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Angelo Riva, Luciano Pilotti

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Green Strategy, Lean Production and World Class Manufacturing: a comparative study of two international world-class companies

Angelo Riva
University of Milan (Italy) and ODCEC

Luciano Pilotti
Professor, University of Milan, Italy

Corresponding Author:
Angelo Riva
University of Milan
Via Festa del Perdono, 7
20122 Milano
prof.a.riva@gmail.com

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ABSTRACT

This paper outlines the evolution from lean strategy to green sustainable strategy based on a comparison of international leading companies in the motor sector. This research uses primary and secondary data. It argues that lean manufacturing and green sustainability strategy and advanced TPS (Toyota production system) model as increasing importance for eliminating waste and for sustainable long-term strategy. Based on empirical data on costs of energy consumption the results show how the strategy of lean management integrated with green sustainability and advanced TPS permits to save energy.

Questa ricerca delinea l'evoluzione dalla strategia lean-green sostenibile basata sul confronto tra aziende leader a livello internazionale nel settore motociclistico. Questa ricerca utilizza dati primari e secondari. I risultati evidenziano come la strategia di produzione snella e di sostenibilità verde e il modello TPS (sistema di produzione Toyota) avanzato hanno un'importanza crescente per l'eliminazione degli sprechi e per una strategia sostenibile a lungo termine. Sulla base di dati empirici sui costi del consumo energetico, i risultati mostrano come la strategia di lean management integrata con la sostenibilità verde e TPS avanzati permetta di risparmiare energia.

Keywords: green strategy, lean manufacturing, sustainability, energy consumption, environmental management, world-class manufacturing

1 – Introduction

Lean-Green Strategy is based on delivering cleaner, more valuable products with the right processes (Verrier *et al.*, 2016; Abreu *et al.*, 2017) to reduce waste and improve the environmental and social conditions (Fercoq *et al.*, 2016). This paper explores the challenges and the opportunities of lean management and green sustainability strategy based on international comparison of leading companies in the motor sector; it reports the interesting case of PIAGGIO (Cristofaro, 2011; Giuliareti, 2012; Caffarena, 2020; Colaninno and Gianola, 2006; Biagiotti, 200; Piaggio, 2000a,b,c,d) and YAMAHA MOTOR

(Yamaha, 2018,2019, 2020a,b,c,d,e; Yanamura *et al.,* 2005; Brondoni, 2021; Pałucha, 2012); still few papers (Chiarini, 2014) are written on the process to determine critical success factors in motorbike sectors.

The key research questions (RQ) of the paper, based on comparative case studies Piaggio and Yamaha motor, are:

Q1: *How is organized the strategy of production and lean management and green sustainability?*

Q2: *What are the analogy and differences between the green production strategies of the companies studied?*

The organization of the paper is: the second section describes the theoretical background and the third the methodological aspects, the fourth section reports the case of Piaggio, in the fifth section there is the case Yamaha, in the sixth section there is the discussion and the last concludes.

2 – Theoretical background. *Theoretical review*

The aim of integration lean and green strategy (Verrier *et al.,* 2016) toward sustainable manufacturing (figure 1) is to get three targets together: a) economic development; b) environmental development; c) social development (high quality of life through renewed quality of wealth and jobs). (Liker, 2004, Dixon *et al.*, 1994; Hall *et al.*, 1993; Hammer and Champy, 1993; Gazzola and Colombo, 2014, Gazzola and Mella, 2003, 2006, 2017; Gazzola *et al.,* 2020).

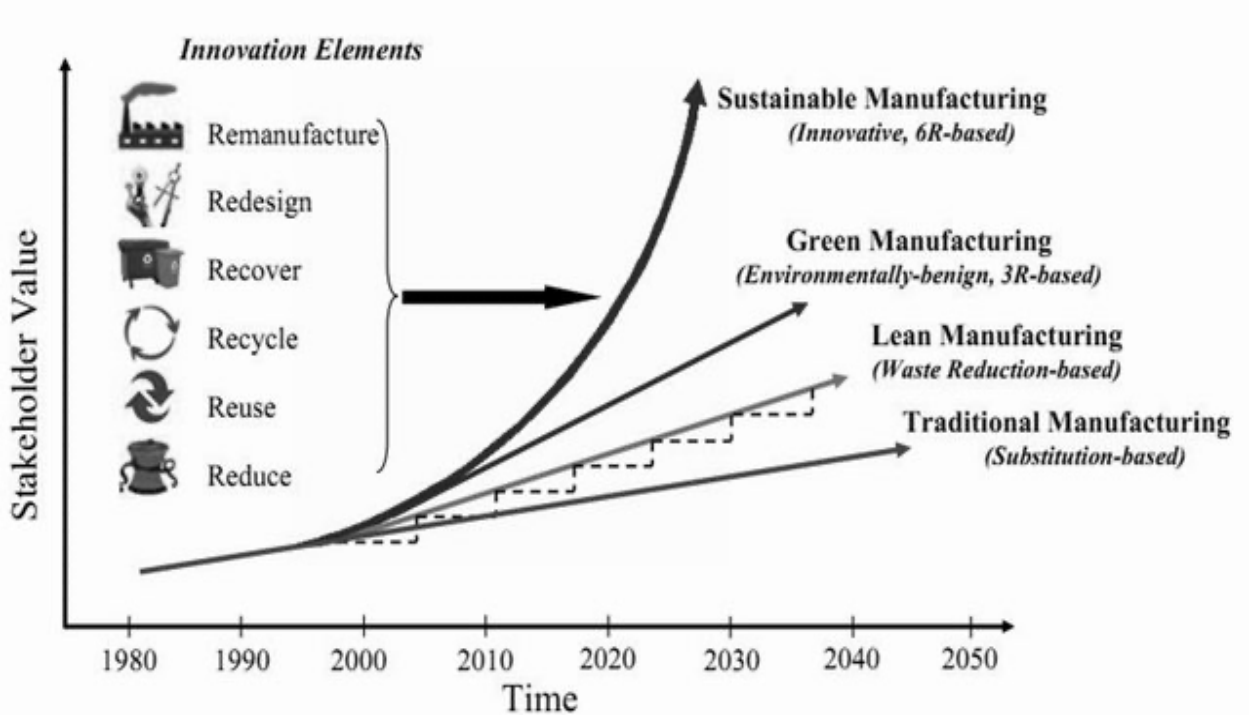

Fig. 1 – Evolution of the integration of lean and green manufacturing during the time (Source: elaboration from Jayal *et al.,* 2010; Mahaboob Basha, 2020)

Some studies analyze how to improve many areas and processes in the enterprise with the integration of green sustainability strategy (table 1).

