also implies the outbreak of the C^0 differentiability class. The set of data points provides a much better spread of values and can more easily and appropriately represent the trend and shape of a curve of values than with other mathematical methods existing in the literature.

One of the most convenient assets of linear interpolation is that it is very easy to understand and employ and generates quick and reliable results which can immediately serve for use within the performed analyses. The necessary calculations for using the linear interpolation method are also are easily and quickly made by hand, which represents another reason why this method is widely used for the interpolation of tabular data [48].

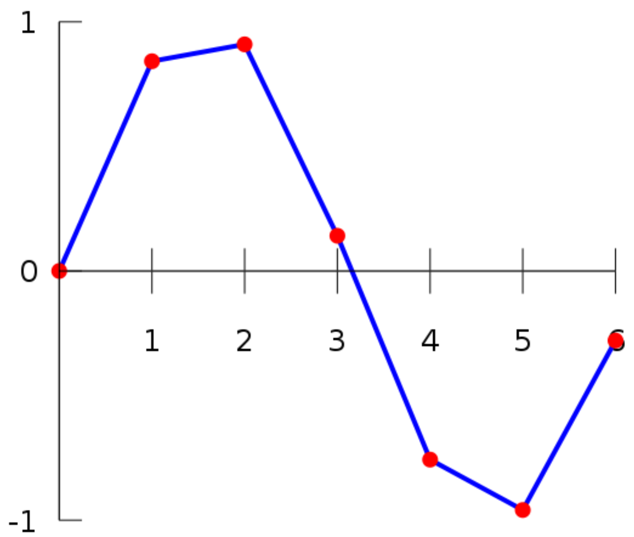

Figure 5.2. Linear interpolation of a data set

Linear interpolation also results in discontinuities at each point and its shape may be a bit rigid due to the lack of "smoothing" of the method which is represented in both figure 5.3 and figure 5.4.

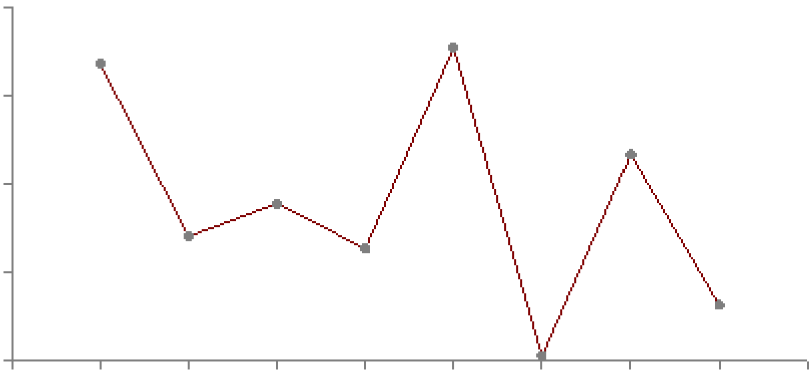

Figure 5.3. Line segments representation through linear interpolation

There are several interpolation methods, linear interpolation being only one of them and the most practical to use, with its inconveniences as well when referring to graphical representation. The sharp edges of the curves obtained through linear interpolation mean that a smoother interpolating function is sometimes desirable in order to more adequately represent trends or curves. One simple alternative would be cosine interpolation as the suitable orientated piece of the employed cosine function provides a much smoother transition between the several adjacent segments as is shown in figure 5.5.

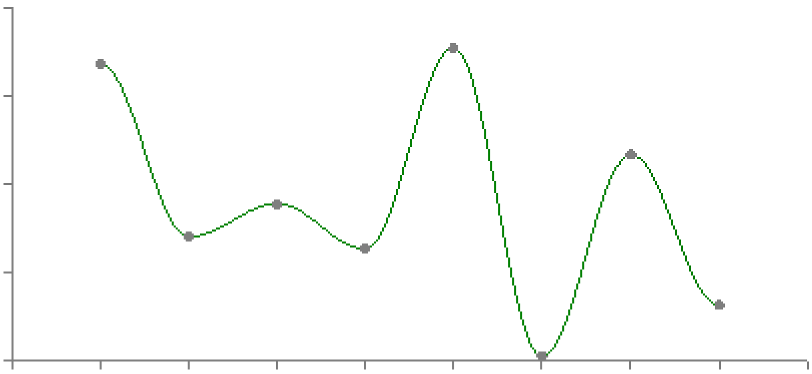

Figure 5.4. Line segments representation through cosine interpolation

Other methods of interpolation exist as well (cubic, hermite, their 3D correspondent, etc.) with their own assets and inconveniences. Cubic interpolation offers true continuity between the segments, but its inconvenience is that it requires more than just the two endpoints of the segment. Hermite interpolation requires four points to achieve a higher degree of continuity and has the features of tension and biasing controls, which can be used to tighten up the curvature or to twist the curve at or about the known points [18].

Linear interpolation is often used to approximate a value of some function f using two known values of that function at other points. Being an approximation the accuracy level is not always very high and there is therefore a degree of variation from the actual value to be considered as a deviation or error. The error of this approximation is formalized with the help of Rolle's theorem (see figure 5.6) which conveys that any real-valued differentiable function attaining equal values at two different points must have a stationary point somewhere between them [12].

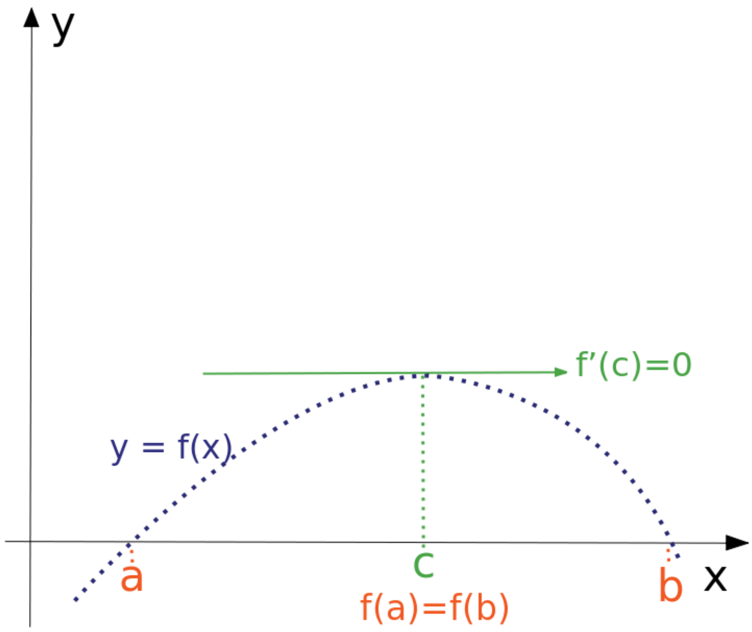

Figure 5.5. Standard version of Rolle's theorem

From a mathematical analysis point of view this means that in this particular case the stationary point between the two different equal points represents the point where the first derivative equals zero. A stationary (or critical) point of a differentiable function of one variable is a point of the domain of the function where the derivative equals zero. Basically this is a point where the function ceases to or "stops" increasing or decreasing which is equivalent to the fact that the slope of the tangent line to the graph at that point is equal to zero. In the case of a differentiable function of several real variables, the stationary point (or critical point) is an input where one value for each variable is introduced, where all its partial derivatives are zero. This in turn also means that the gradient equals zero. The error of the linear interpolation approximation is thus shown in formula (4):

$$R_T = f\ (x) - p\ (x)\ (4),$$

where p denotes the linear interpolation polynomial which can be expressed by equation (5):

$$p\ (x) = f\ (x_0) + \frac{f\ (x_1) - f\ (x_0)}{x_1 - x_0}\ (x - x_0)\ (5)$$

If f has a continuous second derivative, then by using Rolle's theorem one can prove that the the error is determined with the help of the following statement:

$$|R_T| \ \leq\ \frac{(x_1 - x_0)^2}{8}\ \max_{x_0 \leq\ x\ \leq x_1} |f''(x)|\ (6)$$

It is however to be stated that the approximation between two points on a given function does not improve and actually gets worse with the second derivative of the function that is approximated. This is because of the fact that the "curvier" the function is the less exact or appropriate the approximations made with simple linear interpolation become and therefore create a wider lag (see figure 5.7) [31].

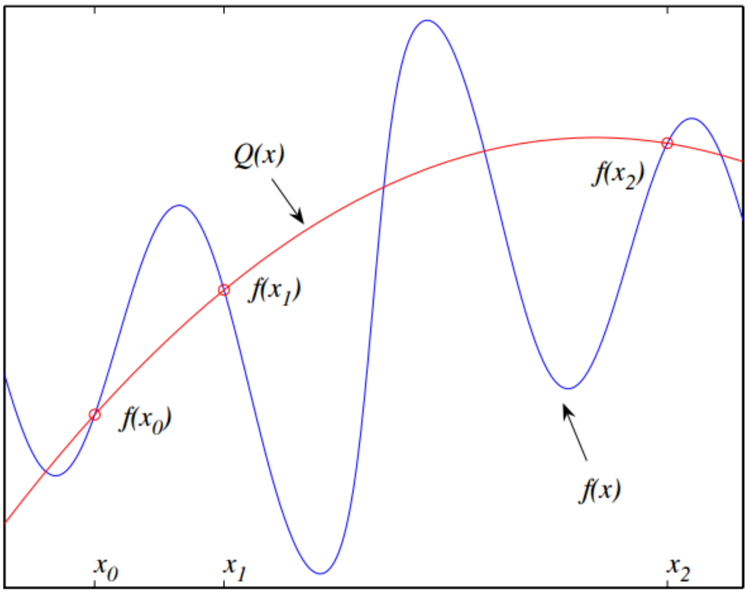

Figure 5.6. The function f(x), the interpolation points x_0, x_1, x_2, and the interpolating polynomial Q(x)

The interpolant from the linear interpolation is thus given by the following equation (7):

$$y =\ y_a + (y_b - y_a)\frac{x - x_a}{x_b - x_a};P\ (x, y)\ (7),$$

which further provides equations (8) and the subsequent equation (9):

$$\frac{y - y_a}{y_b - y_a} = \frac{x - x_a}{x_b - x_a}\ (8)\quad => \quad \frac{y - y_a}{x - x_a} = \frac{y_b - y_a}{x_b - x_a}\ (9)$$

This shows that the slope of the new line between (x_a, y_a) and (x, y) is the actually the same slope as that of the line between (x_a, y_a) and (x_b, y_b). Linear interpolation has the advantage of being quick and easy, but the downside is that it is not very precise. This is highlighted by the following error, where the function which we want to interpolate is *f*, the value of *x* lies between x_a and x_b and we will consider that *f* is twice continuously differentiable. The consequent linear interpolation error will thus be expressed by the following equations, (10) and (11) below:

$$|p(x) - f(x)| \leq C(x_b - x_a)^2 \ (10) \quad => \quad C = \frac{1}{8}\max_{r \in [x_a, x_b]} |f''(r)| \ (11)$$

Basically the equations state that the error is proportional to the square of the distance between the specific data points. In other methods (polynomial interpolation (see figure 5.8), spline interpolation) the same error is proportional to higher powers of the distance between the correspondent data points [66].

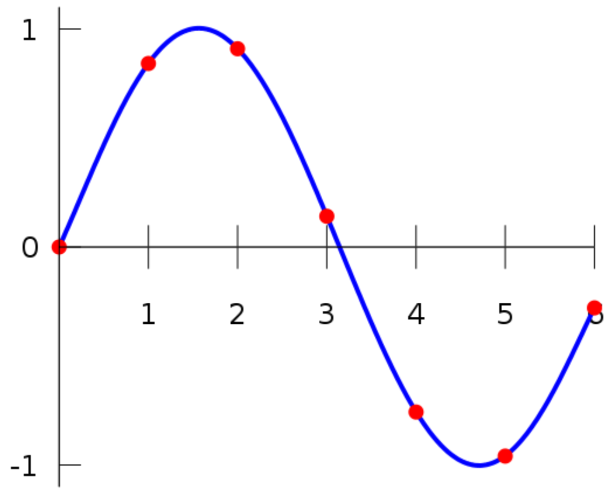

Figure 5.7. Polynomial interpolation of a data set

In mathematics, interpolation is a method of constructing new data points within the range of a discrete set of known data points. In engineering, science as well as in practice data points are obtained either by sampling or by experimentation (science), whereas the practical activity brings out data through the custom processes of each company's activity. This data represents the values of a function for a limited number of values of the independent variable [81].

The fact that in practice in most of times some data may not always be available or very difficult to precisely source, renders the need to estimate, approximate or interpolate the value of that function for an intermediate value of the independent variable. This is important in practice because although sometimes the formula for some given function is known, it is often too complex to evaluate efficiently or the effort needed to provide accurate information is not worth the gains in results. In this sense, the best way to go is to approximate the structure of a complicated function and replace it or model it with a more simple function. A few known data points from the original function can be used to create an interpolation based on a simpler function. Naturally, when a simple function is used to estimate data points from the original, interpolation errors are usually present and unavoidable. However, depending on the problem domain and the interpolation method used, the gain in simplicity is of much greater value than the resultant loss in precision, because the results and their understanding by all the stakeholders is more important than the high detail accuracy of data or the overview of high level mathematical figures, which often lead to confusion and rather alter the main goal of data, which is to provide reliable support for decision making in order to improve efficiency.

In short, the linear interpolation method can be represented in a simplistic manner as is shown in equation (12) below:

$$u_{ij} = \frac{a_{ij} - min\, a_{ij}}{max\, a_{ij} - min\, a_{ij}} \quad (12),$$

where a_{ij} is the corresponding value for each indicator and u_{ij} is the interpolated value obtained ranging between (0,1) as a ratio or between 0 and 100% as a percentage.

5.2. Added value productive time and the associated operational indicators

One of the most important and the key driver of a company's effectiveness is the ability to produce and sell competitive products and services on its market with high customer value. This is a very complex measure of both productivity and efficient value stream mapping in order to achieve an increased proportion of value-adding activities. Added value is generated by transforming the products within internal processes and is the extent to which a company manages to increase the sum of the unit profit, unit labor cost and the unit depreciation cost (economical perspective). Roughly it can also be estimated as the difference between the company's revenue and the intermediate consumption needed to generate this revenue (all types of cost associated with producing and selling of the product on the market).

Typically a manufacturing company will produce more added value than other types of companies (service, merchandising) as it makes transformations upon the raw materials and semi-finished goods before the end product is made. The concept of added value is important for the company and its employees in a similar way as it is linked with both employee and company earnings. It is an essential source for being competitive and shows the measure of a company's effectiveness through the theoretical margin. The theoretical margin shows the capacity of the company to make benefits and by keeping the costs low and value added high it increases the proportion of earnings which remain in the company and contribute to its development. The goal of this approach is to source and quantify how much of the total labor time is actually contributing to add value.

The first step is to separate the total number of employees into 2 categories: the number of employees which can add value and those who cannot add value. Suppose a company has 1200 employees. From these employees there should be a large proportion of staff which is directly linked to the production process and contributes to the value added within the company. These workers are involved in everyday activities and are therefore the ones than can directly make a difference into the ratio of produced added value and delivered customer value as well. The rest of the employees which are usually in charge of support activities as are administration, human resources, accounting, etc. have only an indirect role in creating added value and are seen as auxiliary in the sense of the actual value-adding creation process. In this sense, suppose there are 850 employees that have a direct contribution to this approach and 350 that have an indirect contribution.

The most important part of the value adding-process is its actual creation, which in a manufacturing plant is mainly and basically done by the operators. Judging by the size of the company in our example, we will suppose 300 of the 1200 employees are operators. This means that only one out of four employees is actually and directly contributing to the creation of added value. Also it is sensible to suppose that from the entire working time, the operator will not be able to deliver 100% productivity and achieve maximum efficiency in use of his working time. This is supported by the data in table 1 and by figures 1 and 2. In table 1 a number of 10 random processes have been selected to exhibit the actual time value is being added by the operators within their activity at their workplace. Due to the non-disclosure policy and agreement, only data sourced through linear interpolation is presented within the table.

As the data shows, there is indeed an average 20% of value added within the operators work time, with different processes having a different extent of value added and a different status according to the productivity level of the specific processes. The average deviation (0.0494) from the world class considered level (0.25) is of almost 25%, but there are within this range of processes 3 which have very good productivity and even one with a world class level, which goes beyond the target value for the world class level (0.263).

