The CACTUS approach: Organizational approach for sustainability

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Abstract: Smart Manufacturing acts on production systems performances while applying data identification, relevance selection, hierarchy categorization in a technology-driven approach. It makes use of computer integrated systems and information technology and sensors to enable plants while - in an Industry 5.0 perspective - promoting sustainable and human-centric workplace. In this work, we present a conceptual approach (named "Cactus") that utilizes smart manufacturing and industry 5.0 logic on unconventional plants. The Cactus approach aims at developing a safe, sustainable and adaptable workplace for both small, medium and large factory units in the fast-paced market. Like the cactus adapts itself to live in the driest areas of the world accumulating and reducing the water consumption, and uses its spines to defend against herbivores, the smart Cactus approach reduces the utilization of resources achieving sustainability and minimizing the negative impact on environment through disassembly of EoL products, remanufacturing and recycling while, at the same time, protecting operators from accident and injury. This approach requires collaboration between human and robot to make the production environment safe and effective, integrating human flexibility and robot precision and repeatability. The adaptability and resilience are achieved by utilizing sensors, interoperability and collaboration for flexible and rapid changes in the workplace, following the needs, and changing requirements of the market. The communication is important as it connects the operations management with direct and reverse logistics and with customers. The transparency at the workplace plays significant role for the plant, the human operators, managements and customers, as all the agent involved understand the management vision, operation rules and the fluctuations in supply chains, empowering also the digital skills of the operators. The usability of systems is improved by utilizing sensors and artificial intelligence to increase reliability with forecasting and continuous optimization of both technical and social parts of the workplace environment.

Keywords: sustainability; adaptability; communication; remanufacturing; transparency.

I. INTRODUCTION

The advancement and development of tools and methodologies derived from Information Technology heralded the fourth Industrial revolution (I4.0). Internet of Things (IoT), cyber physical systems (CPS), cloud computing and storage, and advanced collaborative robots (cobots) are some of the tools and methods integrated into industrial units for faster production and services. Those tools allow decentralization and interoperability which in turn provide flexibility and robustness. Moreover, they allow a system to adapt to the business environment and market demands. With Industry 4.0, the concept of sustainable development was introduced to understand the process of adaptation to the market. However, despite the benefits that can be gained through I4.0, research has been lacking on the impacts, positive or negative, that those technologies can bring into economy and society (Felsberger et al., 2020). Human resources and human factor, affected by technologies, is an overlooked aspect in I4.0 research (Neumann et al., 2021). In early 2021, a new framework was introduced encompassing the I4.0 technologies with extended factors. Industry 5.0 (I5.0), proposed by the European Union, complements and extends I4.0 by including environmental and social factors; circular economy and human-centric collaboration. In this context, a sustainable development approach, where all sustainable pillars are investigated equally, could provide advice for business management and strategic directions on how to benefit from smart technologies implementation in the fast-paced market environment, while encouraging growth and productivity.

Before addressing what a sustainable approach should entail, sustainability and management basic ideas are addressed. Sustainability refers in the ability to continue over a long period of time (Kjaerheim, 2005). Furthermore, it is conceived of in terms of three pillars or dimensions, the environmental, economical and social [Purvis et al., 2019]. Thus, sustainability can be achieved when those three pillars are equally managed (fig. 1). In

recent and future societies, there are several difficulties that need to be addressed, such as climate change, overpopulation and ageing workforce, supply, raw material and energy consumption and lack thereof. As such, organizations need to adapt in order to achieve sustainability and continue to grow. In general, management sets the strategy of the organization, and coordinate the agents to achieve the goals based on the resources they have (be it financial, technological, human resources, natural, and also information and data collected from market research and communication with customers). In order to achieve sustainability, organization, both in practice and research, can benefit from readjusting their model in order to adapt to the changes based on the I4.0 and I5.0 frameworks, technologies and information gathering.