Tab. 1 – Literature on lean and green (Source: our elaboration)

STUDY	FOCUS	AREA
Verrier *et al.* (2016)	Model of integration of green and lean	Lean and green
Caldera *et al.* (2019ab); Fercoq *et al.* (2016)	Integration lean and green strategy	Main tools
Aguado *et al.* (2013)	Case study	Environmental innovation
Vais *et al.* (2006)	5S, SMED, SOP	Motion
Fliedner (2008)	Inventory reduction, Lean product flow, lean supply chain management	Greenhouse effects
Upadhye *et al.* (2010)	Literature review	Sustainable development
Deif (2011)	Case study	Green manufacturing
Ball (2015)	Lean layout, Value stream mapping, pull system	Transportation
Triguero *et al.* (2014)	Stakeholder satisfaction	Stakeholder
Chiarini (2014)	Value stream mapping,	Overproduction
Piercy and Rich (2015)	Multiple case analysis	Benchmark performance
Djekic *et al.* (2014)	Autonomation/Jidoka,	Defects
Hong *et al.* (2012)	Structural equation modeling	Quantitative models Benchmark tools
Piercy and Rich (2015)	Total Productive Maintenance (TPM), Takt time	Waiting
Chiarini (2014); Fliedner (2008)	Total productive maintenance	Poor health & safety
Upadhye *et al.* (2010)	Literature review (theoretical)	Sustainable development
Piercy and Rich (2015)	Total Productive Maintenance (TPM), Takt time	Waiting
Chiarini, 2014; Fliedner (2008)	Total productive maintenance	Poor health & safety
Wu *et al.* (2015)	Case studies	Integrated sustainable practices model
Khatri and Metri (2016)	Analytic hierarchy process approach	Factors for sustainability-related strategy

Several studies have shown how the methodology of lean manufacturing can be integrated with other methodologies (Womack and Jones, 2003; Collis, 2016; Imai, 1986; Abegglen *et al.*, 1985, Senge, 1999, Nonaka, 1991, 1995; Qintas *et al.*, 1997; Stack *et al.*, 1992; Cautela *et al.*, 2014; Boston Consulting Group, 2015; Chui *et. al.*, 2010; D'Averni, 2015; Holweg, 2007; Mella, 2021b) (table 2).

Tab. 2 – Lean mudras and their associated green impacts (Source: our elaboration from Pałucha, 2012)

WASTE	GREEN IMPACT
Overproduction	Unnecessary use of raw materials
Unnecessary inventory	Excessive use of space and cost of the asset
Transport	Energy usage in transports and CO2
Unnecessary motion	Energy and consumption
Defects	Waste of raw materials and energy and cost of repair
Inappropriate processing	Unnecessary energy and raw materials
Waiting	Waste of energy and time
Lost people potential	Waste of energy

We focus on lean manufacturing integrated with other methodologies to improve the green sustainability strategy (Ohno, 1988; Verrier *et al.*, 2016; Shingo, 1981; Mella, 2012, 2015; Riva and Pilotti, 2017, 2018, 2019a,b,2020, 2021a,b; Womack and Jones, 1990) (figure 2).

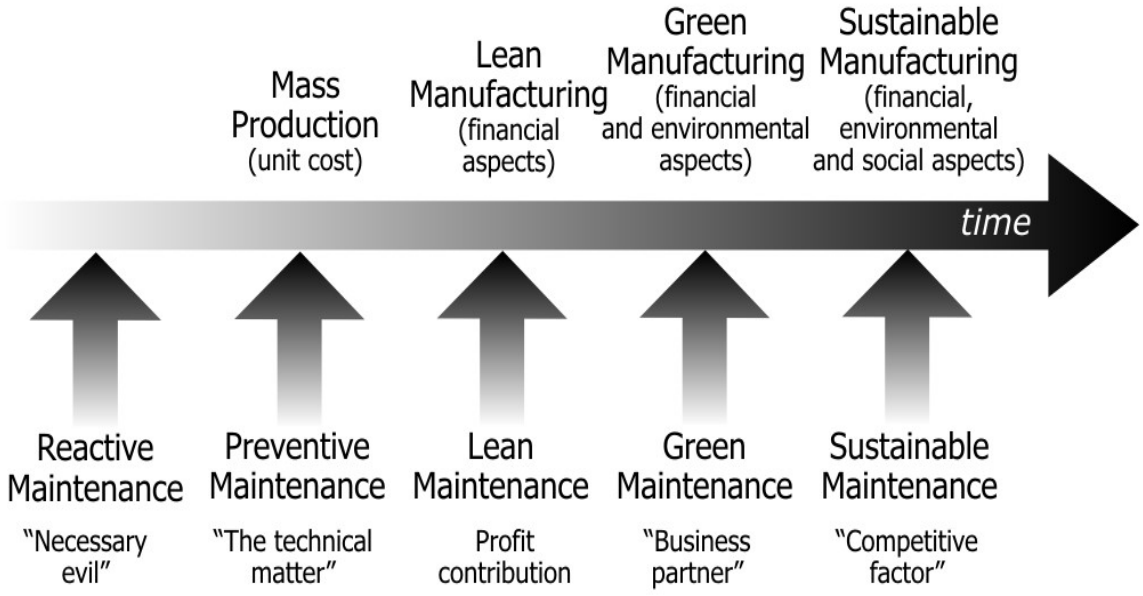

Fig. 2 – Evolution of the integration of lean and green manufacturing during the time (Source: elaboration from Jasiulewicz and Kaczmarek, 2013)

The lean method can be integrated with many theories toward sustainable manufacturing (Goldratt, 1992; Chase and Jacobs, 1992); Riva and Pilotti, 2018) and with WCM (world class manufacturing) (table 3). The strategy of the WCM is to get the "zero" value in defects, inefficiencies, customer dissatisfaction, etc .

Tab. 3 – Lean and World class manufacturing (Source: our elaboration from De Carlo and Simioli, 2018)

STUDY	FOCUS
De Carlo e Simioli (2018)	Comparison of Lean and WCM
Sandeep e Panwar (2016)	Lean manufacturing is one of the best practices of the WCM, along with TQM, JIT, TPM, Six Sigma.
Cerruti (2015)	WCM is nothing more than a particular applicative development of traditional canons of organizational Toyotism.
Villano (2015)	Lean production is the system from which WCM originates.
Silva, *et al.* (2013)	WCM is based on models created by the post-war Japanese manufacturing industry. It adapts the new Lean ideas used by Japan to achieve significant competitive advantages.
Leoni (2013)	WCM is the reference point, internationalized and industrialized, of the Lean production model. It indicates a wide range of organizational elements of production that characterize the companies that compete in the global market, but also incorporate the concept of a dynamic organization in constant and rapid improvement.
Ab Rahman, *et al.* (2012)	During the development of Lean Manufacturing many terms were coined that refer to the same idea and model. including "WCM".
Murino, *et al.* (2012)	WCM is an integrated system that is based, among others, on the adoption of the Lean production principles and which is also used as a parameter to verify the actual state of implementation.
Naviglio (2011)	WCM incorporates the elements of Lean production, but the concept of "leanness" should be rethought, to be included in a larger pattern of strategic production.
Simoni (2002)	WCM companies must possess all the skills of Lean production, combined also with strategic aspects.
De Toni e Tonchia (2002)	WCM is in many respects similar to Lean production, with a focus on achieving World Class performance. When compared to Lean, WCM is also a little more "plump" losing in agility but gaining in Quality and Services.