Table 5.1. Added Value Productive Time of an operator's work time (AVPT) within 10 randomly selected processes

	Added Value Productive Time (AVPT)	Ratio	[%]	Deviation	Status
1	OperationUnit01ProductA02Customer03	0.192	19.2	-0.058	Good
2	OperationUnit01ProductA04Customer01	0.221	22.1	-0.029	Very good
3	OperationUnit02ProductA06Customer02	0.263	26.3	0.013	World class
4	OperationUnit02ProductA05Customer03	0.196	19.6	-0.054	Good
5	OperationUnit03ProductA07Customer01	0.164	16.4	-0.086	Good
6	OperationUnit03ProductA04Customer01	0.223	22.3	-0.027	Very good
7	OperationUnit04ProductA01Customer05	0.209	20.9	-0.041	Very good
8	OperationUnit04ProductA05Customer02	0.189	18.9	-0.061	Good
9	OperationUnit05ProductA04Customer03	0.197	19.7	-0.053	Good
10	OperationUnit05ProductA01Customer02	0.178	17.8	-0.072	Good
	Average	**0.2032**	**20.32**	**0.0494**	**Very good**

This data is outlined in figure 5.9, which highlights the operational process indicators for these random 10 processes.

The blue bar represents the process which has the highest productivity level, therefore being classified as "world class", due to its outstanding performance. The green bars are very good in terms of performance, but are still lacking a small extent to becoming world class, whereas the rest of the yellow bars are performing well, but this level can still achieve improvements and help increase the proportion of value added.

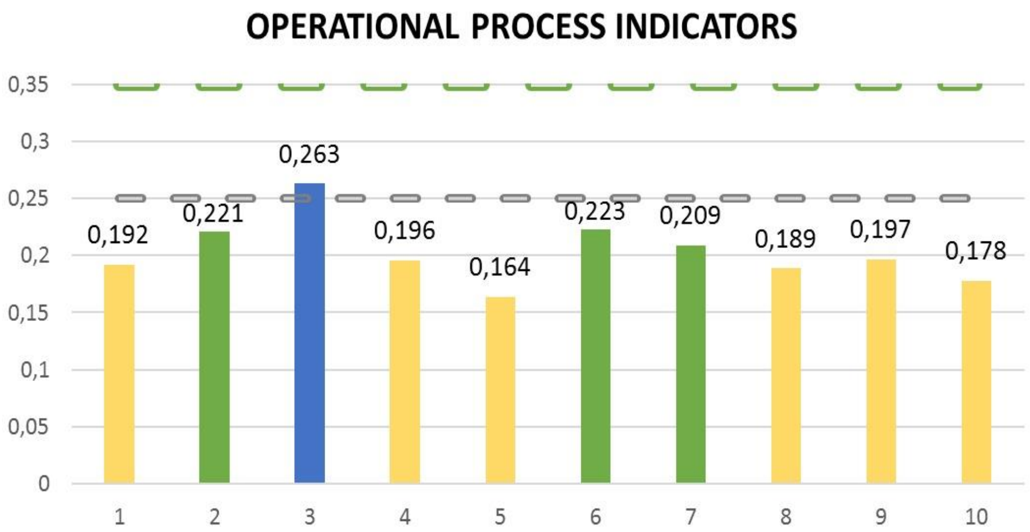

Figure 5.8. Added Value Productive Time (AVPT) within 10 randomly selected processes

This latter information is also emphasized in the radar chart from figure 5.10, where the actual values and the average extent of process time actually adding value are compared to the reference values.

One important application of radar charts is the control of quality improvement to display the performance metrics of any ongoing program. The world class level is represented in grey color, the average values in yellow and the actual ones for each individual random chosen process are shown in blue.

The upper green limit of 0.35 is an ideal state of the company performance and it is only theoretically possible to attain, in practice however, due to the practical issues associated and with the challenges to run a plant within an entire year, it is impossible to achieve, therefore it is only used for referencing.

The red value is however critical and it is the level where the company should not be, because that would mean that there are many operational problems and that an extensive improvement plan is urgently needed to increase effectiveness. This is the zone where achieving improvements is easy and creates a noticeable difference in the running of the plant as well as within the overall productivity and performance.

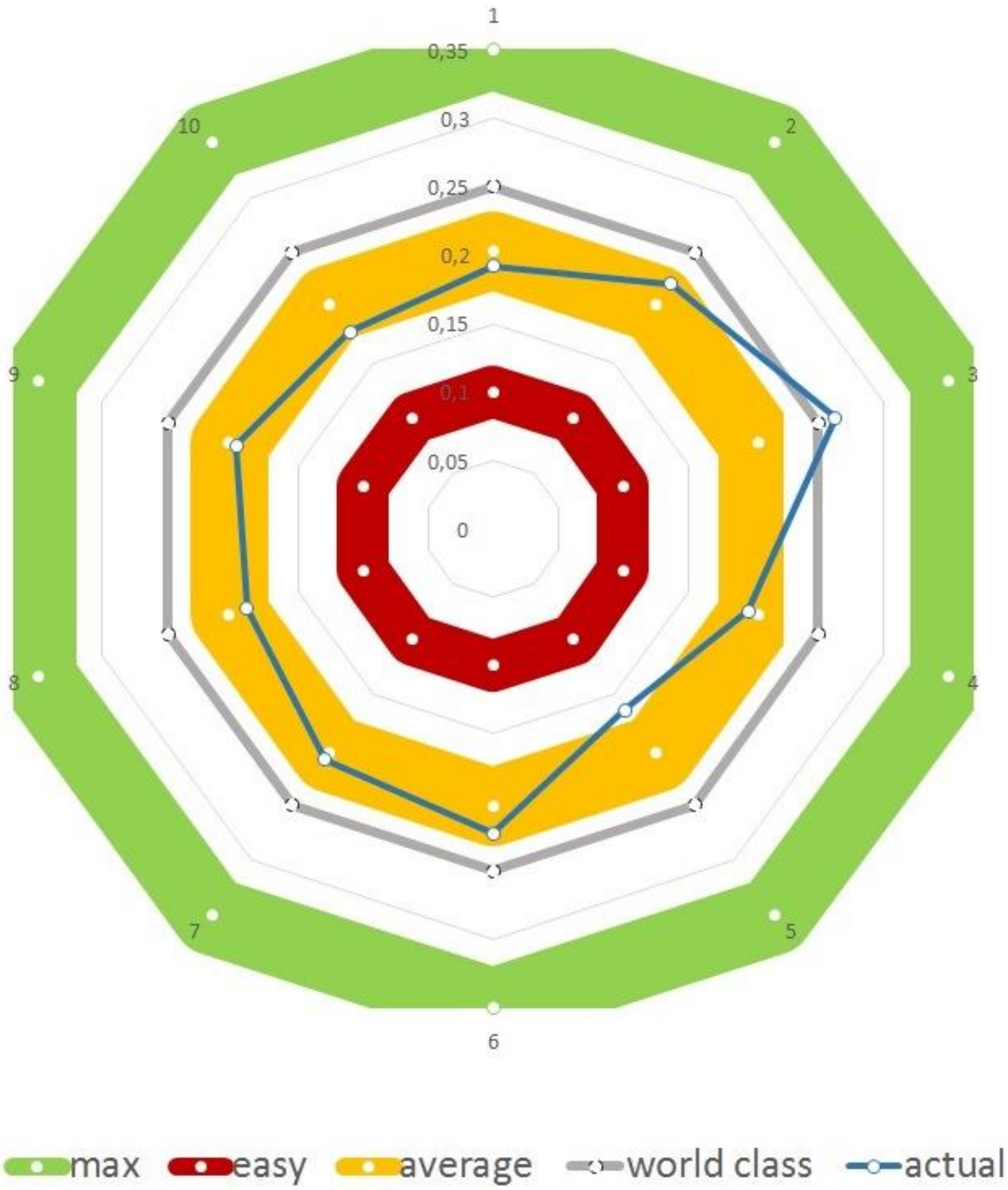

Figure 5.9. Added Value Productive Time (AVPT) within 10 randomly selected processes and their deviation from target levels

Usually the design of the work processes and internal flows will give an exact measure of the operator's activities which really add value and are of high importance and those that are less likely to be as important as the former ones.

For our example we will consider that only 20% of his working time will produce added value (equivalent to 1 hour added value from a total of 5 hours worked).

By multiplying the ratios of the people actually adding value (PAAV), which are the operators in this case, and that of added value productive time (AVPT), we obtain the employee work time added value factor (EWTVAF).

In our case we will conclude that only 1 in 20 operations adds value from a combined point of view of operators and their productive time usage.

$$EWTVAF = PAAV * AVPT = 4 * 5 = 20 \quad (1)$$

The next step is to accurately measure the extent to which the machines and equipment used by the operators is supporting and contributing to adding value within the overall process.

Although machines are available all the time and could theoretically be used to a 100% capability, in practice it is not the case due to several everyday constraints (working days, hours and shifts, preventive maintenance and changeover times, quality deviations which imply scrap and require changing parameters, other lost times and associated wasteful activities, etc.).

For our example we will suppose the effective and productive added value machine working time (MAAV) to be at a level of 50%.

Similar to the employees approach machines and technological equipment also have only a fraction of their working time where they actually transform the products and thus add value to the parts they process (machine organizational intelligence).

This data is summarized in table 5.2, where 10 random machines and equipment have been selected and their added value extent measured by using specific measuring tools and times by the company staff.

As data is not subject of being disclosed, the values obtained have been processed through linear interpolation to enable a percentage representation as well as for comparison purposes.

Data shows that there is an average 25% of value added within the running time of the machines, with different performance levels and added value output ratios. The average deviation (0.0265) from the world class considered level (0.25) is only slightly over 10%, but there are within this range of equipment 4 which have higher productivity than the reference world class level, operation unit 12 having an 18.4% higher level than the reference target.

There are 3 machines which are quite close to this world class level, operation unit 03 with a 0.248 being the closest to attaining the targeted reference value (only a 0.8% difference). The average overall status of this category is however "world class".

Table 5.2. Added Value Productive Time of a machine's work time (MAVPT) within 10 randomly selected processes

	Machine Added Value Productive Time (MAVPT)	**Ratio**	**[%]**	**Deviation**	**Status**
1	OperationUnit01ProductA05	0.239	23.9	-0.011	Very good
2	OperationUnit03ProductA03	0.248	24.8	-0.002	Very good
3	OperationUnit02ProductA02	0.212	21.2	-0.038	Very good
4	OperationUnit04ProductA01	0.217	21.7	-0.033	Very good
5	OperationUnit07ProductA02	0.285	28.5	0.035	World class
6	OperationUnit09ProductA01	0.216	21.6	-0.034	Very good
7	OperationUnit12ProductA03	0.243	24.3	-0.007	Very good
8	OperationUnit17ProductA04	0.277	27.7	0.027	World class
9	OperationUnit11ProductA03	0.282	28.2	0.032	World class
10	OperationUnit12ProductA02	0.296	29.6	0.046	World class
	Average	**0.2515**	**25.15**	**0.0265**	**World class**

This data is outlined in figure 5.11, which highlights the operational machine indicators for these random 10 selected operation units within the plant. The blue bar represents the equipment which has the highest productivity level, therefore being classified as "world class", due to its outstanding performance. The green bars are also very good in terms of performance, and only lack a small extent to becoming world class, showing a high level of achieved improvements and enabling a high proportion of value added within the company's output.

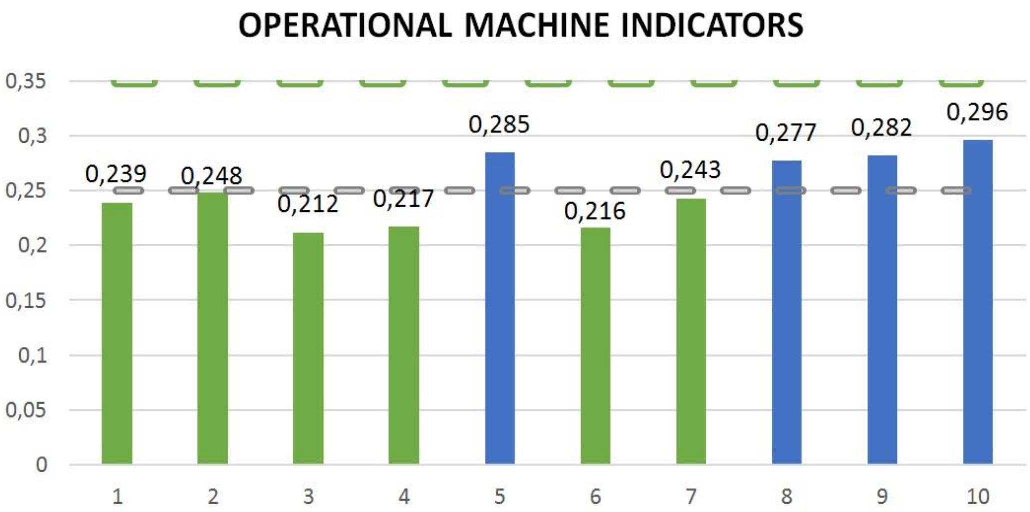

Figure 5.11. Machine Added Value Productive Time (MAVPT) within 10 randomly selected processes

This data is confirmed within the radar chart from figure 5.12, where the actual values and the average extent of machine working time actually adding value are compared to the reference values. The world class upper level is represented in grey color, the average values (which are here equivalent to the world class level) in yellow and the actual ones for each individual operational unit are shown in blue.

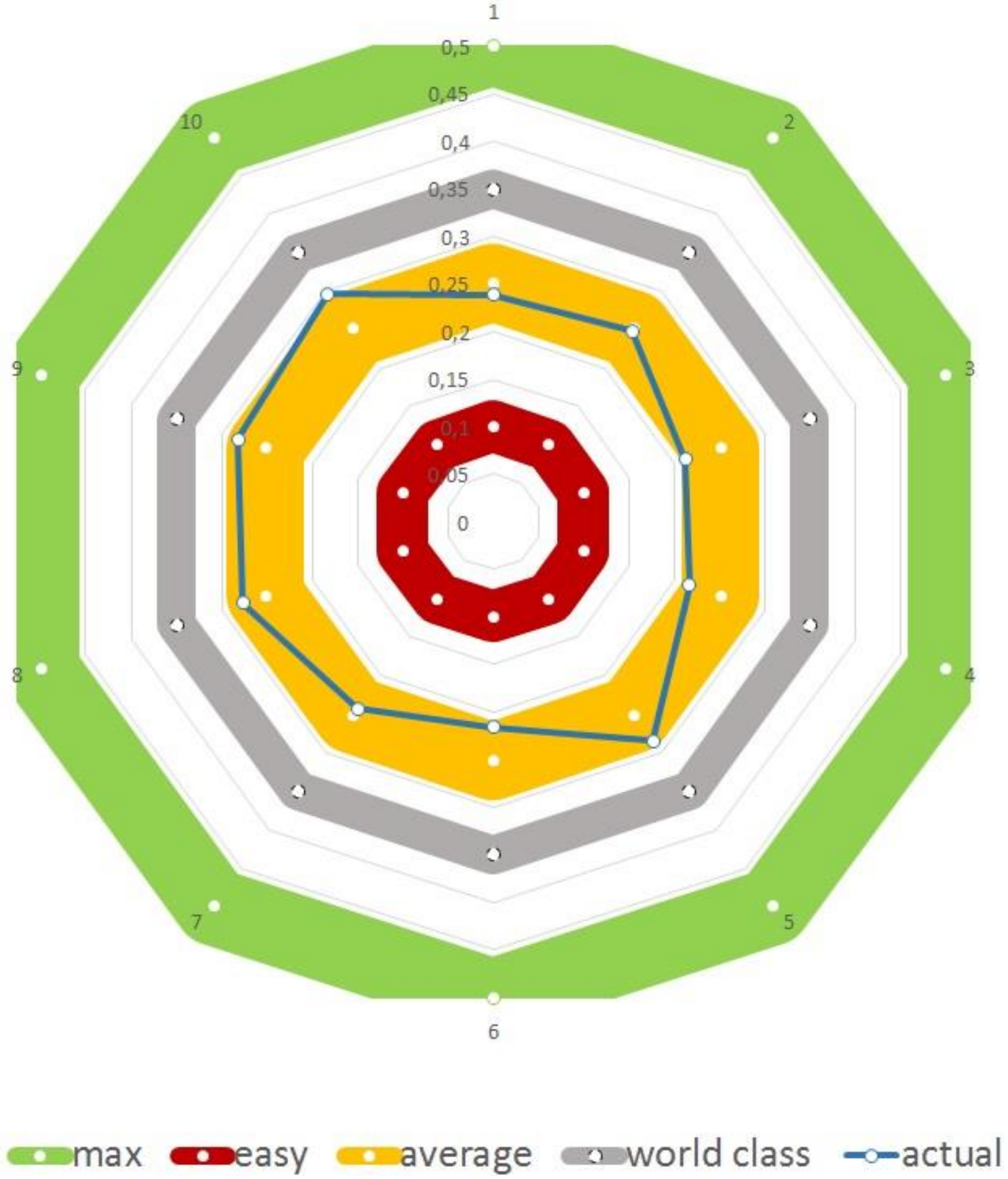

Figure 5.10. Machine Added Value Productive Time (MAVPT) within 10 randomly selected processes and their deviation from target levels

The green limit of 0.5 is an ideal state of the company performance and it is only theoretically possible to attain, therefore it is only used for referencing. The red value is however critical and is the level at which the company is seriously underperforming and where changes are urgently needed to increase effectiveness. The upper world class limit usually applies to highly automatized plants where there is an intense utilization of these means and this can also mean a balancing of the needed personnel as well as higher investment and longer investment returns which need an extensive and thoroughly thought out business plan as well as a long-term strategic planning horizon.