By mimicking nature, we are able to learn and foretell about success and failure (Celep et al., 2017). The comprehension of the basic principles of biology offers the problem-solving attitude of optimal "adaptative" initiatives (Yazici, 2020). Ants, bees, whales and genetics (rather than swarm) and artificial intelligence is used whenever optimisation is required. Dragonfly and its four wings direction is known to be a source of inspiration for drone controlling. Bumblebees remarks the importance of common intelligence and communication. Amoeba underlines the importance of adaptation in organization. Nature, in synthesis, gives industrial practitioner the enablers for the systemic approaching at an efficient arrangement. In that regard, the cactus plan can offer insights on achieving sustainability.

Cactus evolved spines instead of leaves for water preservation which, along with the main body, are covered with areoles and thorns. Despite those adaptations, they retain the ability to absorb natural sunlight for photosynthesis. However, photosynthesis is performed at night, when the temperature is cooler to minimize water evaporation. The thorns have a dual purpose as well; they protect the cactus from external threats, while also creating shade areas to capture the morning fog and water evaporating from the cactus. The main body along with the spines have a spherical shape, and thus surface area is reduced but remains interconnected. The spherical shape and the thick skin that they have, maximizes the storage area and also protects it. It's roots are close to the surface to collect water, while it has the ability to grow roots quickly when there is a lot of water, due to rains, and will "cut" them off when the water stops. The cactus has a growing season, which happens when the environmental conditions allows it while when there is drought it stops growing to conserve water.

The cactus approach acts as an unconventional plant. It utilizes digitalization technologies to provide ways for enterprises to improve their capabilities and production methods, maintain direct communication with the customers, while also aiming in development strategies towards sustainability. However, due to the fast-paced market and customer demands for services and products, organizations sustainable should be flexible and adapt to social, environmental and market demand changes, to achieve sustainability. In this paper, a conceptual approach is developed by utilizing the mechanisms of cactus to adapt, sustain itself and grow. This approach aims towards sustainability and adaptation, through the use of I4.0 technologies and the I5.0 framework.

II. ANALYZING SMART PLANTS

A. Sustain the lean frame

Lean production, or just-in-time production, was introduced as "The Toyota Way" in 1930 in Japan [Ohno and Bodek, 2019]. As a system it aims in using less of an input, by minimizing waste, to generate the same amount of output, while offering more customization (Womack et al., 1990), thus adding more value from the customer point of view (Jadhav et al., 2014). Vinodh and Chintha, 2011, stated that underutilization of creativity of the workforce is considered a waste as well. In that regard, minimizing environmental waste should be included as a strategic objective, as it lowers the environmental impact while adding value from the customers view point. This aligns with the sustainable development scenario which is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987; Hult, 2011). In this scenario, sustainable manufacturing should aim at integrating means and objectives to fulfill all of the sustainability dimensions, namely economic, environmental and social.

Lean manufacturing (LM) frameworks and drivers have been evolving across literature since 1960s. Notwithstanding, Scopus database reports that following the key words: "lean manufacturing framework" or "lean drivers", respectively, 14 and 4 papers appears from 1989. Drivers selection evolves from the effective utilization and management of resources, inventories and workforce, continuous improvement, process and product focus and standardization, planning and mapping and control the supply, alignment and satisfaction of customer, process control and scheduling, time and quality and cost and service management. Those have to be mapped based on rules (Mostafa et al., 2013) for a successful implementation. Roadmap, conceptual, descriptive and implementation framework, guidelines and assessed checklist are the common terms (we found 34 initiatives evolving from 2009 until 2021) that

literature uses to support successful lean implementation. However, Baker (2002) reported that in UK less than 10% of organization are able to support lean strategies. This is attributed to "cultural" (Atkinson 2010) and resisting changes (Bhasis 2012) issues. Straight and strong roots are the major successful elements (mainly indicated as high and low performance ones) for LM implementation (Borlotti et al., 2015). Lean plants require complex - but clear – drivers based on soft and hard "skills" (Shah and Ward, 2007). Organisational culture (Jung et al. (2009), linkage to performance and dynamic contingences (Agarwal et al., 2013), powered operational rules (Mackelprang and Nair, 2010), and attention to humans (Batemann 2005) require involvement (more than investment) in lean adopters. Those sustain the perception, and then implementation, of green initiatives based on lean strategies according to Technical enablers as per the social growth.