3 – Methodology. *The reason of the choice of Piaggio and Yamaha*

We have decided to choose these companies because: a) the companies selected are successful motorcycle manufacturers with many important also race success in international competition during the time; b) the balance-sheet of the company describes some important saving results; c) they all show consistent rates of growth; d) they are two leaders international companies with international importance; Yamaha's motorcycle sales are the second largest in the world and Piaggio's motorcycle is tenth (table 4).

Tab. 4 – Global market share of the motorcycle and bike industry in terms of value (Source: our elaboration Deallab, 2021)

RANK	COMPANY	MARKET SHARE
1.	Honda	22.6%
2.	***YAMAHA***	**10.4%**
3.	Hero MotoCorp	5.9%
4.	Bajaj	5.1%
5.	Harley-Davidson	4.4%
6.	BMW 3	7%
7.	TVS Motor	3.1%
8.	Suzuki	2.6%
9.	Kawasaki Heavy Industries	2.3%
10.	***PIAGGIO***	**2.1%**
11.	KTM	1.8%
12.	Ducati	1.1%

The model of *Lean and Green* permits to analyze the difference between the two company (Verrier *et al.,* 2016). We analyze the case of *Piaggio* (Biagi, 2018; Rancati, 1988; Cristofaro, 2011; Giuliareti, 2012; Caffarena, 2020; Colaninno and Gianola, 2006; Biagiotti, 2006; Piaggio, 2000a,b,c,) and *Yamaha* (Yamaha, 2018 ,2019, 2020a,b,c,d,e; Yanamura *et al.,* 2005; Brondoni, 2021) based on the previous literature using primary and secondary data. About secondary data, we also study the public balance sheet and other documents (tables 5a and 5b).

Table 5a – Piaggio secondary data used in this research (Source: our elaboration)

	MAIN SECONDARY DATA	FOCUS
1	**Piaggio Annual Reports 2016-2021 PIAGGIO (2020a)**	focus on strategy and economy
2	**Piaggio Sustainability Report PIAGGIO (2020b)**	focus on sustainability
3	**Gruppo Piaggio. Progetto di bilancio 2020, PIAGGIO (2020c)**	focus on strategy
4	**Draft of Financial Statements PIAGGIO (2020d)**	focus on strategy and marketing

Table 5b – Yamaha secondary data used in this research (Source: our elaboration)

	MAIN SECONDARY DATA	FOCUS
1	**Yamaha Integrated Report YAHAMAA (2020a)**	focus on strategy
2	**Strategies by Function - Annual Report YAHAMAA (2019)**	focus on strategy
3	**Investor Relations - Yahamaa Reports (2020) YAHAMAA (2020b)**	focus on strategy
4	**Sustainability Reports YAHAMAA (2020c)**	focus on sustainability
5	**Yamaha Motor Group - Environmental Plan 2050 YAHAMAA (2020d)**	focus on environment
6	**Long-Term Vision and New Medium-Term Management Plan YAHAMAA (2018)**	Focus on strategic
7	**World Technician Grand Prix YAHAMAA (2020e)**	Focus on production

About primary data, we collect data and information by contact and interviewees with the experts (table 6) about the areas of research (table 7).

Tab. 6 – Interviewees (Source: our elaboration)

Economic expert in the sectors	10 interviews

We also visit the historical Museo of Piaggio in Pontedera (Pisa). In the museum of Piaggio, there is a description of the culture of innovation of the company during the time.

Tab. 7 – Main issues covering during the interviews (Source: our elaboration)

RQ1 - *How is organized the strategy of production and lean management and green sustainability?*	- strategic guidelines and tools for integration lean and green based on Lean and Green House - main tools and principles - best practices
RQ2- *What are the analogy and differences between the green production strategies of the companies studied?*	- analogies differences based on based on lean and green house - application of tools - cultural difference in vision and strategy

4 – The strategy in Piaggio

4.1 – *History of Piaggio*

Piaggio was founded by Rinaldo Piaggio in 1884. Important was the innovative production of the model of motorbike *Vespa* (1946) (figure 3). Now Piaggio's headquarters is in Pontedera, Italy near Florence. In 1956 with the production of millionth was an important record for the company (Cristofaro, 2011; Giuliareti, 2012; Caffarena, 2020; Colaninno, 2006; Biagiotti, 2006).

Fig. 3 –The Piaggio's production line (Source: Sella)

Today, *Vespa* Piaggio is an international leader in manufacturing two-wheeler and commercial vehicles (scooters, motorcycles three and four-wheelers vehicles) The main brands of the company are Vespa, Piaggio, Gilera, Aprilia, Ape, Porter, Moto Guzzi, Derbi and Scarabeo. Piaggio carries out manufacturing facilities in India, Italy, and Vietnam. Principal markets are in Europe, Asia, and North America (Piaggio, 2020) (table 8).

Tab. 8 – The evolution of the strategy and system of production in Piaggio (our elaboration from Cristofaro, 2011; Giuliareti, 2012; Caffarena, 2020; Colaninno and Gianola, 2006; Biagiotti, 2006; Piaggio, 2000a,b,c,d)

Phase	TIME	MILESTONES
1	**1884-1945**	Founded the company by Enrico Piaggio in Sestri Ponente (Liguria)
2	**1946-1969**	Vespa in Ponterdera (Tuscany)
3	**1969-1992**	Acquisition of important Italian motor manufacturing (Gilera Motor Guzzi, Aprilia)
4	**1992-2010**	Open European market
5	**1992-2021**	Global market and production

Piaggio manufactures and distributes two-wheeler and commercial vehicles: a). Piaggio's two-wheeler segment portfolio consists of scooters and motorcycles (69.4% of the total revenue in 2019 about 1055.3 million euro; b) commercial vehicles segment include three and four-wheelers vehicles along with their spare parts and accessories (30.6% of the total revenue 466.2 million about euro in 2019 (Piaggio, 2000a,b,c,d).