We will suppose that around 25% of the operations a machine performs are actually adding value (MAVPT). By multiplying the ratios of the effective and productive machine working time which is actually capable of adding value and that of the machine added value productive time, we obtain the combined ratio of machine work time added value factor (MWTAVF). In our case we will conclude that only 1 in 8 operations adds value from a combined point of view of effective machine working time and their operational intelligence.

$$MWTVAF = MAAV * MAVPT = 2 * 4 = 8 \quad (2)$$

Thus the sum of both the employee work time added value factor (EWTAVF) and machine work time added value factor (MWTAVF) will provide a rough estimate of the extent to which an organization has already improved and its potential to further improve its operational effectiveness and added value creation in order to enhance customer value and operational profit margin. This we will consider to be the gross improvement capability (GIC) which will provide the gross part of the level of current internal competitiveness and internal improvement capability of the company in its overall operations.

$$GIC = EWTVAF + MWTVAF = 20 + 8 = 28 \quad (3)$$

Physical processes that happen in practice need to be managed by having all the necessary and relevant data to support decision making. The data needs to be relevant, reliable and be available in real time in order for no lag to be present in taking proper actions to improve problem areas. This data also needs to be as simple as possible to be understood and this representation can be made through explicit and implicit methods [6]. These methods employ a specific approach which is used in numerical analysis for obtaining numerical approximations to the solutions of time-dependent ordinary and partial differential equations (as is the case with computer simulations).

There are some important differences between these two methods however which need to be highlighted. The explicit methods calculate the state of a system at a later time from the state of the system at the current time, whereas implicit methods find a solution by solving an equation involving both the current state of the system and the later one. In this sense, the implicit methods is more complex as it takes into account more variables and offers a better view upon the dynamics of a certain system. Thus, if we consider $Y(t)$ as the current state of the system and $Y(t+\Delta t)$ as the state of the same considered system, but at a later time, with Δt

being the elapsed time after the initial state of that system, then equation (1) represents an explicit method, whereas equation (2) represents the implicit method:

$$Y(t+\Delta t) = F(Y(t)) \ (1) \qquad G\big(Y(t), Y(t+\Delta t)\big) = 0 \ (2)$$

The use of either one or the other methods depends of course on the type of issue which needs to be addressed. When using the implicit method however, the use of the operator splitting method is recommended as it rewrites the differential operator as the sum of two complementary operators. This is because one operator will be treated as an implicit one (linear), whereas the other as an explicit one (nonlinear) as is shown in equation (3) below, where the implicit-explicit method is represented:

$$Y(t+\Delta t) = F\big(Y(t+\Delta t)\big) + G(Y(t)) \ (3)$$

The Euler method is a first-order numerical method for solving differential equations (ordinary differential equations). It is an easy method used to solve a differential equation and approximates the behavior of the equation in a certain range. At the same time the Euler method is the most basic explicit method (first-order method) for numerical integration of ordinary differential equations and often serves as the basis to construct more complex methods.

Additionally, because the Euler method is a first-order method the local error (or error per step) is proportional to the square of the step size, and the global error (error at a given time) is proportional to the step size.

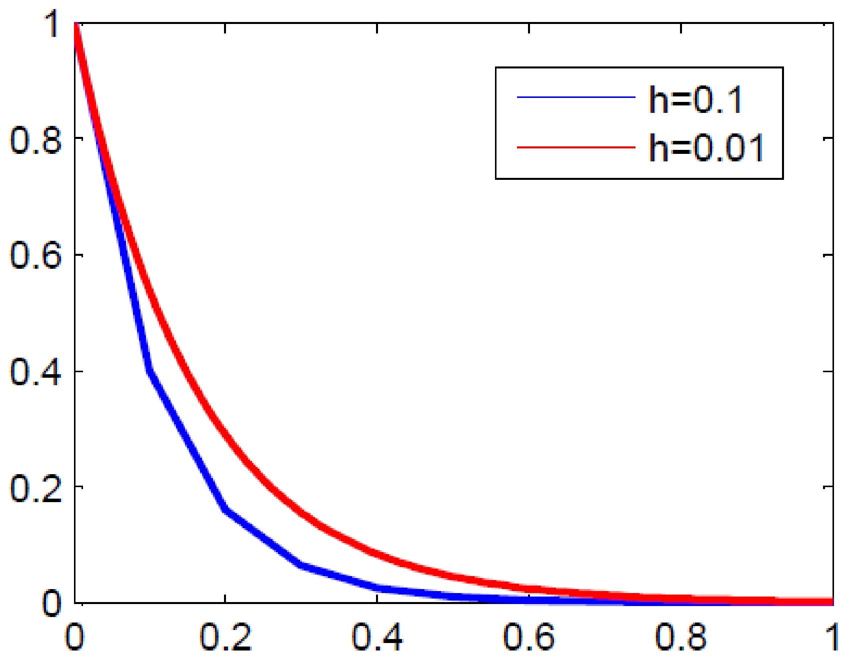

Figure 5.11. Curve accuracy using the Euler method with different step sizes

Euler's forward and backward methods give a pretty good estimation of the curve's shape and amplitude, which is very close to the actual curve's shape when performed with more complex and detailed mathematical methods as is shown in figure 5.13. We can notice by looking at the graph that the two curves (the red actual curve and the blue Euler curve) are almost identical.

For simple functions the use of the Euler method is decently accurate, especially when reducing the step size. However for the case of more complex systems, this may not be the best numerical method to use to approximate the plot of ordinary differential equations, as better methods exist which improve result reliability, as with the Runge-Kutta method. In order to obtain an overview on the reliability of these methods, the differential equations are discretized using the forward Euler and backward Euler methods and compare the obtained schemes. The forward Euler method has the following expression (18):

$$\left(\frac{dy}{dt}\right)_k \approx \frac{y_{k+1}-y_k}{\Delta t} = -y_k^2 \text{ (18),}$$

where $y_{k+1} = y_k - \Delta t y_k^2$for each k = 0,1,…,n (explicit formula for y_{k+1})

The backward Euler method meantime has the following formula (19):

$$\frac{y_{k+1}-y_k}{\Delta t} = -y_{k+1}^2 \text{ (19),}$$

where $y_{k+1} + \Delta t y_{k+1}^2 = y_k$ (19) for y_{k+1}, which enables the quadratic equation (20) with one positive and one negative root:

$$y_{k+1} = \frac{-1+\sqrt{1+4\Delta t y_k}}{2\Delta t} \text{ (20)}$$

Usually solving the equation with an implicit method is much more complicated than a quadratic equation. Because there is no analytical solution, certain root-finding algorithms are used in order to find the corresponding numerical solution.

There is also a third method which combines somewhat these two methods and is called the forward-backward Euler method represented in equation (21), which applies the implicit-explicit method previously mentioned:

$$\frac{dy}{dt} = y - y^2, t \in [0, a] \text{ (21),}$$

where $\left(\frac{dy}{dt}\right)_k \approx y_{k+1} - y_k^2, t \in [0, a]$, which therefore leads to expression (22):

$$y_{k+1} = \frac{y_k(1-y_k\Delta t)}{1-\Delta t} \text{ (22), for each k = 0,1,…,n.}$$

The graphical differences between the three methods can be seen and compared in figures 5.14 and 5.15.

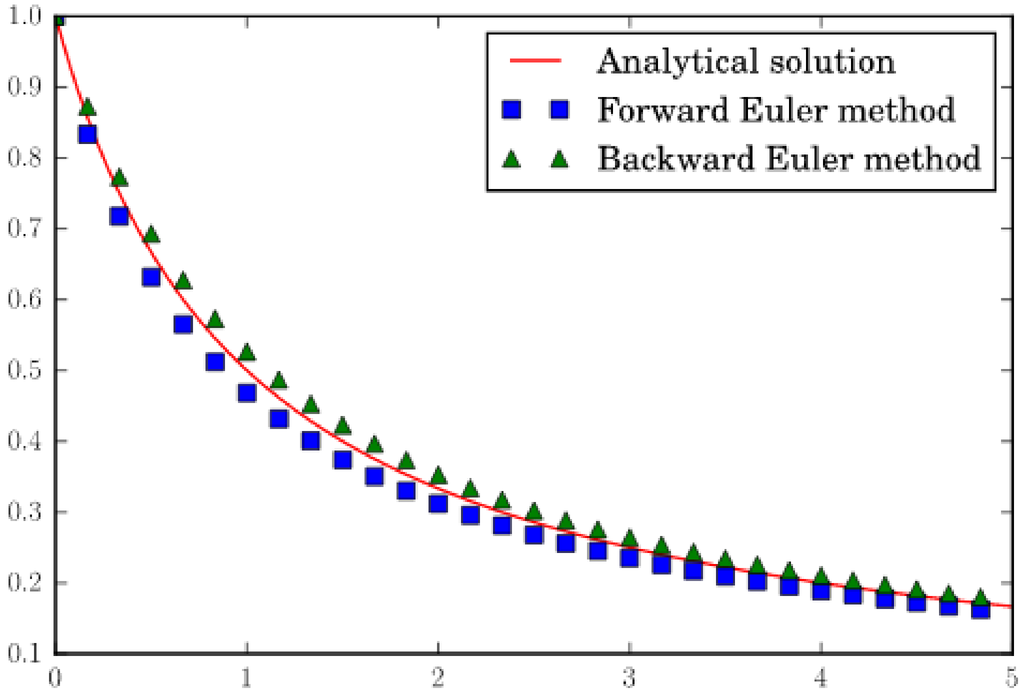

Figure 5.12 Difference between the forward and backward Euler methods

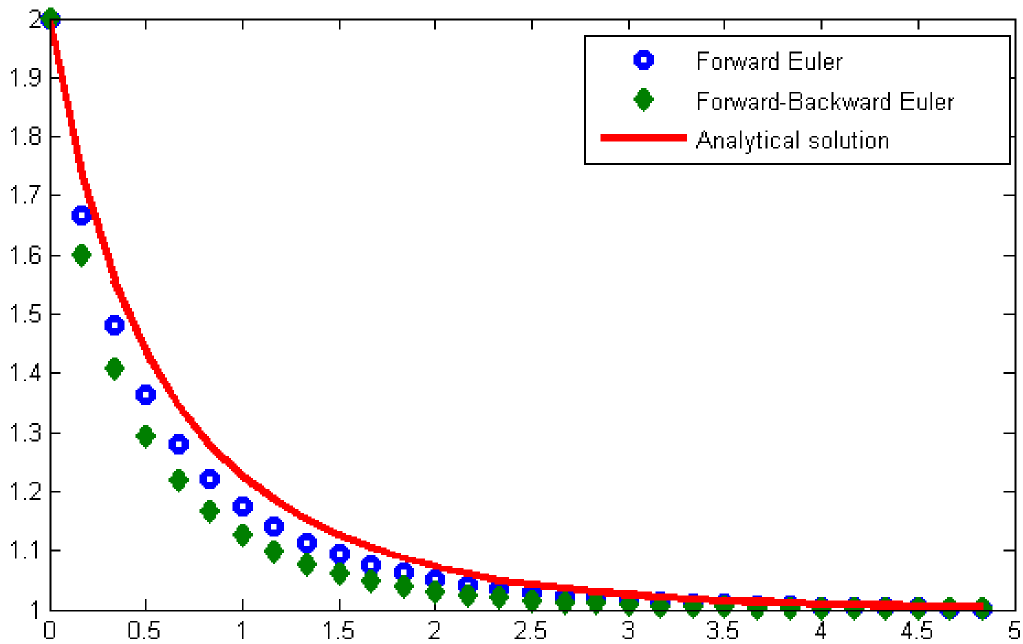

Figure 5.13. Difference between the forward and forward-backward Euler methods

The Euler method is also practical and has an easy step-by-step procedure, which allows it to source reliable results and proves as an important support for both numerical and graphical calculations. This can be verified when faced with the issue of having to estimate (through calculation) the shape of an unknown curve which starts at a given point and satisfies a given differential equation.

The differential equation is essentially a formula and helps to calculate points on the curve. This is possible because the slope of the tangent line to the curve can be measured at any given point on the curve (provided the positions of those points are calculated in advance). The main idea is that although the shape of the curve is unknown at the beginning, the starting point, A_0, is however given. The slope of the curve and its tangent line can therefore be calculated by using the differential equation.

By using this reasoning and by successively taking small steps along the tangent line up to A_1, then A_2, A_3 and so on and so forth, the slope does not change too much and the next point will be fairly close to the curve. This can be seen in figure 5.16, where the unknown curve is in blue, and its polygonal approximation is in red. By extending the reasoning and supposing the next point is actually on the curve, this sequence of iterations help determine a shape which is fairly reliable and pretty close to the actual shape of the curve. These successive iterations create a polygonal curve, which does not diverge too far from the original unknown curve. In addition, the error between the two curves (the one generated and the actual curve) can be reduced in order to better approximate the actual shape if the step size is adjusted to be small enough and if the computation interval is finite [7].

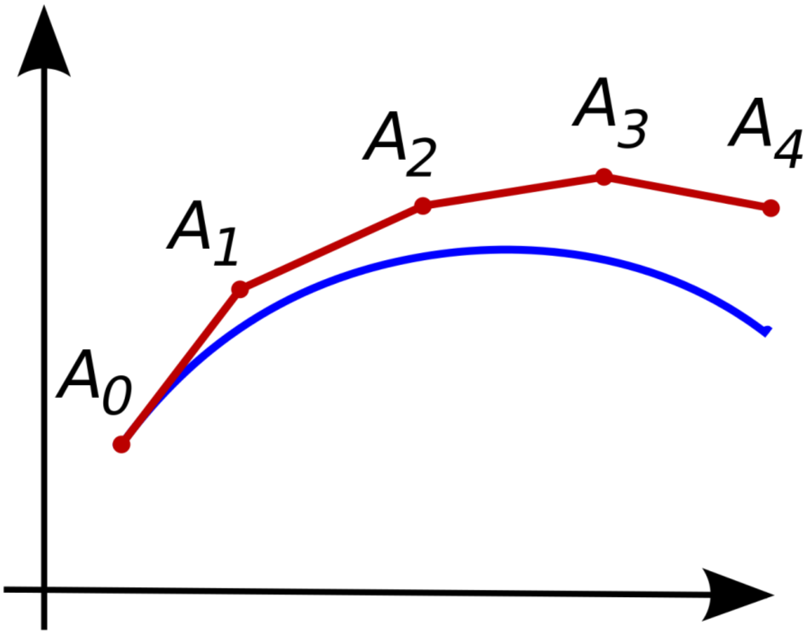

Figure 5.14. The Euler method's accuracy compared to the actual curve

When formalizing these mathematical statements, we have the following:

$$y'(t) = f\big(t, y(t)\big) \text{ (27), where } y(t_0) = y_0 \text{ (28)}$$

if $t_n = t_0 + nh$, where *h* is the size of every step, then one step of the Euler method from t_n to t_{n+1} will be equal to t_n + h, which will in turn lead to (29):

$$y_{n+1} = y_n + hf(t_n, y_n) \text{ (29)},$$

where y_n is an approximation of the solution to the differential equation at the time t_n. This can be formalized as t_n: $y_n \approx y(t_n)$ as the Euler method is explicit, which means that y_{n+1} is an explicit function of y_i for $i \leq n$.

$$y^{(N)}(t) = f\left(t, y(t), y'(t), \ldots, y^{(N-1)}(t)\right) \text{ (30)}$$

To solve equation (30) we introduce the auxiliary variables $z_1(t) = y(t), z_2(t) = y'(t), \ldots, z_N(t) = y^{N-1}(t)$ in order to obtain the resulting equation (31) of a first-order system in the variable z(t):

$$z'(t) = \begin{pmatrix} z_1'(t) \\ \vdots \\ z_{N-1}'(t) \\ z_N'(t) \end{pmatrix} = \begin{pmatrix} y'(t) \\ \vdots \\ y^{(N-1)}(t) \\ y^{(N)}(t) \end{pmatrix} = \begin{pmatrix} z_2(t) \\ \vdots \\ z_N(t) \\ f\big(t, z_1(t), \ldots, z_N(t)\big) \end{pmatrix} \quad \text{(31) [24]}$$

The chosen step size is important in order to better match the Euler method graph with the actual one. The initial value problem y'=y and y(0) = 1 allows for the approximation to be performed through numerical calculations using the Euler method.

We will choose y(4) and the step size h=1 for a demonstration of the method's reliability and graphic accuracy.