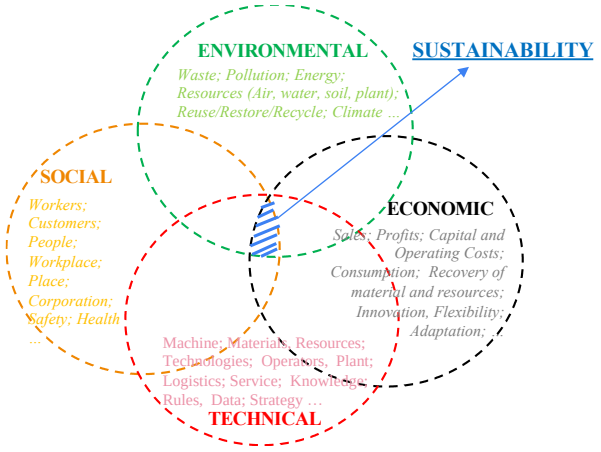

Fig. 1. Achieving sustainability requires all three dimensions (Environmental, Economic, Social). Technical dimension can be utilized to achieve and support it.

Integrated lean-sustainable systems can improve operations and ecological footprint, through processes that eliminate waste both ecologically and economically and through improving social performance. Langenwalter, 2006, studied lean manufacturing concepts integration with sustainable manufacturing, while Herrmann et al., 2008, investigated the relationship between those two systems. Verrier et al., 2014, proposed green and lean indicators to include environmental and social considerations for lean practices. Chiarini, 2014, proposed a general model for green lean production, while Prasad et al., 2016, investigated lean and sustainability systems in terms of applicability for business performance measures. Ruben et al., 2018, in their study provide knowledge on how to implement lean and sustainable concepts in a business scenario.

B. Industry 4.0 and sustainability

Industry 4.0 focuses on interconnectivity and smart automation through the rapid change in technology use of enterprises, industries and society. This is made possible by internet of things (IoT), cloud computing and storage, big data analytics and artificial intelligence (AI) among others (Philbeck and Nicholas, 2018). Interconnection and modularity for networks and communication both with robots, sensors and devices but also with people. Transparency in data and information for decision making support, assist in identifying areas to strengthen or benefit by increasing functionality. There is also the technical side, where human operators are assisted in decision making and problem solving through machine learning and artificial intelligence, and through robotics handling difficult or unsafe tasks. Finally, decentralized decisions through the support of cyber physical systems, that can aid in flexibility and quick adaptations, made easier through transparency in goals and objectives. Those themes along with digitalization aided in the improvement of predictive maintenance techniques, additive manufacturing, smart industries and through smart sensors, support agriculture and food industries.

However, despite the advantages, challenges and problems in implementation exist. The high economic cost of implementation and unclear economic benefit, hinders the adaptation of business models in using their full extent. On the social side of things, privacy concerns are a major issue due to fear of personal data and distrust. The loss of jobs due to robotics and automatic processes taking the roles of human operators (Birkel and Hartmann, 2019) is raising the distrust in robotics which along with lack of regulations and certifications hinders implementation as there are non-defined legal issues and concerns for data security (Birkel and Hartmann, 2019). In the organizational side of things, lack of commitment to change and lack of skill sets and training required for the transition and integrity of processes along with the issues on reliability and stability of communication internally and externally and lack of cybersecurity protocols, are also hindering the implementation.

The I5.0 framework aims in overcoming those issues by proposing the use of I4.0 framework in a sustainable, resilient and human-centric focus (Xu et al., 2021). It aims in sustainability in all three dimensions, focusing in a resource-efficient sustainable industry through circular economy (Fraga-Lamas et al., 2021), while empowering businesses to be competitive. It aims in sustainable energy consumption and value chains that can be resilient in external shocks and crisis. And it aims in a human-centric (Lu et al., 2022) approach through two dimensions: (i) digital technologies and AI, and (ii)

retraining and support in acquiring the necessary skills for human workers.