4.2 – *The Piaggio approach to lean and green strategy*

Based on primary and secondary data (Piaggio, 2000a,b,c,d; Cristofaro, 2011; Giuliareti, 2012; Caffarena, 2020; Colaninno and Gianola, 2006; Biagiotti, 2006), we can analyze how the lean and green strategy in Piaggio is based on some important factors and strategies**.**

Piaggio's strategy is focused on continuous innovation and desires to integrate lean and green strategy (table 9). The strategy of production of electricity Vespa and electric Ape is based on the decision to invest in environmentally friendly engines.

Tab. 9 – Ten Piaggio Lean - green strategy actions (Source: adapted from Piaggio, 2020a,b,c,d; Cristofaro, 2011;Giuliareti, 2012; Caffarena, 2020; Colaninno and Gianola, 2006; Biagiotti, 2006)

	STRATEGY	**ACTIONS**
1	**Vespa elettrica (2018)** **Focus on product and design sustainability**	World-class production based on quality and tradition
2	**Ape e-city electric (2020)** **Focus on product and design sustainability**	Focus on ecology and mobility
3	**Management system based on the ISO 14001-2015 standard** **Focus on green and environmental strategy**	Reducing the emission of CO2
4	**MP3 hybrid is a three-wheel scooter with a combustion engine and electric battery combination.**	Low environmental impact.
5	**Focus on shareholders** **and people and new plant which produces the environmentally friendly engines**	To meet the expectations of shareholders
6	**Focus on environmental and consumption reduction**	Reducing energy consumption
7	**Focus on sustainability processes and lean**	Focused on improvement and quality
8	**Focus on customers** **Focus on global market (best practices)**	Being exemplary in the way its international human resources are managed.
9	**Focus on reduction of waste**	Waste handling and recovery
10	**Focus on green innovation**	Strong investment in new products based on eco-saving

The application of these actions gives some important results (table 10) (Piaggio, 2020a,b,c,d).

Tab. 10 – Results in Piaggio: reduction of energy consumption in Piaggio Group (Source: Piaggio, 2002a,b,c,d)

CONSUMPTION	ELECTRICITY	NATURAL GAS/ METANO
2018	294534	222930
2019	288137	224628
2020	243115	186081
Improvement 2020-2019	-15,6 %	-12,7 %

They are important factors in the strategy based on lean and green sustainability strategy for the reduction of energy consumption. The aim is to focus on processes, recognition of the efforts of the staff, quality upstream and downstream integration, quality and visual management.

4.3 – *Integration of Sustainable manufacturing with a sustainable maintenance*

In Piaggio there is a change in manufacturing strategy during the time; in the first phase there is the evolution from mass production to lean manufacturing; after there is the integration of lean and green manufacturing and at last the evolution in sustainable manufacturing.

Piaggio uses some techniques of World Class Manufacturing (Schonberger, 2008) to improve the quality of results in manufacturing strategy with financial, environmental, and social benefits. World Class Manufacturing is a synthesis of various concepts, principles, policies, and principal techniques for the management and operation in production (table 11).

Tab. 11 – World Class Manufacturing principles (Source: elaboration from Schonberger 2008)

SAFETY – HYGIENE	COST DEPLOYMENT	FOCUS IMPROVEMENT	AUTONOMOUS ACTIVITIES	PROFESSIONAL MAINTENANCE
Quality control	**Logistics and customer service**	**Early product management and early equipment management:** 5S, Safety, Reduce and Reuse Strategy, Employees Involvement, Proactive Knowledge and Compliance, Continuous improvement	**People development**	**Environment**

Piaggio intends to invest in product innovation with attention to the environmental situation. The company offers a range of products that include scooters, mopeds, and motorcycles from 50 to 1,400 cc marketed under the Vespa, Piaggio, Gilera, Aprilia, Moto Guzzi,

Derbi, and Scarabeo brands. It also operates in the three- and four-wheel light transport sector with its Ape, Porter, and Quargo ranges of commercial vehicles.

The company categorizes its business operations into three geographical segments: EMEA and Americas, India and the Asia Pacific:

a) EMEA and Americas segment accounted for 57% of the company's total.

b) India with 28.3%.

c) The Asia Pacific with 14.7%. Piaggio is a manufacturer of two-wheel motor vehicles.

4.4 – *Application of environmental quality control and reduction of consumption and minimize energy waste*

Piaggio uses the ISO 14001-2015 environmental procedure to improve the environmental strategy. The implementation is based on some processes and phases (table 12) following the Deming (PDCA) cycle.

Tab. 12 – Develop an implementation plan for environmental quality control using the Plan-Do-Check-Act cycle for ISO 14001:2015 (Source: our elaboration from Piaggio, 2002a,b,c,d; Cristofaro, 2011;Giuliareti, 2012; Caffarena, 2020; Colaninno and Gianola, 2006; Biagiotti, 2006)

PHASE	PDCA	ACTION
1	**PLAN**	Benchmarking organization's competency and training requirements for iso 14001:2018 collecting and analyzing data, assessing information, and reporting results. Planning environmental performance evaluation by selecting relevant indicators. The planning step is to identify gaps in your current system and processes.
2	**DO**	Operate the planned strategy
3	**CHECK**	Review overall environmental performance. Conduct performance evaluation and management review
4	**ACT**	Improve overall environmental performance. Ensure that corrective actions are completed

Piaggio uses environmental strategies all over the world. Piaggio also operates in China with a joint venture (Zongshen Piaggio Foshan Motorcycles, based in Foshan in the province of Guangdong) in which it holds a 45% stake.

Piaggio has production plants in Pontedera (Pisa), which manufactures Piaggio, Vespa. The internalization of the strategy permits sharing the best practices.

5 – The strategy in Yamaha Motor

5.1 – *History of Yamaha Motor*

Yamaha Motor Co. is a Japanese manufacturer of motorcycles, marine products such as boats and outboard motors, and other motorized products. The headquarters is in Iwata, Shizuoka, Japan. The company was established in 1955 upon separation from Yamaha Corporation (with was focused on musical instruments)

The company's products include motorcycles, scooters, motorized bicycles, boats. Yamaha's motorcycle sales are the second largest in the wo\rld (see tab. and Yamaha is the world leader in water vehicle sales (figure 4).

Fig. 4 –Yamaha's production line (Source: Motorbear)

During the time in Yamaha there is a strong strategy for support innovation (table 13).