The function *f* is defined by $f(t, y) = y$ through $f(t_0, y_0) = f(0,1) = 1$ for $f(t_0, y_0)$ by using the Euler method from the expression (32) below:

$$y_{n+1} = y_n + hf(t_n, y_n) \text{ (32)}$$

The slope of the line that is tangent to the solution curve at the point (0,1) is thus calculated, as it is the change in y divided by the change in t, or Δy/Δt. The step size value is 1 in this case: $h * f(y_0) = 1 * 1 = 1$.

The step size thus generates a change in *t*, which also creates a change in the value of *y*, as a result of multiplying the step size and the slope of the tangent as is shown in the next expression: $y_0 = hf(y_0) = y_1 = 1 + 1 * 1 = 2$.

These steps are then successively undertaken in order to source the values for y_2, y_3, y_4 as is shown below:

$$y_2 = y_1 + hf(y_1) = 2 + 1 * 2 = 4,$$
$$y_3 = y_2 + hf(y_2) = 4 + 1 * 4 = 8,$$
$$y_4 = y_3 + hf(y_3) = 8 + 1 * 8 = 16.$$

The conclusion is that y_4 = 16, which enables us to find the exact solution to the differential equation: $y(t) = e^t$, which gives the following result: $y(4) = e^4 \approx 54.598$. Although we can observe that the quantitative approximation is not very accurate, figure 5.17 shows that the qualitative aspect is pretty good and from a mathematical point of view, it is also right.

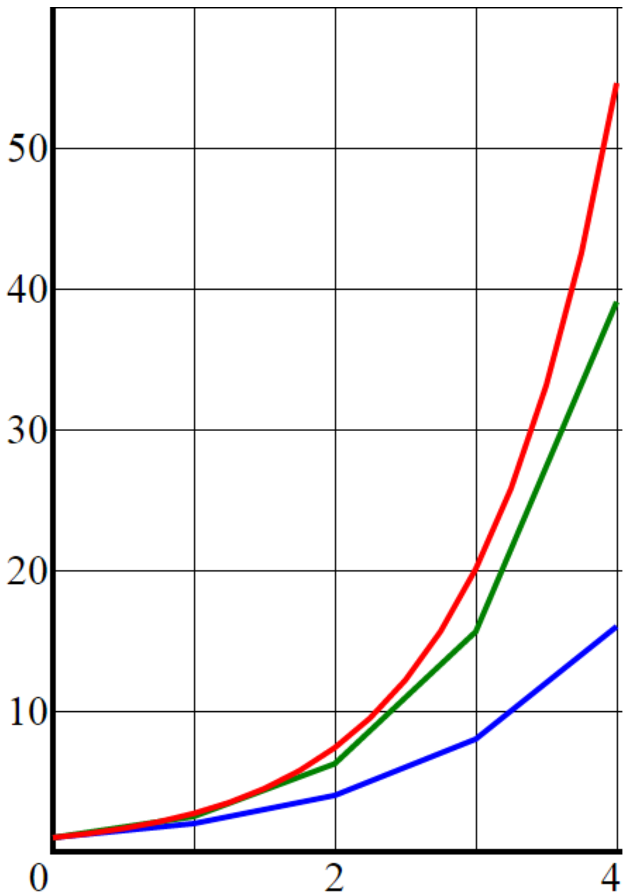

Figure 5.15. Euler method (blue) accuracy compared to the midpoint method (green) and the exact solution (red) with h=1 (step size)

However, the Euler method is more accurate if the step size *h* is smaller, for example just by reducing the step size from 1 to 0.25, we reduce the error by 50% compared to the initial situation. This is shown in figure 5.18 quite accurately.

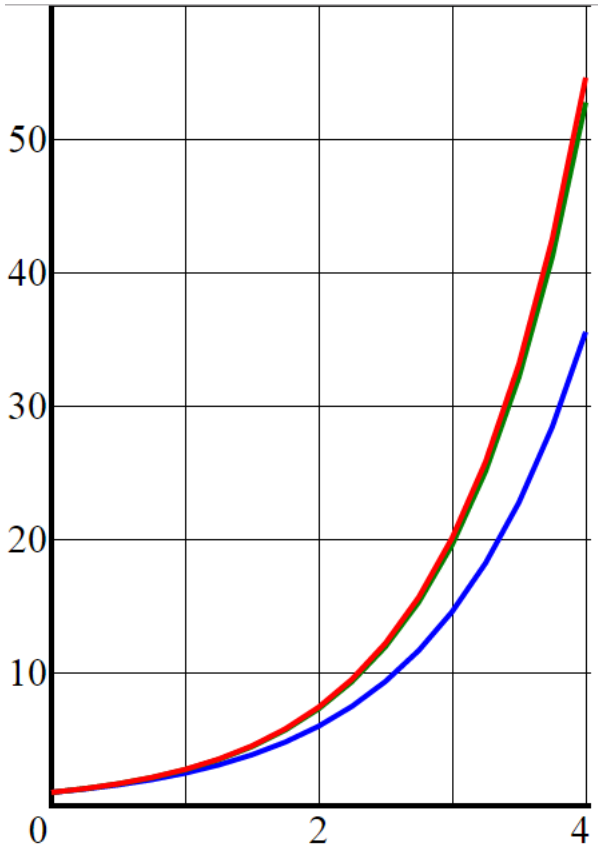

Figure 5.16. Euler method (blue) accuracy compared to the midpoint method (green) and the exact solution (red) with h=0.25 (step size)

It is also found that the error is roughly proportional to the step size, especially in the case of fairly small values of the step size. This statement is true in general and also applies to other equations as well, as is the global truncation error. Other methods behave more favorably, as the the error of the midpoint method is roughly proportional to the square of the step size. This is the reason why the Euler method is called a first-order method, while the midpoint method is considered of second order. Should a very high level of accuracy be desired, then more fine methods, such as the Runge–Kutta methods or linear multistep methods are generally employed as they would better suit that particular purpose and figure accuracy [44].

The Euler method can also be derived through the Taylor series of the function y around t0 as is shown in equation (33) below:

$$y(t_0 + h) = y(t_0) + hy'(t_0) + \frac{1}{2}h^2 y''(t_0) + O(h^3) \quad (33)$$

The statement of the differential equation being $y' = f(t, y)$, this helps to analyze and estimate the error committed by the Euler method and can also be used and extended to other methods, as its use is very flexible in these circumstances.

By substituting the forward finite difference formula for the derivative (as is shown in equation (34) below) through the differential equation $y' = f(t, y)$, this can lead to the backward Euler methods among others:

$$y'(t_0) \approx \frac{y(t_0+h)-y(t_0)}{h} \ (34)$$

By integrating the differential equation from t_0 to t_0+h and combining the following set of equations (35) and (36), we will again come across the Euler method and are able to source other various linear multistep methods as well, proving the flexibility of these computations:

$$y(t_0 + h) - y(t_0) = \int_{t_0}^{t_0+h} f\big(t, y(t)\big)dt \ (35)$$
$$\int_{t_0}^{t_0+h} f\big(t, y(t)\big)dt \approx hf\big(t_0, y(t_0)\big) \ (36)$$

The Euler method has however an error, which can be approximated by the local truncation error, where the error is computed at a single step or the global truncation error, where the error is computed at a given time.

The local truncation error is the difference between the numerical solution after one step (y_1) and the exact solution at the time of computation $t_1 = t_0 + h$ through $y_1 = y_0 + hf(t_0, y_0)$which is best found by using the Taylor series from equation (37):

$$y(t_0 + h) = y(t_0) + hy'(t_0) + \frac{1}{2}h^2y''(t_0) + O(h^3) \ (37),$$

which enables the difference between these equations to source the local truncation error from equation (38) if there is a bounded third derivative for y:

$$y(t_0 + h) - y_1 = \frac{1}{2}h^2y''(t_0) + O(h^3) \ (38),$$

which shows the reliability of the Euler method's error is less accurate than for other higher-order techniques, but that for small step sizes h, that the local truncation error is approximately proportional to h^2.

If y has a continuous second derivative, then by using Lagrange's theorem and if $\varepsilon \in [t_0, t_0 + h]$ we obtain the following expression for the local truncation error:

$$y(t_0 + h) - y_1 = \frac{1}{2}h^2y''(\varepsilon) \ (39),$$

which in turn will provide the second derivative equation (40) below when applying $y' = f(t, y)$ [112]:

$$y''(t_0) = \frac{\partial f}{\partial t}\big(t_0, y(t_0)\big) + \frac{\partial f}{\partial y}\big(t_0, y(t_0)\big) f\big(t_0, y(t_0)\big) \quad (40)$$

The global truncation error is the cumulative effect of the local truncation errors committed in each previous step and it is to be expected that the global truncation error will be proportional to *h* given that the number of steps is $(t - t_0)/h$, which is proportional to *1/h* and the error is proportional to h^2.

The precise form of the bound does not have a major implication in practice, because it vastly overestimates the actual error committed by the Euler method (in most of the cases). However it expresses the fact that the global truncation error is (approximately) proportional to *h* and thus renders the Euler method to be of first order [57].

The absolute global truncation error is then considered to be of the form provided by the equation (41) below:

$$|GTE| \leq \frac{hM}{2L}\left(e^{L(t-t_0)} - 1\right) \quad (41),$$

where *y* has a bounded second derivative and *M* is an upper bound on the second derivative of *y* on the given interval, whereas *L* is the Lipschitz constant of the Lipschitz continuous in its second argument function *f*.

There is also the issue of rounding associated with these errors, which may result in big rounding errors although the truncation error will be small for extremely small values of the step size. The negative implications of this effect of the rounding error can however be avoided if compensated summation is used in the formula for the Euler method [24].

5.3. The logistic function as a source for the effectiveness improvement chart

Another good tool to formalize and validate the dynamics of the improvements within a company is the logistic function. The logistic function (or logistic curve) is basically a curve which grows almost exponentially until a certain point, from which it begins to slow down growth, as the increase gets asymptotical with the behavior or the curve approaching a stage of maturity.

This curve is shown in both dynamic and mathematical representation in figures 5.19 and 5.20 below.

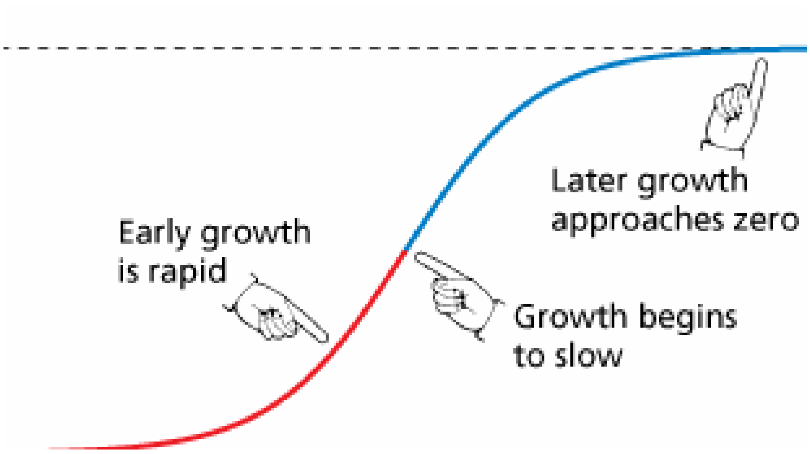

Figure 5.17. The logistic function's dynamic interpretation

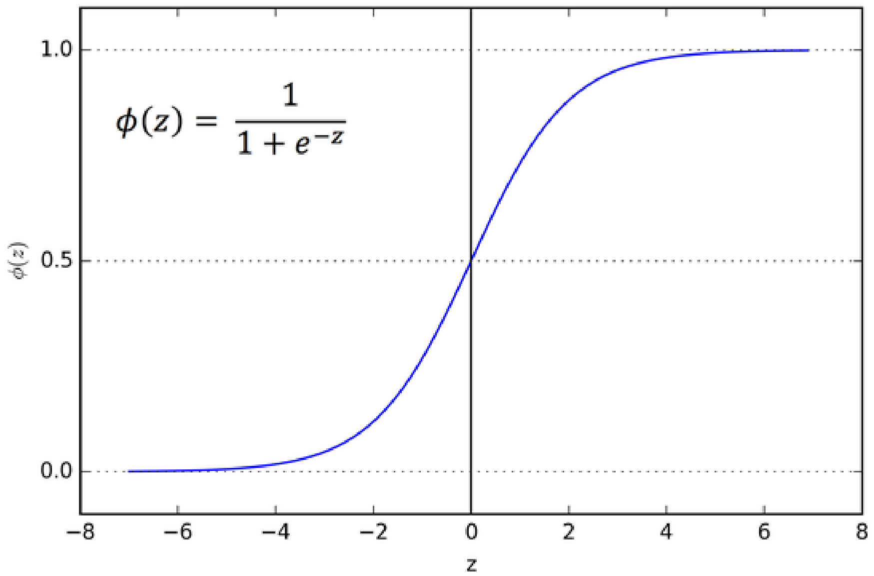

Figure 5.18. The logistic function's mathematical graph

In a more mathematical description, the logistic function combines two kinds of exponential growth. The first kind is the classic exponential growth, with a pattern of increase at an increasing rate. The growth rate of this function is exponential, thus proportional to the size of the function's value. The other type of exponential growth is bounded exponential growth. This function takes a decaying exponential and subtracts it from a fixed bound and as the decaying exponential dies out, the difference rises up to the bound. The bounded exponential function models growth which is limited by some fixed capacity, as is the case in practice with production facilities which can only reach a certain maximum capacity and which cannot be exceeded unless there are investments made in the extension of the plant and/or in productive layout modifications. Logistic functions are thus able to model resource limited exponential growth, when outputs are small (exponential growth) as well as when the outputs near capacity (bounded exponential growth) [75].

The logistic function is expressed with the following equation (42):

$$f(x) = \frac{L}{1+e^{-k(x-x_0)}} \text{ (42)},$$

where L is the curve's maximum value, *e* is Euler's number (approximately equal to 2.71828) or the natural logarithm base, *k* is the steepness of the curve and x_0 is the x-value of the sigmoid's midpoint (the logistic curve has an "S" shape as the sigmoid curve).

The sigmoid curve and function represented in figure 5.21 are a special case of the logistic function.

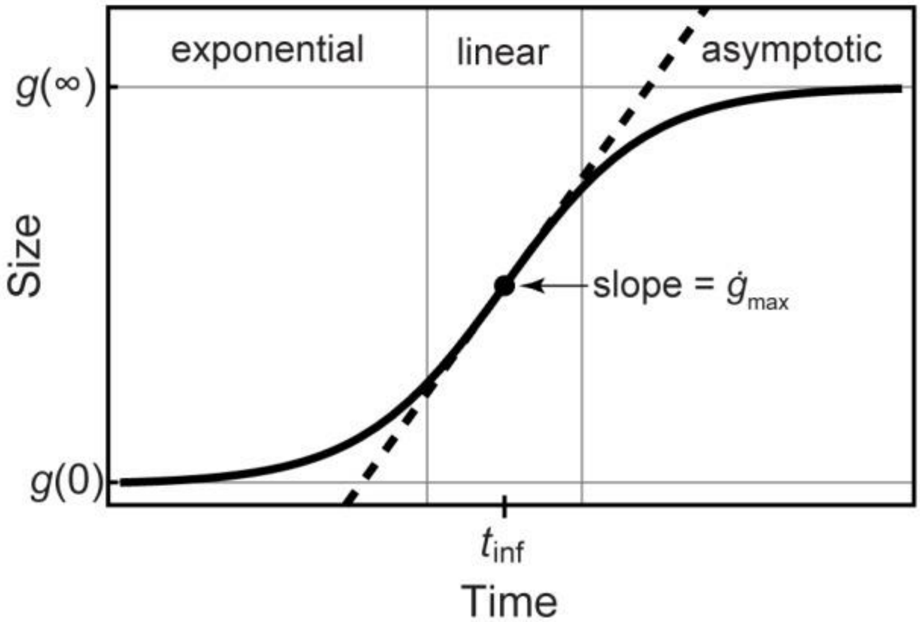

Figure 5.19. Representation of the sigmoid function

The function was studied by Verhulst in relation to population growth, as in the initial stage of growth it is approximately exponential then growth slows down as saturation arrives and at maturity growth actually stops [120].