C. *Cactus adaptability traits*

Cactus is a well-known plant that live in areas ranging from humid to extremely dry environments. As such, they evolved traits that assist them in surviving extreme situations. The plant stems still conduct photosynthesis, although the process is being done at night for lower temperatures while preserving water. The process is regulated by the stomata in the stems that has clockwork like properties; they open at night and close at day. They are small in size and deep in the tissue and not close to the surface. The cacti plants have developed spines instead of leaves, that act as buffers, creating shade and trapping air and evaporated water around the spine. The spines are also helpful as they collect moisture from fogs; the collected moisture drips into the ground where the cactus roots, developed to grow short and near the ground, collect the water and nourish the plants. Moreover, spines, as well as the central branch, have thick skins and a spherical space that provide more water storage space and protection from evaporation.

The cacti plants and their spines are covered in needles which cover the surface area and serve a dual purpose. They create shade and prevent loss of water by trapping the water evaporated from the plant, and they act as preventative measures against herbivorous animals from eating the plant. The plant has a waxy skin which covers the surface except the stomata to avoid water evaporation, but also aids in keeping the plant cool in hot and dry climates. Finally, cacti grow when the external environment permits, using the water they have in storage, while when drought periods start the growth pauses; this keeps cacti alive for a larger period of time.

III. CACTUS PERSPECTIVE AS A BUSINESS APPROACH

In this era of digitalization and rapid technological advancements, people have open access to everything that research and businesses can offer. This allows them a wide range of product options and services, which are constantly updated due to the advancement of technology. Fast decisions through data communication, feature extraction and big data analytics (Sony 2020). IoT with horizontal and vertical integration can be used to create transparent, predictive and adaptable manufacturing systems (Tabin et al., 2021). Simulating virtual contexts may assess predictability of optimal assessment in the ever-increasing complexity and ever shortening lifecycles of product, process and system domain (Yildiz et al., 2021). Using resources in a make to order perspective while reducing movements and shipments and responding to customers' needs are the fundamental of an additive technology (Leino et al., 2016). However, ocial awareness, ecological sustainability, energy consumption are some of the issues that needs to be addressed for sustainable development. This section discusses the lessons that can be learned from the cactus plan and how to use its mechanisms and traits for a management plan aiming at sustainability and quality products and services (fig. 2).

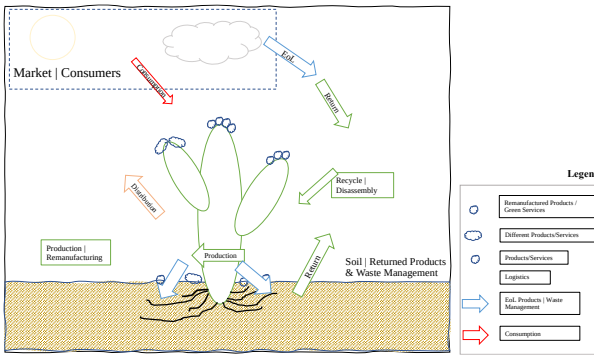

Fig. 2. CACTUS perspective as unconventional Smart Frame

A. *Environment – Business World*

In nature, cactus can survive in harsh and dry environments by utilizing all its parts to collect water from every source it can, perform photosynthesis, survive while also being able to grow when it meets the requirements. In the consumer world, due to digitalization, organizations and enterprises compete in a fast-paced market environment where most resources are finite, customers' needs and demands are changing and where a single crisis can affect the survivability of both customers and businesses, as shown by the COVID-19 pandemic. Those variables are connected to the harsh environment, where sun and water represents the resources and market conditions, while the herbivores that threaten the cactus plant can be represented by cyber threats and turbulences in the market. However, when the environmental conditions are suitable, they can enable business growth, offering new services or products or by growing their organizational or logistical structure.

B. *Realizing the business goal*

In general, the goal of a business should be sustainability in economic, environmental and social, both customers and human workers, aspects while also providing quality products and/or services. To achieve those goals, the strategy should involve use of technological advancements (including services, software and robotics), collaboration between agents, optimal use of human, operational and natural resources, a network of collected information and data, and also be adaptable and flexible to the changes and turbulences that will affect their survivability. Here we present the CACTUS

approach for sustainability, where its initial indicates collaboration of entities, adaptability to any factor, continuous communication connecting the business with the market and with its human operators, transparency in objectives and decisions, promoting usability of systems and finally, exercising safety measures to self-protect. Furthermore, all human entities need to learn and have knowledge of the tools and technologies that are used or will be used in the future, to safeguard production or offering services by avoiding human-system errors and lack of knowledge in decision making.