Tab. 13 – The evolution of the strategy and system of production in Yamaha (Our elaboration from Yamaha, 2018,2019, 2020a,b,c,d,e; Yamamura *et al.*, 2005; Brondoni, 2021)

PHASE	TIME	MILESTONES
1	1887-1954	Founded the company by Torakusu Yamaha in 1887 in Hamamatsu
2	1955-1979	Open motor division with production of ya-1 ("red dragonfly") 125cc single cylinder
3	1980-2000	Acquisition of important motor manufacturing
4	2000-2021	Expansion and internalization, diversification
5	2011-2021	Innovation in the product global market and production

5.2 – *Main strategy and targets for 2050*

Yamaha follows a long-term strategy and develops a plan with a target up to 2050 for integration of lean and green strategy (table 14) (Yamaha, 2018, 2019, 2020a,b,c,d,e). The focus is on innovation to improve the results in some areas: a) products; b) resources; c) addressing environmental preservation and biodiversity globally. The reduction of CO2 emissions is an

important element for improving the quality of the product. Yamaha intends to be a leader in the integration of lean and green sustainability strategies. The long-term vision permits defining the main targets and priority actions.

Tab. 14 – Yamaha Lean - green strategy target 2050 and priorty actions (Source: adapted from. (Yamaha, 2018,2019, 2020a,b,c,d,e; Yanamura *et al.*, 2005; Brondoni, 2021)

	Target for 2050	**Priority Actions**
	PRODUCTS **Providing environmentally friendly personal mobility** **50% reduction of CO2 emissions from products by 2050 (on FY2010 levels)**	
1	Reduction of CO2 emissions from the use of products by users	Promotion of development to improve fuel efficiency
2	Development, promotion, and spread of next-generation mobility	Energy diversification
	Business Activities 50% reduction of CO2 emissions throughout the life cycle (on FY2010 levels)	
3	Reduction of CO2 emissions generated in the operation of productions（t-CO2/net sales）	Reduction of CO2 emissions per sales at factories globally
4	Reduction of CO2 emissions in logistics	Reduction of CO2 emissions per transportation unit
	RESOURCE **50% reduction of "resource use" (on 2010 levels)**	
5	Reduction of new resources use by recyclable resources use	Promotion of saving of limited resources by 3R development/manufacturing
6	Reduction of waste generated in the operation of production	Promotion of waste reduction
7	Reduction of water consumption in operation of production	Promotion of water consumption reduction activities based on water stress scenarios
8	Reduction of packing materials in logistics	Enhancing returnable packing materials
	Addressing Environmental Preservation and Biodiversity globally	
9	Activities to protect fields of product use by users (land, sea, and air)	Promotion of activities to preserve nature globally
10	Activities to protect ecosystems of land/ocean	Promotion of activities in line with our outline of biodiversity initiatives

5.3 – *The result in energy reduction*

The global trend of Yamaha is for a reduction in energy consumption (table 15). In some regions (China and Central South America) is very strong.

Tab- 15 – Results in Yamaha : reduction of energy consumption in Yamaha (Source: (Yamaha, 2018, 2019, 2020a,b,c,d,e)

	2019	2018	2017	2016	2015
Europe	314,128	276,040	291,754	298,122	314,784
North America	927,928	874,540	884,450	910,487	980,963
Japan	3,273,060	3,289,194	3,376,16	3,435,581	3,432,997
Oceania	27,244	19,657	20,509	18,652	3,509
Central and South America	317,855	311,398	290,325	289,407	347,753
China	315,049	363,525	428,597	410,264	475,902
Total (GJ)	9,818,568	9,506,816	9,881,22	10,125,179	10,514,720

5.4 – *Corporate vision and green sustainability*

There is a strong integration among the corporate mission of Yamaha, management principles and action guidelines, and integration of green-lean strategy (table 16).

Tab. 16 – The corporate vision, management principles and actions guidelines of Yamaha Motor (our elaboration from Yamaha, 2018, 2019, 2020a,b,c,d,e; Yanamura *et al.*, 2005; Brondoni, 2021)

<table>
<tr><th colspan="2">CORPORATE MISSION</th></tr>
<tr><td colspan="2">KANDO CREATING COMPANY.
Offering new excitement and more fulfilling life for people all over the world</td></tr>
<tr><th>MANAGEMENT PRINCIPLES</th><th>ACTION GUIDELINES</th></tr>
<tr><td>I-CREATING VALUE
that surpasses customer expectations</td><td>I-ACTING WITH SPIRIT
Meeting change with swift and informed action</td></tr>
<tr><td colspan="2">To continue to produce value that moves people,
we must remain keenly aware of the customer's evolving needs.</td></tr>
<tr><td>II-ESTABLISHING A CORPORATE ENVIRONMENT
that fosters self-esteem</td><td>II-SPIRIT OF CHALLENGE
Courage to set higher goals without fear of failure</td></tr>
<tr><td colspan="2">We must build a corporate culture
that encourages enterprise and enhances corporate vitality.</td></tr>
<tr><td>III-FULFILLING SOCIAL RESPONSIBILITIES GLOBALLY</td><td>III-PERSISTENCE
Working with the tenacity to achieve desired results, and then evaluating them</td></tr>
<tr><td colspan="2">As good corporate citizens,
we act from a worldwide perspective and by global standards.</td></tr>
</table>

The culture of Yamaha is focusing on respect for the environment and passion for innovation and to find the always better methodology and tools to improve the condition (Yamaha, 2018, 2019, 2020a,b,c,d,e).

6 – Discussion and managerial implication

We can find some common elements in the strategies of Piaggio and Yamaha during the time for integration of *lean and green sustainability strategies*. In general, the results of the two companies (see tab 10 and 15) describe a good improvement of the saving energy consumption. To obtain these results we can determine some critical factors with management implications:

6.1 – *Principle and tool in Piaggio and Yamaha: Lean and Green house*

Both Piaggio and Yamaha Motor use the *Lean and Green Hous*e that define the principles, tools, values for implement a sustainability strategy based on lean (Ohno, 1988; Shingo, 1981) and green strategy and WCM (table 17). Important it to have a global strategy based on some priorities: a) strategy for reducing energy consumption; b) strategy for reducing landfills; c) strategy for reduction in carbon footprint; d) strategy for reducing water consumption

Tab. 17 – WCM strategy (Source: our elaboration from Pałucha, 2012)

10 WCM Pillars	10 Managerial Pillars od WCM
1• Safety - Workplace safety 2• Cost Deployment - Sources of economic loss 3• Focus Improvement - Focused improvement of a specific problem 4• Autonomous Maintenance - Workplace Organization 5• Professional Maintenance 6• Quality Control - Quality Control 7• Logistic / Customer Services 8• Early Equipment Management, Early Product Management - Acquisition strategy for work equipment / processes 9• Environment - Environment and use of energy servos 10• People Development - Development of staff skills	1. OPL One Point Lesson 2. SOP Standard Operating Procedure 3. SMP Standard Maintenance Procedures 4. 4M MAN / METHOD / MATERIAL / MACHINE problem breakdown method to identify sensitive areas 5. 5W 5 WHY ask and iterate questions about the reason for a phenomenon 6. 5W + 1H WHAT / WHERE / WHEN / WHICH / WHO / HOW place the phenomenon within these items 7. 3M objective evaluation of the workplace 8. KAIZEN specific improvement projects 9. KPI Key Performance Indicators - Objective indicators of results 10. KAI Activity indicators (see Kaizen)

The combination of many tools and methodology permits to development of a sustainable strategy (5S, Safety, Reduce and Reuse Strategy, Employees Involvement, Proactive Knowledge and Compliance, Continuous improvement).