The logistic function's mathematical properties from equation (43) are also well adapted to the progress within an organization and its ability to produce best results within a certain range of time and understand how difficult it is to make improvements and the importance of these efforts to support current and future results.

$$f(x) = \frac{1}{1+e^{-x}} \text{ (43)},$$

where the parameters of the standard logistic function are k=1, x_0=0 and L=1 and enables it to also have a derivative which can easily be calculated by performing the following set of calculations in order to obtain the end form from equation (44):

$$f(x) = \frac{1}{1+e^{-x}} = \frac{e^x}{1+e^x} \quad => \quad \frac{d}{dx}f(x) = \frac{e^x*(1+e^x)-e^x*e^x}{(1+e^x)^2}, \text{ which leads to:}$$

$$\frac{d}{dx}f(x) = \frac{e^x}{(1+e^x)^2} = f(x)\big(1-f(x)\big) \; (44)$$

The equation (44) also has the property that $1-f(x) = f(-x)$, which implies that $x \mapsto f(x) - 1/2$ is an odd function and implies that the function is also the solution of the simple first-order non-linear ordinary differential equation with the boundary condition that $f(0) = 1/2$.

The qualitative behavior can be interpreted as follows: the derivative is null when function is unit and the derivative is positive for f taking values [0,1] and negative for f above 1 or less than 0. The unstable equilibrium at 0 and the stable equilibrium at 1, implies that for any function value >0 and <1, it will grow to unit. When rewriting equation (44), we obtain:

$$\frac{d}{dx}f(x) = f(x)\big(1-f(x)\big) \; (44),$$

$$\frac{dy}{dx} = y(1-y) \quad => \quad \frac{dy}{dx} = y - y^2 \quad => \quad \frac{dy}{dx} - y = -y^2,$$

which has a special solution because it is a special case of the Bernoulli differential equation: $f(x) = \frac{e^x}{e^x+C}$, where another well-known form of the definition of the logistic curve will be obtained when the value of the constant on integration will be C=1, as is shown is equation (45):

$$f(x) = \frac{e^x}{e^x+1} = \frac{1}{1+e^{-x}} \quad (45)$$

The analytical solution shows that the logistic curve has an exponential growth for the negative argument, then a linear growth when nearing the 0 value and then approaches 1 in similar manner from a quantitative point of view.

The logistic function is also tied to the logistic distribution, as is shown in the following sequence:

$$2f(x) = 1 + \tanh\left(\frac{x}{2}\right), \text{ which can also be written as: } \tanh(x) = 2f(2x) - 1,$$

which is the resulting equation from the following succession of calculations: $\tanh(x) = \frac{e^x-e^{-x}}{e^x+e^{-x}} = \frac{e^x*(1-e^{-2x})}{e^x*(1+e^{-2x})} \quad => \quad f(2x) - \frac{e^{-2x}}{1+e^{-2x}} = f(2x) - \frac{e^{-2x}+1-1}{1+e^{-2x}} = 2f(2x) - 1$, this also implies the fact that the hyperbolic tangent relationship leads to another form for the logistic function's derivative, as is shown in the following formula: $\frac{d}{dx}f(x) = \frac{1}{4}sech^2\left(\frac{x}{2}\right)$ and enables a view upon the rotational symmetry. In this latter case the sum of the logistic function and its reflection about the vertical axis, $f(-x)$ is given by the following sequence:

$$\frac{1}{1+e^{-x}}+\frac{1}{1+e^{-(-x)}}=\frac{(1+e^{x})+(1+e^{-x})}{(1+e^{-x})(1+e^{x})}=\frac{2+e^{x}+e^{-x}}{1+e^{x}+e^{-x}+e^{x-x}}=\frac{2+e^{x}+e^{-x}}{2+e^{x}+e^{-x}}=1,$$

showing that the logistic function is rotationally symmetrical about the point with the coordinates P(0,1/2) [101].

The applications of the logistic function are quite numerous, but there is an interesting application which matches the objectives within a manufacturing plant as well, in the economics section. Here we have the progress of the diffusion of an innovation through its life cycle, or in a more practical approach, the implementation of change in a factory in order to enable a strong competitive environment.

One of the best reflections in this sense is Tarde's view [116], in which he sees three stages of developing innovations: the difficult beginning, the take-off and the maturity phase. The beginning is laws keen to be tough, as is the case with any change or new layout and organization restructuring. This is due to the fact that the idea has to struggle within a hostile environment full of opposing habits and beliefs of the people who are used to doing things differently prior to the new setting proposal.

Change management techniques however enable for this resistance to be overcome and for the new ideas to be more quickly adapted with the mutual consent of all implicated parties. Then there is the growing phase, where the improvements and changes provide immediate results and productivity gains which are both noticeable and appreciated by all the working staff. This is also reflected within the company's KPIs which monitor the performance and the alignment of the actual results with the planned output or the forecasted goals.

From a mathematical point of view this stage corresponds to the exponential take-off of the idea $f(x)=2^{x}$, where motivation and staff acceptance of the new layout and its associated organization is quite high. The third and final phase is the maturity phase where the rapid growth and the productivity gains become less spectacular and the organization enters a routine phase where major improvements are more difficult to implement as the stability of performance becomes a habit and part of the organizational culture of the company.

From a mathematical point of view this third stage is logarithmic $f(x)=\log(x)$ and corresponds to the time when the impulse of the previously implemented new idea gradually slows down. This is also enhanced by the fact that the development within an organization is constant and it is normal for other new ideas to appear which pressure new changes to be implemented within the organization and adapt the organizational culture to meet certain demands and constraints of several types. This has the effect of stabilizing the progress of innovations, which from a mathematical description point of view approaches an asymptote.

There is also the generalized logistic function, which is an extension of the logistic function and enables more flexible S-shaped curves, as is shown in figure 5.22.

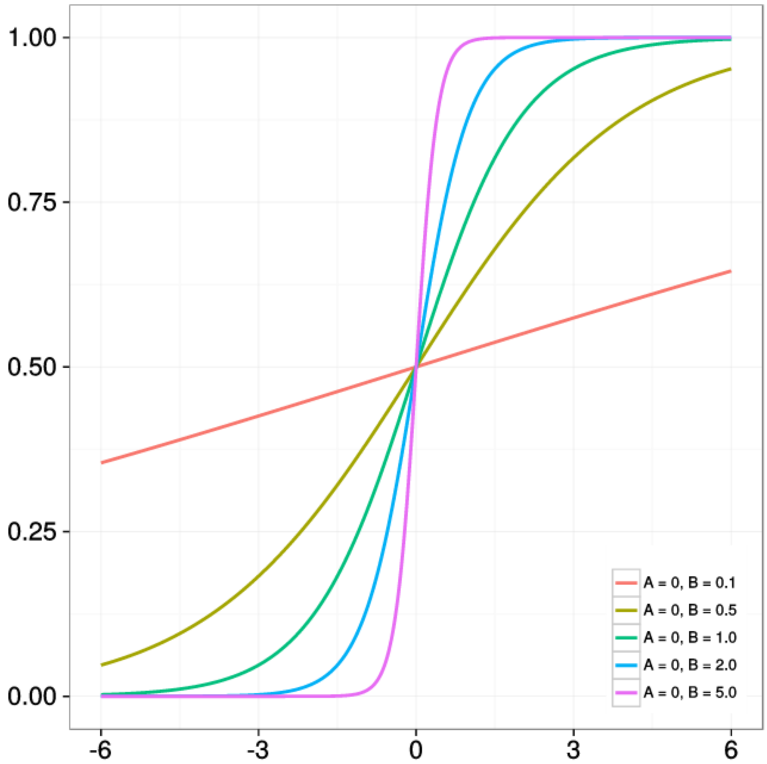

Figure 5.20. Generalized logistic function with variation of the growth rate

This curve models growth and has the following mathematical expression (46):

$$Y(t) = A + \frac{K-A}{(C+Qe^{-Bt})^{1/v}} \text{ (46)},$$

where we have the following parameters, which are expressed to represent the random *Y* function (for example size) according to *t* (the time): *A* is the lower asymptote, *K* is the upper asymptote (*K* is called the carrying capacity if *A*=0), *B* is the growth rate, *C*=1 (usually), *Q* is related to the value *Y(0)*,and if *v*>0, this affects near which asymptote maximum growth occurs. Formula (46) can also be rewritten for simplification as is the case shown in expression (47):

$Y(t) = A + \frac{K-A}{\left(C+e^{-B(t-M)}\right)^{1/v}}$, where M is the starting time t0: $(t_0) = A + \frac{K-A}{(C+1)^{1/v}}$,

which in turn leads to simplifying the setting of both a starting time and the value of *Y* at that particular time and renders the following rewritten expression (47):

$$Y(t) = A + \frac{K-A}{\left(C+Qe^{-B(t-M)}\right)^{1/v}} \quad (47)$$

The logistic function in this case is the situation where *Q*=*v*=1 and which has a maximum growth rate at time *M*. Interestingly, the generalized logistic function has a particularity if $Y(t_0) = Y_0$and $Q = -1 + \left(\frac{K}{Y_0}\right)^v$, should *v* and *α* be both greater than 0. This reveals a special case of the generalized logistic function, which leads to the solution of the so-called Richards' differential equation [98], as shown in expression (48):

$$Y(t) = \frac{K}{\left(1+Q_e{}^{-\alpha v(t-t_0)}\right)^{1/v}} \quad => \quad Y'(t) = \alpha\left(1-\left(\frac{Y}{K}\right)^v\right)Y \quad (48)$$

The classic logistic differential equation is a particular case of the Richards' equation as is shown in expression (49):

$$Y'(t) = Yr\frac{1-exp\left(vln\left(\frac{Y}{K}\right)\right)}{v} \approx rYln\left(\frac{Y}{K}\right) \quad (49),$$

provided that $\alpha = O\left(\frac{1}{v}\right)$and *v*=1, which enables to obtain the Gompertz curve in the specific limit $v \to 0^+$. Should certain data parameters be needed and estimated, then we must compute the partial derivatives of the logistic function (at the time *t* and for the case *C*=1) as shown in the sequence below:

$$\frac{\partial Y}{\partial A} = 1 - \left(1+Q_e{}^{-B(t-M)}\right)^{-1/v} => \frac{\partial Y}{\partial K} = \left(1+Q_e{}^{-B(t-M)}\right)^{-1/v}$$

$$=> \frac{\partial Y}{\partial B} = \frac{(K-A)(t-M)Q_e{}^{-B(t-M)}}{v\left(1+Q_e{}^{-B(t-M)}\right)^{\frac{1}{v}+1}} => \frac{\partial Y}{\partial v} = \frac{(K-A)ln\left(1+Q_e{}^{-B(t-M)}\right)}{v^2\left(1+Q_e{}^{-B(t-M)}\right)^{\frac{1}{v}}}$$

$$=> \frac{\partial Y}{\partial B} = -\frac{(K-A)e^{-B(t-M)}}{v\left(1+Q_e{}^{-B(t-M)}\right)^{\frac{1}{v+1}}} => \frac{\partial Y}{\partial M} = -\frac{(K-A)Be^{-B(t-M)}}{v\left(1+Q_e{}^{-B(t-M)}\right)^{\frac{1}{v+1}}} \quad [65]$$

The Gompertz function is a special case of the generalized logistic function and has an interesting practical applicability [26]. The Gompertz function is a type of mathematical model for a time series, where growth is slowest at the start and end of a time period, which is very similar to the practical case of employee productivity.

From a mathematical point of view or interpretation the right-hand valued asymptote of the function is approached much more gradually by the curve than the left-hand one, which can be seen in figure 5.23.

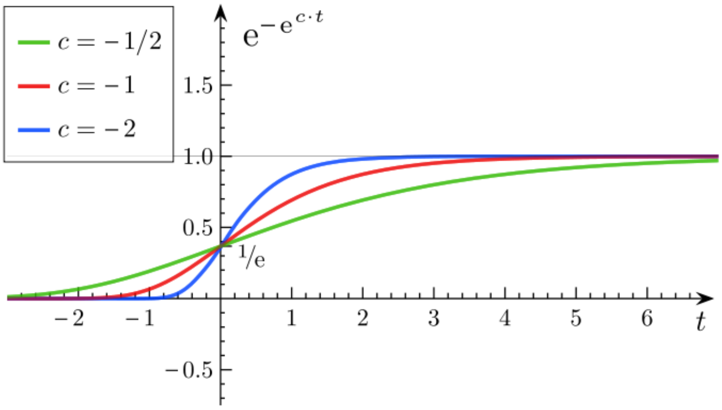

Figure 5.21. The Gompertz curve when varying the growth rate

The difference is that in the logistic function both asymptotes are approached by the curve symmetrically, whereas in this case we have an asymmetrical behavior. Productivity has a similar tendency, as there is a needed lag time before employees are able to perform their jobs at a good and productive level, and they need to keep this steady rhythm until the end, where as they approach the end of their work time, their dynamic starts to decrease normally as the effort over their working time has accumulated and they can no longer focus properly on their job at hand. The Gompertz function completes Tarde's view [116] upon the three stages innovation development (difficult beginning, take-off and maturity phase) previously stated and is represented through the following equation (50):

$$y(t) = ae^{-be^{-ct}} \text{ (50)},$$

where *a* is an asymptote, as $\lim_{t \to \infty} ae^{-be^{-ct}} = ae^0 = a$, *e* is Euler's number (approximately equal to 2.71828), *b* sets the displacement along the x-axis (translates the graph either to the left or to the right), whereas *c* sets the growth rate (or *y* scaling) and *b* and *c* are both larger than 0 (*b*>0, *c*>0).

The Gompertz differential equation (51) is also the limiting case of the generalized logistic differential equation (52), where *v*>0 as long as the following statement: $\lim_{v \to +\infty}(1 - x^{1/v}) = -\log(x)$ exists. The two equations (51), (52) are:

$$X'(t) = \alpha \log\left(\frac{K}{X(t)}\right) X(t) \text{ (51)} \quad \text{and} \quad X'(t) = \alpha v \left(1 - \left(\frac{X(t)}{K}\right)^{\frac{1}{v}}\right) X(t) \text{ (52)}$$

The inflections points from figure 5.23 appear in the graph of the generalized logistic function and that of the Gompertz function when the following expressions are met:

$X(t) = \left(\frac{v}{v+1}\right)^{v} K$, for the case of the generalized logistic function and

$$X(t) = \frac{K}{e} K * \lim_{v \to +\infty} \left(\frac{v}{v+1}\right)^{v}$$, for the case of the Gompertz function.

Another important aspect to take into consideration is the effectiveness of the finished product, which being subject to a more or less industrial process is prone to errors in a certain extent. These errors caused by either the programming of the machines or several types of human errors affect the quality through scrap, breakdowns or rework activities, which automatically imply that quality of the produced finished goods will in reality almost never attain 100% on internal factory level.

We will suppose that all the work needed to perform auxiliary and support activities to rework, repair and reestablish the proper functioning of machines in case of errors and malfunctions will on average add 30% to the expected total cost of manufacturing a perfect product. The quality cost multiplication factor (QCMF) will thus be 1.30 as we will have to spend 1.30 monetary units on average in order to produce 1 perfect product from the point of view of our targeted quality level (either by our internal standards or by our customers strict specifications).

By multiplying the gross improvement capability (GIC) with the quality cost multiplication factor (QCMF) we will obtain the factor of added value improvement (FAVI). In our case the product on these values will provide the following result:

FAVI = GIC * QCMF = 28 * 1.30 = 36.4 (4)

The value of the factor of added value improvement (FAVI) will provide the position on the effectiveness improvement chart (EIC). The effectiveness improvement chart shows the level attained by the company at a specific point in time and is an instant photo of the results already achieved to improve efficiency as well as the range it is lacking to further improve its operational functioning. The chart highlights the fact that improvement is easier to achieve in the beginning, whereas throughout time the improvement margin gets scarcer and less visible, but it is exactly this margin which makes a huge difference to main productivity, operational profit margin and customer value figures which can bring the plant into the top level within all business relevant aspects.

This chart also encompasses the most important cost sources (materials, depreciation, labor, other) and will determine the extent to which the company can benefit from its theoretical margin from the product selling price. If the cost is low, this implies added value is high and thus the theoretical margin will also be higher.

As figure 5.24 shows, the effectiveness improvement chart is divided into 4 zones, according to the degree of difficulty in order to achieve improvement and visible company relevant results. Thus the first zone is the red zone, where improvements are easily achievable as only a very small amount of the company's activities add value.

Usually this improvement area ranges somewhere from 1 of 1000 activities or less to 1 of 100 activities or less which actually add value, which in the end do not provide satisfactory results, as the overall performance of the company is considered insufficient. Within this zone company operations have a very high potential of making effective improvements, mainly by reorganizing the existing layout, simplifying process flow and reducing wasteful activities in a thorough approach.

The second zone is the green zone where achieving improvements becomes more difficult, as the sources of easy improvement have already been addressed in the red zone. The green zone means possible improvements range somewhere from 1 of 100 activities or less to 1 of 50 activities or less which actually add value, which in the end generates good results for the company, whilst the overall performance of the company is considered satisfactory.

This is also the last zone where the improvement line is linear on the effectiveness improvement chart, meaning that the efforts that need to be undertaken to achieve certain improvements are still rather proportional, mainly by redesigning existing layout, improving space utilization and enhancing process effectiveness within a more complex overall approach.