6.2 – *Application of the process O.A.A.A.I (objective-aim-analyze-action-implementation)*

The strategy of Piaggio and Yamaha is coherent with the application of standardization of the process (Liker 2005; Harata and Boden 2012). For planning for the strategy of the lean and green strategy is important to follow the O.A.A.A.I (objective-aim-analyze-action-implementation) based on five phases (table 18).

The phase for application of lean and green sustainable strategy is based on the O.A.A.A.I Process:

a) definition of Objective;

b) definition of Aim;

c) Analysis of the situation;

d) project the plan of Action;

e) Implementation.

This methodology is useful for improving the lean journey using a set of lean tools.

Tab. 18 – Process O.A.A.A.I (objective-aim-analyze-action-implementation) (Source: our elaboration from Pyzdek, 2000; Harata and Boden, 2012)

	PHASE	STEPS	STEPS
1	OBJECTIVE	Green Sustainability Strategy	Lean
2	AIM	Environmental impact reduction Reduce and reuse	Waste Reduction
3	ANALYZE	Develop a Waste Reduction Action Plan (WRAP) Assess requirements and prepare for Waste wise accreditation	SPC Process control planning Cause-and-effect, FMEA
4	ACTION	PLAN OF ACTIONS Reduction energy consumption, Landfill, carbon footprint, water consumption,	Project management Skills Knowledge discovery Establish a methodology for improvement Focus on customer value stream
5	IMPLEMEN-TATION	MILESTONES (results-date)	

The process O.A.A.A.I (objective-aim-analyze-action-implementation) is very useful for determining the strategic vision of the company and can be integrated with the PDCD cycle of Deming and Hoshin Planning (Harta and Bodek, 2012).

6.3 – *Lean and green Value Stream and Advanced TPS (Toyota production system)*

Other important tools to implement the lean and green approach are based on the model consists of the following five steps:

1) Stabilize the value stream (VS);

2) Identify environmental aspects and impacts;

3) Measuring environmental value streams;

4) Improve environmental value stream;

5) Continuous improvement (Liker, 2005).

Also, there is the implementation of an Advanced TPS (Hirohisa and Fikes, 2021; Riva and Pilotti, 2021) focus on productivity, workability, cost, and quality management integrated with many other methods and models (table 19).

Tab. 19 – Objectives, resources, and results. The main model to integrate lean and green strategy is Piaggio and Yamaha (Source: elaboration from Liker, 2015).

OBJECTIVES	THEORIES	GREEN STRATEGY	METHOD TPS
I) Reduce and reuse **II) Stakeholders' satisfaction** **III) Focus on roductivity workability, cost, and quality management** **IV) "No waste", "No stock", "No failure", "No defect"** **V) Enviromental–Social–Economic development**	**1) ADVANCED TPS Toyota Production System(TPS)** **2)Lean Manufacturing elements (LEAN)** **3)Total Quality Management (TQM)** **4)Total Productive Maintenance (TPM),** **5)Total Industrial Engineering (TIE),** **6)Just In Time (JIT).**	Increase the flexibility of the production process making it possible to meet market expectations and customer needs, Improve the quality of products, Improve processes, Constant reduction of manufacturing cost, Active involvement of workers in the improvement of processes An effective system for motivating employees.	1)Problem selection, 2)Understanding objectives, 3)Planning activities, 4)Cause analysis, 5) Defining and implementation of preventive measures 6) Monitoring of results,

Piaggio and Yamaha have in common many aspects about the integration of advanced TPS, green strategy, and lean management. Both the companies use many procedures of World Class Manufacturing (figure 5)

In conclusion, there is an impact of green strategy on the reduction of wastes (over-production, defects, unnecessary inventory, inappropriate processing, excessive transportation, waiting) and energy-saving.

The results are for an improvement of reduction of energy consumption based on the innovation of processes.

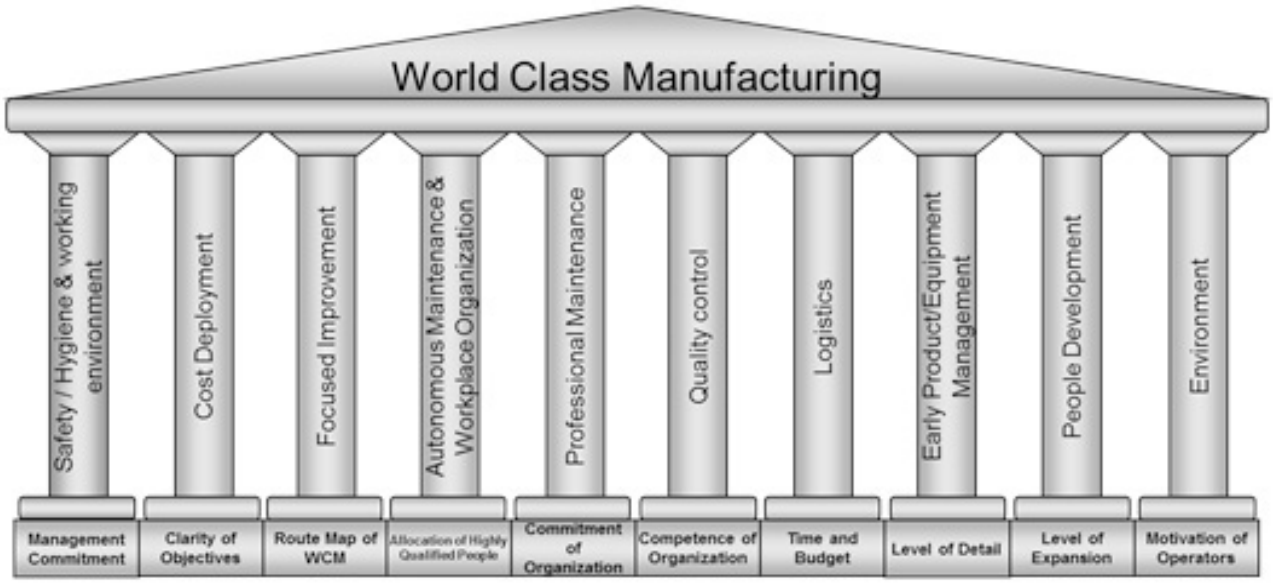

Fig. 5 – World Manufacturing and the 10 pillars (Source: elaboration from Pałucha, 2012)

7 – Conclusions

7.1 – *The importance of integration of lean and green strategy and effects on environmental performance*

About the **first question**, *"How is organized the strategy of production and lean management and green sustainability?",* we discover that:

***A – FIRST*: in both the companies there is the importance of an integrated system of lean and green strategy for sustainability (table 20). Piaggio (Piaggio, 2020a,b,c,d,; Cristofaro, 2011; Giuliareti, 2012; Caffarena, 2020; Colaninno and Gianola, 2006; Biagiotti, 2006; Mella, 2014, 2018, 2021b) and Yamaha have some differences in strategy and management. Yamaha strategy (Yamaha, 2018,2019, 2020a,b,c,d,e; Yanamura *et al.,* 2005; Brondoni, 2021) defines a long term strategy based on 2050 target and action plan; on the contrary, Piaggio focus on the product innovation and application of quality control using the "Plan-Do-Check-Act" cycle for application of ISO 14001:2015 ISO.