The blue zone is the third zone and is the one which already reaches the top of the effectiveness improvement chart, as major improvements become very difficult to achieve. The blue zone's range of possible improvements starts at 1 of 50 activities or less and tends to reach 1 of 25 activities or less which actually add value within operational and organizational performance. The blue zone also marks the end of the linear improvement line as it starts to curve, emphasizing the fact that improvements in this area are more difficult to improve, but the results generated in case of achieving these improvements can lead to very impressive figures (25-50%). These improvements are mainly supported by innovative improvements within current layout, high productivity figures within all added value operational areas and effective overview of key performance indicators (KPIs) within relevant areas.

The last zone is the light grey zone, which implies reaching the highest possible level of overall operational, organizational and managerial performance. When reaching this zone a company is considered a top class player in its domain and is easily able to compete with any other competitor on international level. Although within this level further improvements are very scarce, the effectiveness of the overall performance is very high, as at least 1 of 25 activities actually adds value within operational and organizational performance. The improvement line in this case is rather asymptotic.

This world class level is supported by a very disciplined staff with a continuous improvement approach in both own workplace as well as within current layout, very high factory effectiveness through high level productivity figures and internal quality first pass yield (FPY) rates within all added value operational areas and a strong organizational culture focused upon generating adding value to the customer.

This is the ultimate level a plant can achieve even though improvement possibilities are very scarce and harshly difficult to find, the generated results can prove absolutely impressive in the sense of achieving cost reductions by up to 50% and significantly increasing profit margins, especially on operational level, thus increasing the theoretical margin and the rate of added value in the same time. This combined effect provides very high quality products for the customers at the best possible cost with a proportional benefit for both the company and its employees.

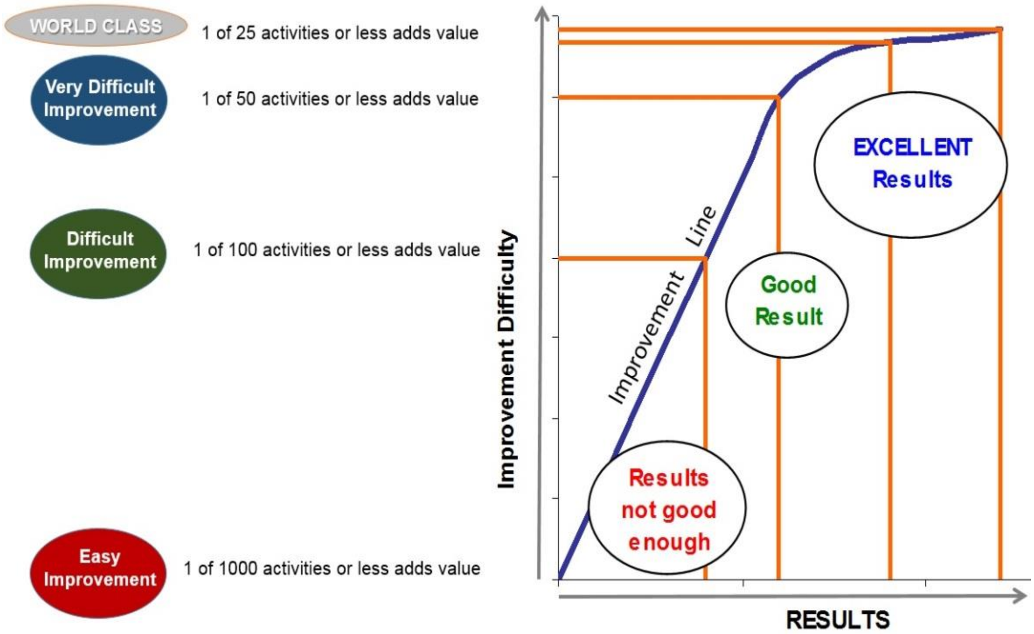

Figure 5.22. The effectiveness improvement chart (EIC)

The effectiveness improvement chart also contains the most important cost sources (materials, depreciation, labor, other) and reflects the gross margin it can source from its operational activity. The position of the company on the chart will determine the extent to which it can make the most of its theoretical margin from the product selling price. If the relative costs are low, this implies the share of added value in the sales price is high and thus the theoretical margin (which encompasses the gross margin) will also be higher.

This simple approach accurately quantifies the complex issue of added value and measures the degree of internal performance as well as organizational and operational intelligence of the plant. The approach focuses on the employees actually adding value (engineers and operators), the real productivity of the machines and the issue of quality within the organizational culture. For the operators this means precisely knowing how they perform their tasks and help them to add value by improving their workplace for better and more efficient results. This can only be done by calculating the time the operators can effectively add value within their workplace and most important, avoid any interruptions which may prevent the operator from his daily work in order to increase the proportion of the time in which he is adding value from the total work time. This is the concept of flow, which keeps an operator working in a normal pace, focused within the workplace, without any disruptions or interruptions, in order to achieve his daily goals without losing concentration. Also for the other employees, those who do not directly add value, it is important to see how their role can be optimized to provide support for other necessary activities within the plant. As for the machines two aspects are very important: defining the added value time in the machine cycle time and establishing and applying the proper utilization of the technical and technological equipment.

The concept of quality is one of the most important goals of the company, not only to meet the customer's set of specifications, but also the proactive internal approach to maintain high quality standards. This means doing everything right from the first time, to have the proper things done from the beginning without the need to check everything at different stages of the process or intervene and rework certain steps. Reliable quality is the pillar of customer satisfaction which can be achieved through a thorough and effective process design avoiding to produce scrap and the associated extra time for rework of handling, warranty and urgent transport costs. High quality levels however cannot be achieved without the support of quality employees with skills and capabilities. The people are the ones which add value or support processes adding value, therefore it is vital that they are motivated, have a good level of satisfaction within their jobs and that fluctuation figures remain low in order to achieve best results. Quality is based on a three-way approach: prevention, the skills of the people and innovation. Prevention basically implies simplifying every process and reducing complexity. This is a proactive approach in order to prevent problems appearing in the functioning of the company and its operations and make every task and process as simple as possible to prevent any type of human errors. Reducing waste is one of the main challenges as there are quite a few classic types of waste which can appear in daily operations and the choice is very simple: either an activity is adding value or it is producing waste and thus needs to be eliminated. The people however are the ones that need to filter and figure out which of these activities need to be adjusted, redesigned or eliminated in order to improve company effectiveness. Innovation is one of the most important factors to take into account, as it a source of continuous improvement and competitive advantage.

Contrary to most beliefs, innovation does not mean continuously changing or adding new features to products, but relates to making new changes to the layout, process flow of workplace design as to bring some kind of improvement either by making the flow of materials faster, the organization of the tasks better or by making the work of the operators more comfortable within their workplace or work area. By always being focused on the effectiveness of the activities, through this mindset opportunities to improve within certain process linkages will be found and help enhance overall plant productivity.

5.4. The effectiveness of the systems thinking process

The most important key success factor for any business is to have a clear focus upon its business strategy, to know what its strategic objectives are and to know how to provide high value to the customers. By implementing a strong organizational culture where there is a lot of focus on the main business assets (the macro approach) and by applying the proper techniques in order to support and enable the effective functioning of all manufacturing areas (the micro approach), a plant can become one of the best not only within its group, but it can source a very high level of competitiveness and establish a benchmark in business performance. In order to enact this level of process effectiveness the plant has to manage certain concepts in order to achieve results and obtain success, which can only be done by having a clear and performance-focused systems thinking. There are 2 different levels of the systems thinking process: the macro approach and the micro approach. The macro approach is based upon the business strategy and this is where the key focus areas for the business unit are defined and need to be prioritized. A manufacturing plant needs to focus on three main areas to become highly competitive within its market: quality, cost and adding value.

Quality is an order qualifier, of course, because you need to focus on quality in order to satisfy the customer's demands and specifications. There is a two-level quality process, one for the customer, which the company needs to meet when delivering its products and where the quality of the outputs sent towards the customers is as close as possible to a perfect 100% rate, with a zero defects performance objective. Upholding a high standard in quality and being reliable with the features and characteristics requested by the customers is fundamentally important for both the present and future of the business, therefore it is not negotiable to neglect any aspects of the customer's specifications. Besides the quality delivered to the customers, which is the external aspect of quality, there is also a quality standard set within the company, which is a target for constant improvement in order to at least match that of the customer (internal quality). This is mainly assessed by the total defects discovered upon a certain number of parts (parts per million, ppm), a defect rate which needs to be constantly reduced in order to assure high performance. The target for the company needs to be to match internal quality performance with external quality performance, to be as efficient as possible within operational performance and source as little time as possible with rework or handling scrap.

This matching of both internal and external quality requirements will make workload and procedures to be aligned and balanced and source a very high level of operational effectiveness within the plant. Moreover the fact that quality standards are aligned will also enable more productivity and balanced working tasks for the employees, allowing them to have more of their time dedicated to their actual core jobs and every-day tasks and not be hindered by non-productive disruptions.

The next important feature is cost, because in automotive industry it has become one of the most important preoccupations in recent years, especially after the economic crisis at the beginning of the millennium. The very complex dynamics and the technological evolution in fitting new equipment's into today's cars has increased at a very high rate and projects for the upcoming modern cars are even more high-tech and demand a lot of skilled resources as well as important investments and financial means from both the car manufacturers, their research and development centers and their supply chains as well.

All of these new projects and developments are coming very fast and require a high amount of capital from the budgets of the entire automotive industry supply chain, which is further challenged by the fact that the life cycles and the new product development times have become a lot shorter than before and this puts extra pressure into the return on investment (ROI) figures.

In order to balance these expenses, both carmakers and their supply chain partners are making extra efforts in order to succeed in improving their operational activity both on short-, medium- and long-term. This is however not easy, because these improvements usually imply configuration changes of layout, flow management, bottleneck priority rerouting, innovative changes, and effective operational performance of both individual and interlinked departments for a proper functioning of the whole system and an overall productivity improvement in the functioning capacity of the plant. Cost reductions can be done properly when they do not affect the operational performance in a negative manner and when they are enabled in the attempt to not just cut down cost, but to also improve working conditions in order to source higher productivity levels by using fewer resources.

Other supply chain level cost-cutting solutions may include supplier or component consolidation, low-cost country sourcing, cost analysis tools (reverse costing, design to cost, competitor benchmarking, etc.) or applying value engineering and value analysis tools in order to achieve high effectiveness potential and financial efficiency within several or all operational processes. One of the most important features of these cost-cutting techniques is that the end product in itself should still bear the same level of quality and its specifications, despite having been manufactured within more tighter budgetary constraints.

Quality and cost are nevertheless the main preoccupations of most car manufacturers as well as the entire automotive industry supply chain. There is however another important competitive factor to add to the performance of a factory or manufacturing plant and that is the amount of added value it produces and the perceived customer value. This is one of the most important features in order to source a high level of competitiveness and achieve a lasting long-term competitive advantage on the automotive market.

Adding value is an expression of a plant's capacity and ability to focus upon what the customers want and willing to pay for when they buy the product with its desired requirements and specifications. It is therefore an essential acknowledgement of the plant's effectiveness and efficiency at the same time and renders an important note upon the manufacturing facility's potential to have a very high amount and proportion of its activities dedicated towards adding value to the products. Adding value is also a measure of the plant's organizational ability to manage quality and cost challenges, enabling high customer value, which translates into a competitive position on the specific market and a benchmark for other automotive industry plants.

This overall global management policy focused upon the three main directions (quality, cost, adding value) is the macro approach. The business strategy of the plant is thus aligned with the most important operational performance targets and can thus produce high productivity figures as well as provide high value to the customer. These results can only be achieved by having an interlinked thinking of the overall plant effectiveness and not just focusing upon individual departments. It is vital for all departments to work effectively together in order to source overall or global performance of the entire system and not only provide local optimum performance, because the overall performance is at its best when all the links are contributing as a team for the common best result and this is not always possible if the separate entities are competing internally for their own individual goals, which may sometimes hinder the overall result of the plant.

This is called systems thinking and it is one of the most important macro techniques to achieve a highly productive management level that can source very good results for the manufacturing plant, both in economic terms (cost, profit, other financial indicators), as well as in a high level of customer value (quality, added value) and is at the root of world class manufacturing competitiveness as described in figure 5.25.

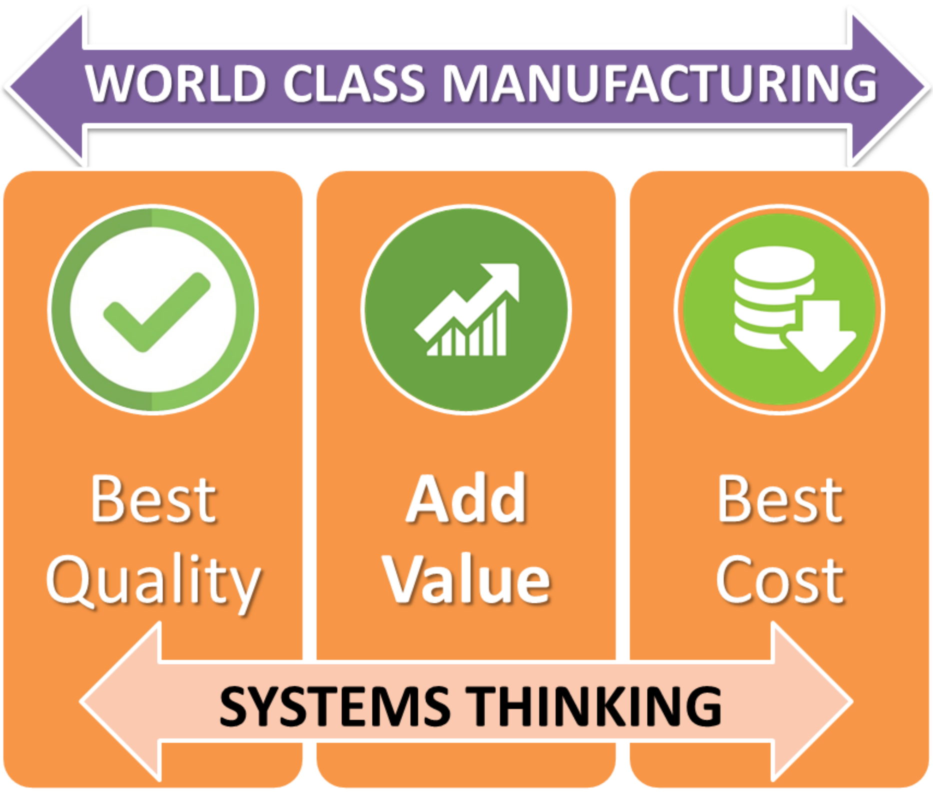

Figure 5.23. The Macro approach: World class manufacturing competitiveness

The success of the implementation of the macro approach however is based upon managing to source the desired results through a very effective operational performance of the plant (the micro approach). This is where added value is created every day and where improvements are made in order to achieve higher productivity figures with the target to constantly increase the quality of the output levels and associated products in order to provide value to the customer.

If the macro approach is a more strategy oriented approach, the micro effectiveness is based upon applying the proper techniques to achieve the desired strategic plan and vision of the plant. The effective functioning of all manufacturing areas thus depends upon the proper usage of the techniques and tools and can be basically summed up by three main concepts: simplify, reduce waste and improve.

Simplifying is the first step of this process as all manufacturing steps, processes and tasks need to as simple as possible in order to avoid complexity. This is important because by avoiding complexity, there are a lot of potential problem areas which are eliminated and the basic approach can focus on the core tasks of the manufacturing process and create more added value. Among the most important features is a very easy and simple layout, which makes the production process and physical flows easier to follow and manage. This can also be done through the help of some classic production aiding concepts as is the Poka-Yoke concept or the 5S, which both help source an effective and efficient manufacturing process as well as a good and organized overview upon the production area by having a very tidy standardized set of working cells and workplaces.

The next step is to reduce waste, any activity which does not directly add value and is not absolutely necessary needs to be eliminated in order to make way for a more useful task, space dedication or time usage by the employees previously involved in those non-added value processes. This will allow for a more productive and effective time usage and will increase the overall ratio of value-adding activities and processes throughout the plant, therefore sourcing customer value and competitive advantage for the company.

This part of the micro approach is usually done by applying most of the Lean management principles, or more specifically the Japanese Muda concept or the value stream mapping (VSM) technique in order to properly point out the correct focus upon the processes within the plant that add value and source customer value.

The last of these micro concepts is the improvement: here, a lot of tools are available to be used and to enable the desired manufacturing effectiveness: among the most important we can point out the 6 Sigma, Kaizen or DMAIC concepts. The concepts help to align processes within high quality standards (6 Sigma), continuously help find areas for improvement or innovative changes which bring benefits for the employees or in productivity (Kaizen) and help gain a very structured and result-oriented mindset for most of the plant’s processes and manufacturing related activities (DMAIC).

Similar to the macro approach however, the micro approach also has a system thinking which needs to be considered when applying these techniques. Within this systems thinking there are a couple of very important concepts that help enable the high level of added value which is desired as a strategic output towards the end of the plant’s manufacturing process.

The first of these concepts is the concept of flow (or the tube concept), which emphasizes the importance of a very smooth and continuously running process which does not have any kind of interruptions. The main feature of this concept is the reliability of the process as with the constant flow of tasks, activities and jobs, there is a very high potential of productivity and good overall effectiveness within the plant. Should these activities also be supported by good efficiency figures, then the process has high value-adding potential. In order to achieve this high level of effectiveness there are a couple of manufacturing support concepts which need to be applied properly and enable an efficient process as well.

Some of these concepts may help reduce non-productive times (SMED), increase the time machines are running continuously without breakdowns (TPM) and sourcing no defects or quality related issues (TQM), therefore rendering consistency to the whole plant and its underlying processes.

In order to manage the diverse areas with good results and high efficiency rates it is important to focus upon visual management, not only in supervising the physical part of the processes, but also by assessing the level of performance in regards to the established output levels.

Thus visual management is more effective when it is done by using proper and real-time KPIs to have a constant feedback upon performance progress and to know when progress is ahead of schedule, on schedule or behind schedule and what the reasons are. This is also effective for motivating the employees as they can set their pace accordingly in order to meet their daily output levels and adjust their rhythm accordingly in order to even get bonuses in case of higher performance levels.

Using such visual management tools can also help manager to better control their output targets and performance indicators as well as have a better overview upon the plant’s performance and quickly source the root cause for any delays or interruptions. Moreover such an extensive performance-measuring tool also allows for individual performance assessment which is also very useful when new positions are open for those employees which have proven to be hard-working and who have invested their energy and skills into performing their jobs at a very high professional standard.

The last important concept within this approach is the empowerment of the people, of the employees of the plant. This is important because you cannot source very good results if you do not have the right people to perform the jobs accordingly and with a very performance-oriented approach. Sourcing the right people is a complex and sometimes difficult process, but when the team is focused on the organization’s goals then results will come very quickly.

The main challenge is to find the right people and this means finding employees that will have the correct mindset to align to the company’s ambitions, the motivation to carry out their jobs in a professional and effective manner on an everyday basis and having the focus set upon performance, upon constantly wanting to improve their own and their teams results in the short-, medium- and long-term.

These people are very important to the company, because they are the guarantee of the correct implementation of the organizational culture and the basis for achieving the targets set within the macro approach, therefore they need to be appreciated and need to also feel the fact that they are the most important resource within the company.

The Micro approach (focused upon the effectiveness of the plant’s organizational culture and its operational performance) is represented in figure 5.26.

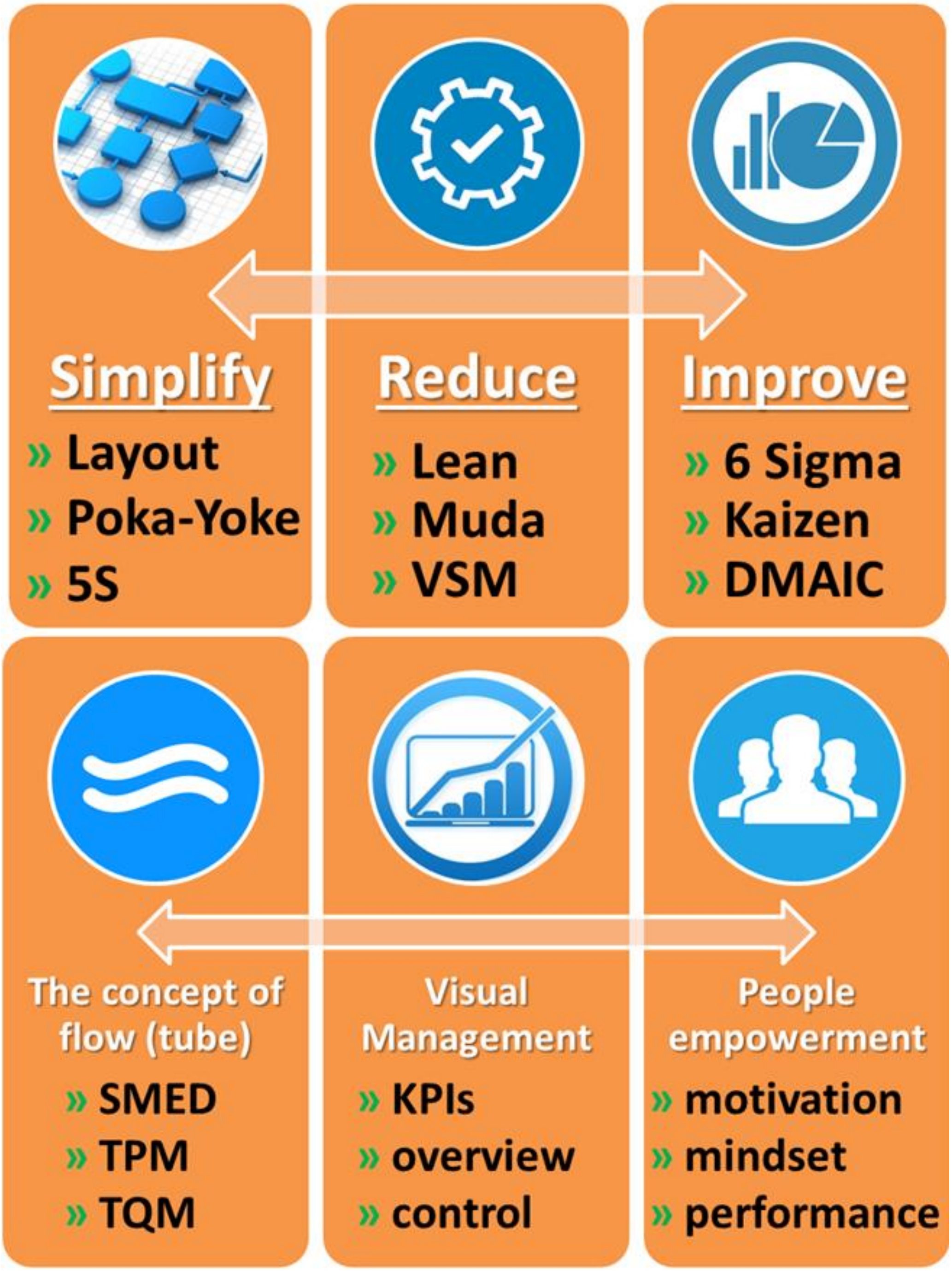

Figure 5.24. The Micro approach: Organizational culture and operational effectiveness

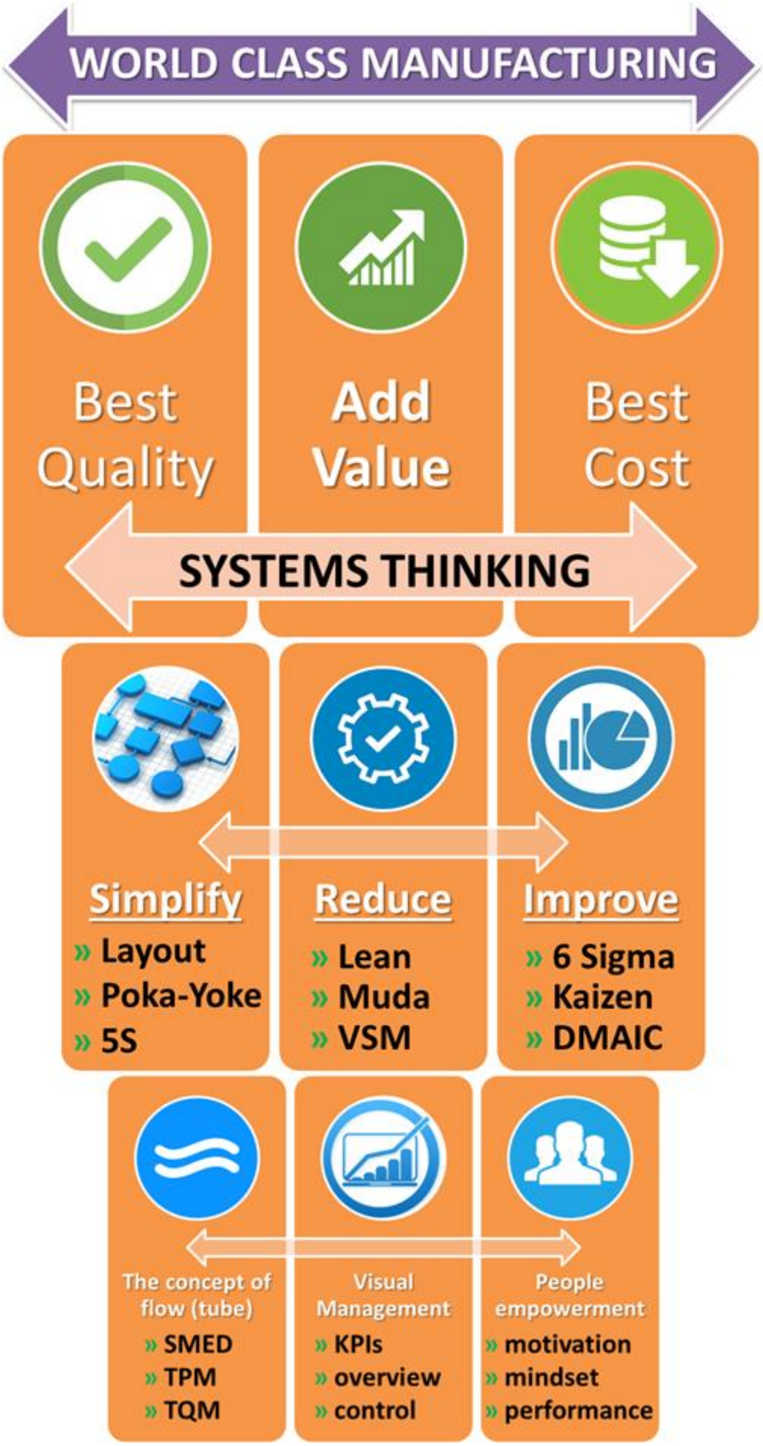

Figure 5.25. The global approach to become a world class manufacturing plant

In order for a manufacturing plant to achieve the world class manufacturing competitiveness it strives for, it is necessary to apply both the macro and micro approaches in conjunction (highlighted in figure 5.27) for them to enable the highest possible level of performance from the plant and provide high customer value.

The combined approach of the macro and micro visions of the plant will source high added value and organizational and operational effectiveness, which will enable the manufacturing site to improve its overall competitiveness and its position on the market. Depending upon the specific factors and conditions within its environment the plant can actually achieve a benchmarking rank either only within its group or it can become a worldwide reference from which best practices can be sourced. This would be the expected result and a very consistent key success factor from having a clear focus upon an added-value oriented business strategy. The key of the successful implementation of this global approach is however the systems thinking and the proper involvement of the people in the improvements needed within the plant. Redefining the roles of the employees, empowering them and motivating them will create the setting for some important innovative changes and improvements which will help improve effectiveness and overall plant efficiency, leading to higher added value ratios and productivity figures. Managing the plant's own success is also a challenge, but this is normally not an issue with the right people and the right mindset. They will focus on performance, because there are at the basis of the results and will want to see their work producing benefits.

A plant's overall performance depends upon the performance of its employees and the people need to feel motivated and challenged at their jobs, liking what they are doing and helping their colleagues and team member to achieve results and succeed in their company projects. By having a clear overview upon the strategic goals, coordinating resources to achieve internal performance targets and motivating people to be innovative the plant will steadily achieve major improvements which will position it within the main industry players and enable it to become a world class manufacturing plant and compete with any other company in the world in all significant business indicators.

Achieving such a high level of competitiveness is like assembling a puzzle, at the beginning it is not easy to find all the right matching pieces, but when the whole begins to come together then the results are quite impressive as they enable a very effective and productive system performance which in turn provides very good customer value. Progress is more obvious at the beginning when improvements are very easy to see within KPIs and also every-day operational performance, but it is when the upper-limit improvements are made where the difference between a very good and an excellent (or world class) plant are made, because this marginal difference sources the distinctive and decisive differentiation that enables a plant to provide high added value products, at the best quality and at the best price. This small difference is the key to become a highly competitive automotive industry player that will have a very strong competitive position on the market on short-, medium- and long-term.

6. CONCLUSIONS, PERSONAL CONTRIBUTIONS AND PERSPECTIVES FOR THE FURTHER DEVELOPMENT OF THE RESEARCH

This last chapter is the final part of the thesis, which summarizes the intermediate conclusions of the previously presented chapters and presents the overview of the thesis by emphasizing the personal contributions of the author and future research perspectives.

6.1. Thesis summary and conclusions

Chapter 1 presents a short overview of the automotive industry on several levels in order to provide a complete setting upon the issues and importance of the companies which are part of this complex and very competitive supply chain.

The chapter provides relevant data about production, sales and the main worldwide car manufacturers from the automotive industry, as well as the dynamics of the industry in recent years, along with the most important challenges faced by the carmakers in today's interconnected environment.

This data is then continued with the most important features of the automotive industry from Romania, where the importance of the automotive business is underlined through data from the macroeconomic environment (GDP, exports and number of associated jobs in the economy) as well as the extent of the national supply chain which is driven by the main carmakers which have manufacturing plants in the country, Dacia in Mioveni and Ford in Craiova.

The chapter also includes a well-focused overview upon the country's western region concentration of important automotive suppliers (Continental Automotive, Johnson Controls, Delphi, Valeo or TRW being within the top 10 worldwide automotive suppliers) and the main competitive advantages and assets of this part of the country for attracting foreign investments in the automotive industry: best-cost country, geographical position, high quality infrastructure, technological center, highly qualified and skilled employees, high concentration of universities in the region and very good motivation from the workforce towards performing well at their jobs.

The last part of the chapter underlines the importance of the support for the automotive industry provided by road infrastructure improvement and motorway network enlargement for enabling a sustainable long-term development in Romania in view of the concentration of the competition from neighboring countries: Czech Republic, Slovakia, Poland and Hungary and also provides some data upon the growth dynamics of the automotive industry within recent years and its development perspectives.

Chapter 2 presents some of the most important performance assets in automotive industry, as well as their strategic and operational implications.

The first subchapter highlights the importance of competitive advantage, which can be attained by the companies either through best cost or differentiation advantages in order to gain an important position on the automotive market.

In order to be able to reach such a position the company has to understand the importance of the value chain and its main features. The value chain is basically a set of interlinked activities which are composed of primary functions as are logistics, production and marketing which are supported by auxiliary features in order to provide value to the customer. To be able to do this, the company must design processes and activities which mainly add value to its products and services and have a very good perceived value by the customers for which they are willing to pay.

The value chain approach for assessing competitive advantage and customer value is then highlighted, showing the necessary steps that should be taken in order to obtain highly effective processes and efficient results within the manufacturing activity of the plant. These steps include internal cost analysis, internal differentiation analysis , vertical linkage analysis as well as organizational and managerial challenges of the value chain analysis. The value chain analysis approach requires proper strategic thinking, deep understanding of all processes and interlinked activities, as well as constant awareness in order to be able to continuously adapt to an improved workplace structure while maintaining the process flow and having high operational performance supported by the associated performance indicators (KPIs).

The following subchapter presents the different organizational structures that companies can employ in order to help support their management of all the processes and activities, their main features and characteristics, advantages and disadvantages as well as the situations where they would be best suited for in order to provide maximum outputs and high efficiency.

The last subchapter features the importance of layout effectiveness and value chain improvement strategy. The first part of this subchapter presents the gains obtained through layout effectiveness during a 3-year timespan at a manufacturing plant in the western region of Romania by improving productivity and work efficiency in a documented manner, by showing the steps and transformations done to several of the plant's most important production, logistics and other dedicated areas and their respective constraints and desired characteristics.

The follow-up of the plant's operational performance is ensured by employing visual management, which helps to monitor performance, by assessing the most important and relevant KPIs and the planned and effective output levels. Results have also been obtained at others levels as well, as is the case with operational efficiency: reducing waste, adding value and improving effectiveness has been done throughout almost all of the plants' significant areas in order to achieve the best possible performance and have provided important time and cost savings.

Chapter 3 emphasizes the current challenges and assets in automotive industry production that car manufacturers are facing and are trying to adapt to in order to gain a more competitive position on the globalized car market.

Automotive industry production's main goal is to provide best quality products at the best possible cost in order to enhance market share and volumes and be able to continue development and improve profitability indicators in the long-term. The extent to which this goal is achieved affects the pricing strategy and is the main driver of all managerial and organizational efforts within the manufacturing plant, where machine and labor flexibility issues have to be solved as well as modification, mix and new product flexibility schedules integrated within the operational scheduling of the manufacturing facility.