***B – SECOND*: in both the companies there, is the importance of an integrated system based on an evolution of advanced TPS (Toyota Production System). In Piaggio and Yamaha there are the application important elements (figure 6) based on improvement in quality, cost, productivity, and workability.

C – The answers to the first question are consistent with past studies (Caldera *et al.*, 2019ab; Mella, 2021b; Fercoq *et al.*, 2016; Chiarini, 2014; Mella, 2014, 2018; Pilotti and Riva, 2017, 2018, 2019a,b, 2020, 2021a,b; Piaggio, 2020a,b,c,d ; Cristofaro, 2011; Liker, 2015; Yamaha, 2018, 2019, 2020a,b,c,d,e; Yanamura *et al.*, 2005).

Tab. 20 – Lean nad green strategy in Piaggio and Yamaha and effects on environmental performance (Source: elaboration from Piaggio, 2020a,b,c,d ,Cristofaro, 2011;Giuliareti, 2012; Caffarena, 2020; Colaninno and Gianola, 2006; Biagiotti, 2006, Liker, 2015; Yamaha, 2018,2019, 2020a,b,c,d,e; Yanamura, *et al.*, 2005).

Lean and green strategy	Lean and green house	Lean and green tools	Effects on environmental performance
Step 1: Stabilize the value stream Step 2: Identify environmental aspects and impacts Step 3: Measuring Environmental Value Steams Step 4: Improve environmental value Steams Step 5: Continuous Improvement	**PRODUCTION** Minimize cycle time Reduce error through proof equipment	Value stream mapping Total productive maintenance 5S	Identifying environmental impacts Assessing areas to be improved
	PLAN Optimize production	Lean layout Value stream mapping Push system Pull system	Improved waste management Improved energy efficiency
	WORKER improvement initiatives	KPI Quality circles Employee engagement Kaizen events	Improved waste, water, and chemical management

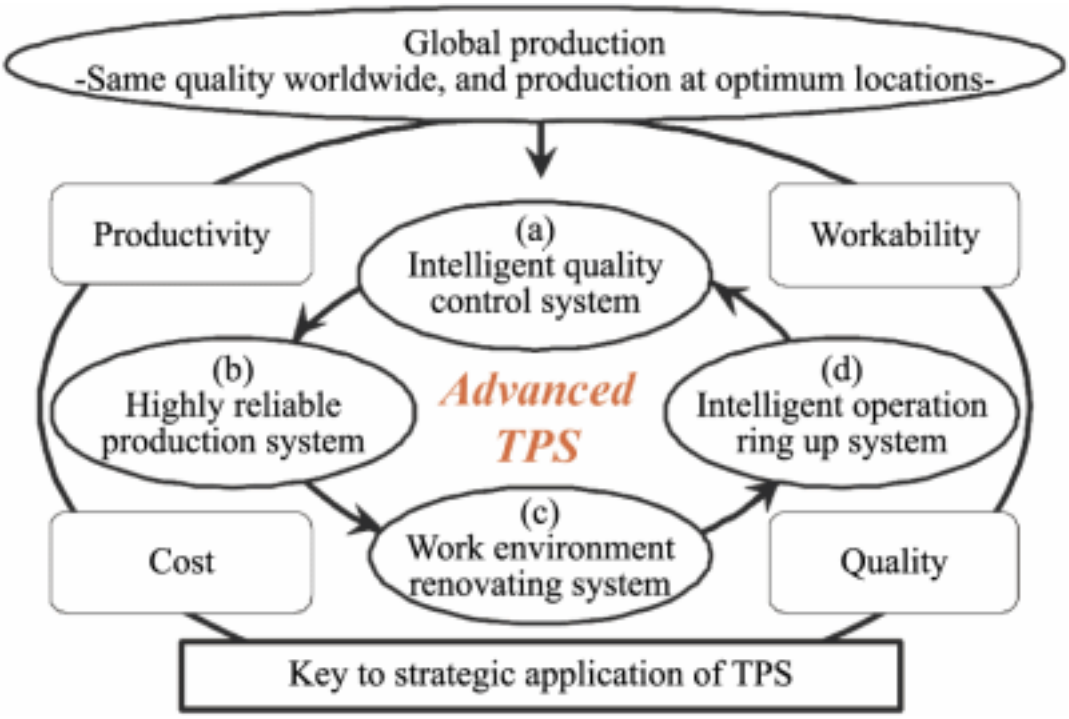

Fig. 6 – Advanced Toyota Production System (Source: elaboration from Hirohisa and Fikes 2021; http://ipezone.blogspot.com/2011/03/japans-lean-mfg-become-worlds-problem.html)

7.2 – *Benchmarking the critical success factors in Piaggio and Yamaha*

About the **second question**, "*What are the analogy and differences between the green production strategies of the companies studied?"*, we discover that:

(a) – *FIRST*: both companies focus on the integration of lean and green sustainability strategies, but there is some difference in the strategies (table 21).