The issues and challenges thus associated with agile manufacturing in automotive industry production are presented in the next subchapter, where alternative assembly layout configurations are discussed as well as an emphasis upon the continuous improvement process within the lean management philosophy through the most important principles: Just in Time (JIT), Total Quality Management (TQM), Total Preventive Maintenance (TPM) and Human Resource Management (HRM).

The efforts to attain agile manufacturing within a production plant are mainly due to the importance of customer focus and a value-oriented approach from the manufacturers which is being supported by using the proper tools, such as value stream mapping (VSM) in order to source the most effective processes and to try to improve productivity and the added value ratio within all the processes in the plant.

The next subchapter deals with the changes and challenges in automotive industry today, which are every-day issues and which shape the competitive nature and the development of the industry throughout recent years. The main challenges refer to cost pressures, shorter product life cycles, the increased use of electronic equipment which has also prompted many consumer electronics companies to enter the automotive market and have added to the complexity of the supply chain as well as to the range of electronic and software products available on modern cars.

Production flow principles and systems in automotive industry have to thus meet the needs of the company and the global challenges as well therefore there is a big emphasis upon productivity and efficiency. The subchapter dedicated to this topic discusses the main tools used by the plant to achieve its results: the concept of flow, no inventory in the line, clear visualization of all the process deviations, improving material flow and plant layout and no buffers or bottlenecks, all principles applied simultaneously having a big contribution to rendering the plant highly effective and supporting it to achieve best results.

The Six Sigma principle and its utility is also discussed in the following subchapter, where the DMAIC concept (an acronym for Define, Measure, Analyze, Improve, Control) is explained as part of the quality process in order to improve existing processes, to stabilize certain processes and their designs within the plant. For creating new product or process designs the DMADV (an acronym for Define, Measure, Analyze, Design, Verify) project methodology is employed as part of the same quality procedure.

The challenges of cultural differences and features of the Romanian work culture are equally important to understand when working within a specific environment, because by properly understanding the characteristics of the workforce, through the right techniques the potential to achieve best results can be highly increased in order to motivate, empower and inspire the people to do their best and bring results to the plant's operational performance, which is at the base of creating added value, providing high customer value and enables the company to gain a very strong competitive position on the automotive market.

Chapter 4 presents a consistent part of the main challenges related to managing production in automotive industry, as well as many practical issues related to operational effectiveness.

The first subchapter of this section provides a more overall view of the industry and its complexity which is mainly due to globalization and its associated opportunities, every-day challenges, issues and constraints.

The increasing competitiveness in the automotive industry in which not only car manufacturers are involved, has also been extended to their suppliers' network, meaning the working in the industry is becoming more and more demanding in terms of quality, cost control and meeting deadlines. The required level of motivation and mindset alignment in organizational culture is thus utterly important for a plant to deliver high performance and achieve its objectives by providing high customer value. This part shows the principles on which this level of motivation and mindset alignment is based and how they apply in real examples at different plants in automotive industry with the associated obtained results.

Logistics and supply chain integration is one of the fundaments for a successful collaboration in the automotive industry and has to also bear the constant pressure in cost reduction for this part of the manufacturing process and plays an important role for its degree of effectiveness.

The harsh challenges associated with building a reputation of best quality over time are also described in the next subchapter, where the importance of working together as a team is emphasized by the need to create added value, which can only be done by properly combining the skills and assets of people, processes and practice. Plant effectiveness helps the facility to develop added value and bring value to its customers by focusing on process flow by skilled people, with experience and motivation which support the delivery of high productivity rates and competitive advantage for the manufacturing plant.

Another important success factor for manufacturing plants is outlined in the next subchapter, as improving effectiveness can only be done through proper synchronization of all processes and activities within the manufacturing facility. The subchapter explains why is it important to pass from partial to global optimization and achieve a high rate of performance for inputs, outputs and most important, for the linkages of a production system.

The next subchapter presents the results of the improvement process for automotive electronic production in a best-cost country production plant, along with some automotive industry competitive characteristics and production plant challenges, how the WCM principle was applied in an approach to achieve effective organization within a best-cost country production plant and how the implementation of the correct organization principles brought very impressive results within a best-cost country production plant from western Romania.

The last part of this chapter is dedicated to explaining the world class concept for a manufacturing plant which is mainly focused upon operational performance, productivity and its adding value capability. This part highlights the importance of designing an effective workplace with a clear focus on operational performance and reliability, outlines how workplace effectiveness is the result of employee productivity and a performance-based mindset and why when implementing the world class concept best results are only possible with the total implication and hard work of the best people.

Chapter 5 presents how measuring the degree of value added activities within a company is a means for continuous improvement towards world class manufacturing (WCM).

This chapter outlines some very important aspects that are very important and relevant within any production facility, as are standard times and their key role in a manufacturing plant. The desired average values are best approximated and simulated by using some mathematical tools as are the linear interpolation method, which are then refined through Rolle's theorem, cosine interpolation and polynomial interpolation in order to provide more accurate qualitative and quantitative results for these calculations.

The following section is dedicated to the added value productive time and the associated operational indicators, where the Added Value Productive Time of an operator's work time (AVPT), of a machine's work time (MAVPT) and their deviation from target levels are analyzed and compared within 10 randomly selected processes from the plant's operational processes and machine indicators. Results are then expressed graphically for better understanding of the values and their differences and they are further refined by using the Euler method for a more fine and accurate representation.

Providing a tool for the comparison of the performance level of manufacturing plants is then one of the most important parts of the thesis as the logistic function is a source for the effectiveness improvement chart proposed by the author in this section.

The mathematical graph and dynamics interpretation of the logistic function are then completed by the sigmoid function and the associated mathematical relations, a variation of the growth rate through the Gompertz curve which source the effectiveness improvement chart (EIC) as a measuring tool of the performance state of the company, its progress and dynamics and its potential to grow further in the future.

The last part of the chapter is dedicated to formalizing the effectiveness of the systems thinking process and emphasizing the Macro approach, to achieve world class manufacturing competitiveness, and the Micro approach, to source organizational culture and operational effectiveness, as they commonly support the plant's global approach to become a world class manufacturing plant.

6.2. Propositions for future research and limitations

Automotive industry has become in recent years one of the most complex, challenging and competitive business environments. The increasing number of features that modern cars are equipped with, the technological progress and the innovation in the industry has also further added to the complexity and the network extent of the automotive supply chain. This creates the need for improved effectiveness from each supply chain partner and an important amount of adaptability in order to ensure an efficient transition between production and logistics (inbound and outbound).

The challenges for an automotive industry supplier or company part of this very dynamic and strongly competitive supply chain are thus increasing and the pressure to improve internal and operational performance is constantly growing, therefore a formalized approach to support these efforts is needed in order to attain a competitive position on the global market. The factor of added value improvement (FAVI) formula will provide the position of the plant on the effectiveness improvement chart (EIC) and render its level of performance, improvement capability and dynamics and competitive potential on the global market.

The effectiveness of the plant and its capacity to increase its overall productivity and added value creation as well as the customer value ratio it provides depends on the quality of the systems thinking process. By combining the Macro and Micro approach, the plant can source and achieve significant performance improvements, by enabling a strong organizational culture and a high level of operational effectiveness, as they commonly support the plant's global approach to become a world class manufacturing plant.

These tools should be considered as a departure point for the generation of a further, more enhanced version of a production system improvement methodology or program that should nevertheless remain practical and provide a quick, easy-to-use and understand relevant assessment of the overall effectiveness of a car manufacturing facility.

Based on the experience of the author in production and logistics as well as in the management of a manufacturing plant, the following additional research topics which can further broaden the understanding of performance drivers in automotive industry as well as the pertinence of the obtained results can be proposed:

1. The present configuration of tools (the factor of added value improvement (FAVI) formula, the effectiveness improvement chart (EIC) and the combined systems thinking – Macro and Micro approach) can be **adjusted according to a carmaker's own appreciation and view** upon the extent to which that specific facility needs to use these means for specific purposes (operational, tactical or strategic) as well as within the timespan it considers that a desired effect is being generated and has an improvement effect or positive impact on its overall activity level (short-term, medium-term or long-term, etc.); this could source several possible extra features to the presented tools and could help enhance and improve

the methodology, in the end providing a more complete and pertinent analysis tool – although the tools provide all the most important and relevant areas to be assessed the analyzed companies will not always have the same size, departments, number of employees, amount of workload and daily challenges, therefore the application of the methods and the obtained results should also be considered by taking into account these parameters for a better understanding of the end results

2. The factor of added value improvement (FAVI) formula, the effectiveness improvement chart (EIC) and the combined systems thinking – Macro and Micro approach could also be formalized into a **performance measurement program or software** which could generate all these performance metrics and dynamics and provide all the relevant data in real-time to support the decision-making process on several management levels within the manufacturing plant (operational, middle management, top management) – despite being a very practical measurement tool and providing user-friendly and pertinent company activity and performance indicators, a program or software is a very complex system and needs to meet the needs of more companies in order to be properly employed and provide overall benefits, as well as have several adjustment, adaptability and optional features to render it more flexible and adapted to the requirements of the plant which considers using it; this creates a problem in the sense that criteria is no longer the same for all the analyzed parties and thus results need to be further refined to obtain a more equitable comparison; moreover, providing too much flexibility may enable the newly created program or software to lose much of its comparison capability due to the adding or suppressing of more or less additional or optional features, meaning that it is no longer the same comparison platform for all the analyzed manufacturing facilities; balancing out these features could prove to be a quite challenging task for further researchers

3. The present configuration of tools (the factor of added value improvement (FAVI) formula, the effectiveness improvement chart (EIC) and the combined systems thinking – Macro and Micro approach) could further be **enhanced by adding some performance indicators** regarding the actual level and extent of the added value within certain areas to obtain a more precise estimation of the productivity and added value creation ratio as well as the degree of customer value and the specific proportion where it is created throughout the entire processes of the company to provide a more complete overview upon the important areas within the company for both operational improvement purposes as well as strategic management decision-making – gathering and exactly quantifying this information is sometimes mathematically not possible, therefore subjective assessment is sometimes needed in order to provide some figures to work with when performing the calculations, which in turn will alter the objectiveness of the results seen as personal evaluations, when no clear values or even intervals are provided, will always lead to subjectivity in results' appraisal and differences and deviations from the actual state in similar cases depending upon the person who is conducting the auditing of the performance a certain process within the plant

4. Perhaps one of the most interesting research propositions would be to use the present configuration of tools (the factor of added value improvement (FAVI) formula, the effectiveness improvement chart (EIC) and the combined systems thinking – Macro and Micro approach) as a **comparison methodology to try and compare the performance of production sites** belonging to either the

same manufacturer for internal benchmarking purposes (for company performance analysis, benchmarking and standardization of bet practices) which can help the car manufacturer better tailor its decision-making, tactical plans and overall strategy in the long-term or for production sites belonging to competing firms in order to assess their differences in characteristics, productivity figures and overall effectiveness within the manufacturing process and associated logistics activities – this approach would however require the assistance of an independent auditor as well as a very proper collaboration from both audited manufacturing sites and a very objective and professional delivery and use of the provided data from all implicated parties

5. The factor of added value improvement (FAVI) formula, the effectiveness improvement chart (EIC) and the combined systems thinking – Macro and Micro approach could also be **formalized into a more scientific methodology consisting of some mathematical formulas** inspired from the present thesis (linear interpolation, Euler's method, logistic function, etc.) which could probably be easily converted into a more complex and complete set of formulas and algorithms which could provide a mathematical basis for further enlarging the scientific approach relating to performance measurement of a manufacturing facility – this would however require gathering some very consistent data from the plant's operating level, finding a very good mathematical path that would adequately represent all the relevant historic data, dynamics and provide insights to future development and it seems challenging to find the proper mathematical relations that would suit several different processes in such a way as to find a balanced methodology

6. One of the most practical approaches regarding the present configuration of tools (the factor of added value improvement (FAVI) formula, the effectiveness improvement chart (EIC) and the combined systems thinking – Macro and Micro approach) would be to **design a simple and user-friendly classic tool**, that could easily be used within plants without having to install a specific software or other external applications in order to make it run; such a tool could even be in the form of an Excel complex variety of sheets with the most important indicators being highlighted and outlined, as well as all the basis data which had sourced these overview results; the tool could also integrate some interesting an relevant graphical material in the form of charts, graphs, radar charts, etc. in order to help the user understand the data quicker and with a more comprehensive overview of all aspects – this would imply gathering information and requesting feedback within intermediate stages of the tool designing process in order for the end product to match as adequately as possible both the needs and requirements of employees and staff which would use the tool for analyses and decision-making, a process which could prove challenging and would most probably require several intermediate versions until finding a final one which would be considered acceptable by those who would finally use it.

6.3. Personal contributions within the thesis

1. The author's main contributions presented throughout the present thesis are as follows:
2. making a synthesis on the key events that have shaped the automotive industry throughout recent years both worldwide as well as in Romania, with

relevant data from the key industry players and highlighting the automotive industry's contribution and importance within the economy

3. conducting a comparative analysis upon the competitive nature of the automotive industry sector in the western region of Romania, with the main suppliers working within the automotive supply chain and the main competitive advantages of the region which attract these companies to build and extend their plants in this part of the country
4. summarizing the main figures of the Romanian automotive industry as well as those from neighboring Central and Eastern European countries (CCE) in order to outline the growth evolution, development perspectives and high competitive nature of the Romanian automotive industry (Chapter 1)
5. presenting a synthesis with the main features and characteristics of the value chain and competitive advantage, along with some examples from the automotive industry in order to outline the importance of these concepts in understanding how to provide high customer value and being successful as a manufacturing plant
6. compiling an outline with the differences of the organizational structures that companies can employ in order to help support their management of all the processes and activities, their main characteristics, as well as the situations where they would be best suited for in order to provide maximum outputs and high efficiency rates
7. conducting an extensive case study upon the layout effectiveness of a plant by improving its productivity and work efficiency and showing the steps and transformations done to several of the plant's most important areas (production, logistics, other dedicated areas) and their associated constraints and desired functional characteristics
8. presenting the benefits of visual management within a manufacturing plant: monitoring performance, assessing planned and achieved output levels, analyzing other relevant KPIs and its influence upon operational efficiency: reducing waste, adding value and improving effectiveness, as means to achieve the best possible performance
9. summarizing the main changes and improvements in operational efficiency: production line and process changes, operational changes in the workplace, improving layout and space utilization, ergonomic changes, common space and logistics improvements, employee careers and development perspectives, as important means for increased productivity and plant performance (Chapter 2)
10. outlining the main issues within an automotive industry plant: high quality, low costs, meeting strict deadlines, the challenges of flexible and agile manufacturing, providing customer value, as well as renown management techniques from the industry, presented with references from relevant research literature
11. presenting some of the most toughest challenges an automotive supplier is facing in its every-day activity and long-term planning strategy, with its practical implications as well as with relevant research literature references
12. explaining the effectiveness of simplification within the production process and its benefits by applying some innovative techniques in a specific manner to improve production flow and how these concepts can source important results to the manufacturing plant

13. providing an overview upon the complexity and the linkages between brand ownership in automotive industry as well as a short synthesis upon the main collaborations and evolution within the industry in last couple of years
14. elaborating an innovative approach to explain the challenges of cultural differences and features of the Romanian work culture, the characteristics of the workforce from the western region and how to use the right techniques to achieve best results in operational performance and enable the plant to gain a very strong competitive position on the automotive market (Chapter 3)
15. presenting a synthesis of production management issues in automotive industry and how globalization, motivation and mindset in organizational culture, logistics and supply chain integration affect operational effectiveness and plant performance
16. summarizing the most important features of an effective synchronization process and how to successfully pass from partial to global optimization to increase performance and results
17. conducting a case study upon a production plant and applying the world class manufacturing (WCM) principle in adapted manner and aligned with the company's organizational culture principles in order to improve overall performance
18. designing an approach for an effective workplace with a clear focus upon improving and maximizing its operational performance and reliability on short-, medium- and long-term
19. emphasizing and highlighting the most important elements that drive employee productivity and a performance-based mindset in order to build the best possible team that will provide the best possible results for the plant and source high customer value (Chapter 4)
20. compiling an outline of the most relevant aspects that provide the standard times within any production facility and the mathematical tools used to improve approximation and refine accuracy of the obtained results
21. elaborating the factor of added value improvement (FAVI) formula as a result of a case study upon the added value productive time of the operators' and machines' work time and their deviation from target levels within randomly selected processes from the plant's operational processes
22. designing the effectiveness improvement chart (EIC) as a performance measuring tool of the plant, its progress and dynamics and its potential to grow further in the future
23. developing a global approach to become a world class manufacturing plant by formalizing the effectiveness of the systems thinking process through world class manufacturing competitiveness principles (the Macro approach) and organizational culture and operational effectiveness concepts (the Micro approach) and combining their features for an integrated outlook (Chapter 5)

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