(b) – *SECOND*: in Piaggio and Yamaha it is important the integration of three models (Green sustainable strategy, Advanced TPS, and lean management) based on an integrated process (table 22)

Tab. 21 – Benchmarking: based on Lean and Green House model the main difference between Piaggio – Yamaha (Source: our elaboration Cristofaro, 2011; Giuliareti, 2012; Caffarena, 2020; Colaninno and Gianola, 2006; Biagiotti, 2006; Piaggio, 2000a,b,c,d Yamaha 2018,2019, 2020a,b,c,d,e; Yanamura *et al.*, 2005; Brondoni, 2021)

N°	LEAN AND GREEN HOUSE MODEL AND CRITICAL SUCCESS FACTORS		PIAGGIO	YAMAHA
1	**Continous Improvement**	Electricity Focus on product sustainability	****	*****
3	**Supply Chain Relationship**	Management system based on the iso 14001 - 2015 standard	*****	****
4	**Green and Environmental Strategy**	New plant which produces the environmental friendly engines	****	***
5	**Proactive Knowledge**	Focus on green innovation A combustion engine and electric battery combination	****	*****
6	**Employees Involvement**	Focus on shareholders and people	****	*****
7	**Value Stream Mapping and Gemba Walk**	Focus on 5S and safety	*****	**
8	**Quality, Enhacencement and Skill Motivation**	Focus on sustainability process and technological	***	******
9	**Monitor Process Indicator**	Focus on customers	***	****
10	**Tracking the Waste Visual Management**	Develop a waste reduction action plan	*****	*****
	*low ; ****** high			

Tab. 22 – Process O.A.A.A.I (objective-aim-analyze-action-implementation and the integration of models **(**Source: our elaboration)

	PHASE	INTEGRATION OF THREE MODEL
1	OBJECTIVE	1) GREEN SUSTAINABILITY STRATEGY (environmental impact) 2) ADVANCED TPS (Toyota production system) (productivity, cost, quality, workability) 3) LEAN (waste reduction)
2	AIM	
3	ANALYZE	
4	ACTION	
5	IMPLEMENTATION	

(c) – The answers to the second question are consistent with past studies (Chiarini, 2014; Pilotti and Riva, 2017, 2018, 2019a,b, 2020, 2021a,b; Piaggio, 2020a,b,c,d; Liker, 2015; Caldera *et al*., 2019ab; Yamaha, 2018,2019, 2020 a,b,c,d,e; Yanamura *et al*., 2005; Mella, 2021b; Fercoq *et al*., 2016; Harata and Boden, 2012; Mella, 2014, 2018) .

The original contributions of this paper (highlights) are:

A *– The original description and analysis of the lean and green strategy of two international companies during the time; the comparison of the main difference between these two important international companies and benefit of integration of lean and green strategy* (figure 7).

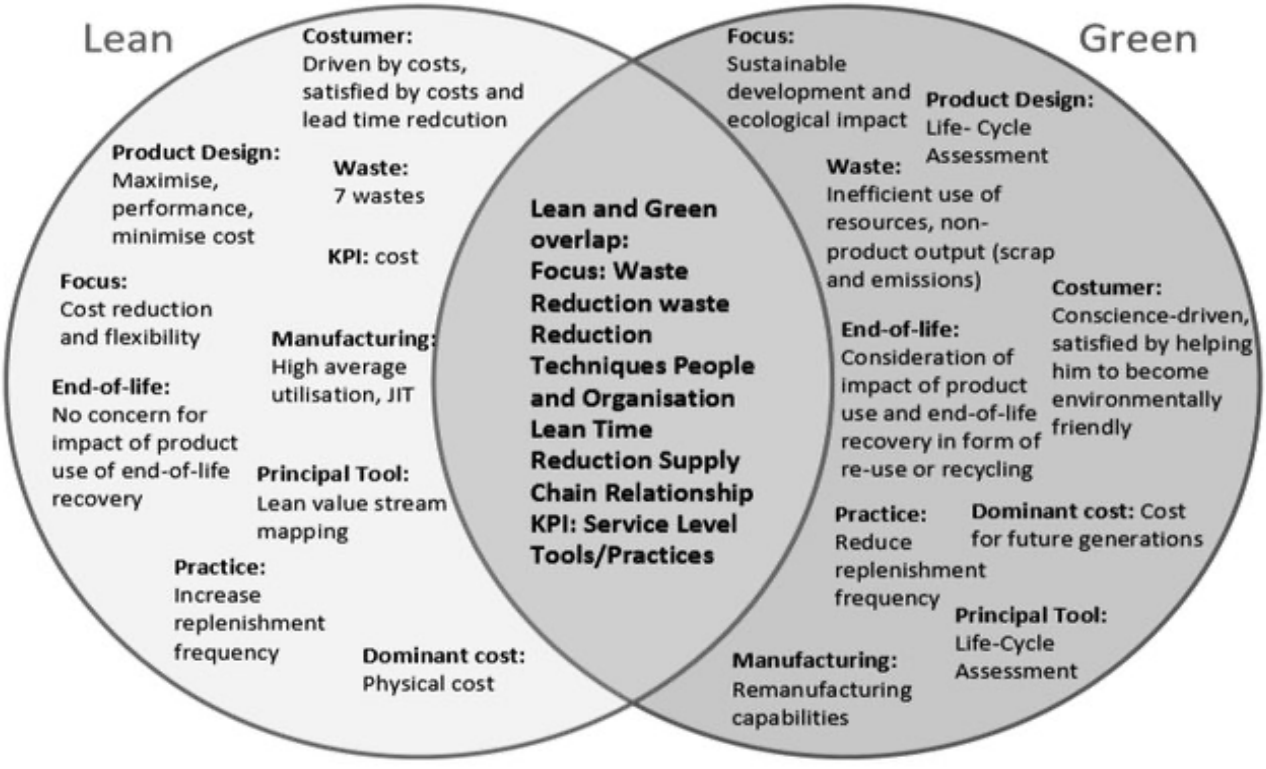

Fig. 7 – The Lean and Green integration strategy (Source: our elaboration from Mahaboob Basha, 2020)

B *– the analysis of the economic impact on energy consumption strategy based on data of environmental consumer saving in the last years* (table 23).

***C** – The proposal of a new practical framework for strategic implementation of the lean and green strategy based on these best practices.*

The limit of this study is to focus only few cases. Further research can analyze the other companies in this sector. In conclusion, Piaggio and Yamaha motor are focused on the integration of best practices in lean and green strategy for a long-term sustainability strategy.

Tab. 23 – Integration of green and lean and WCM (Word Class Manufacturing) (Source: our elaboration)

DIMENSION	LEAN STRATGEY AND GREEN	WORLD CLASS STRATEGY
PRINCIPLE	General organization to reduce wastes and green strategy	10 technical pillars and 10 managerial pillars, with further 7 steps
PRODUCTION	Sustainable strategy	Cost deployment
QUALITY CONTROL	No Value Adding Activity (NVAA) and Life cycle assessment	"Zero defects"
MEASUREMENT	Limited number of KPI (Key Performance Indicators), measurements made very often, with results shared with the rest of the company through a visual control system	High number of KPI, but with a centralized control system of the measured parameters
STRAGEGY OF CHANGE	"Bottom up" approach	"Bottom up" approach, taken by following the 10 pillars
MOTIVATION AND ORGANIZATION	Leadership	Discussed in a systematic way in the managerial pillars
STRATEGIC EMPHASIS	Continuous improvement in personal development perspective, and as a tool for reducing waste	Every action and business decision must be aimed at achieving global excellence
TARGET	Drastic reduction of waste, creation, and flow of value	Zero waste, zero defects, zero stocks, zero failures

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