C. CACTUS approach

Having set up the basis with the cactus connections, environment and business goal, the approach is now introduced. A summary of the link between cactus, cactus approach, smart technologies and sustainability focus can be seen in fig. 3. The cactus traits and features serve different interconnected roles, sometimes contributing in multiple functions, in order for the plant to sustain itself. There is interaction with the environment, by acquiring resources or protecting from extreme environments, while also serve an inside role to the organization of the cactus itself. The role of a business is to offer a service or a product and to be sustainable. In order to achieve that it needs energy resources, which can be drawn from renewable energy sources, similar to the stem of the cactus, thus promoting environmental sustainability and minimizing the ecological footprint. Solar panels to collect sun energy, thermal power from earth heat, wind energy sources, hydropower from flowing water and even biomass from plants are energy sources that can be utilized to lower the dependence on fossil fuels and sources that can harm the environment; the turn to renewable energy sources while needing an initial financial investment, in the long run it will minimize energy expenditure. Use and reuse of natural sources can be also applied. Furthermore, as the stems accumulate and store water, organizations can accumulate resources for production; those materials can be also returned End of Life (EoL) products for re-use, remanufacturing and recycling.

The CACTUS approach utilizes the ability of the cactus plant to reduce exposure to harmful situations while protecting the inside part, by being flexible and fitting its managerial and productive practices, allowing the minimization of the resources used and exposure to outside interference. Cactus also has hierarchical groove structure, channeling the watering through an accordion system. In our approach, organizations, be it small-medium or large industries, can benefit from adopting agile procedures. In this way, transparency can be achieved through quick communication, top to bottom and reverse, and clear objectives and strategies while also being able to be prepared and quickly react to internal and external factors, through sensing, forecasting and cybersecurity, by adapting its operations and procedures further improving economic sustainability. In this area, machine learning and digital twins can be used for forecasting and preventive measures, through simulations and data analysis of data gathered from exterior and interior sources. Moreover, following the roots' ability of the cactus, an organization can benefit by interconnectivity and digitalization to be closer to the end customer and global circumstances in order to be sensitive to sudden changes and demands. Close communication with customers through direct communication with representatives, allowing customers to know the objectives of the company, probing with qualitative methods on new opportunities can support sustainability. As such, in case of extreme conditions, turbulence or economic growth, connections with the market and financial entities should create a network from which the organization can both stay alert react to changes, thus being able to benefit from reacting early.

Furthermore, as the cactus has spines that serve multiple roles, an organization using the cactus approach can use smart technologies for multiple purposes. Use of sensors and CPS can alert and provide information on process involving operations management entities to improve reliability and quality. Artificial Intelligence can be used for preventive maintenance purposes and forecasting. Digital twin can provide information on production and workplace environment, by simulation, to increase safety and minimize waste, while the use of physical-driven digital twin can be used to improve preventive maintenance procedures. Moreover, it aims to improve the company's measures towards market and material supply fluctuations, serving a dual purpose. Firstly, it protects itself in relation to raw materials through the recovery of components from EoL products, by utilizing remanufacturing processes and connection to the market, and in relation to finished products by efficient communication with logistics and commercial channels.

In terms of safety, the cactus approach aims in bolstering cybersecurity, to protect the organization and its personnel, and the customers from malicious attacks in its digital infrastructure, preserving its social structure and connections. At the same time, it works towards providing a safe environment for its human operators in all stages of production and service offering. Robotics and artificial intelligence are utilized for human robot collaboration by protecting the operators from fatigue and/or dangerous operations, while also adhering to human factors and ergonomics (HF) for safe practice. Entropy evaluation of the collaborative environment can provide insights on how to improve the workplace and support human workers (Panagou et al. 2021). It offers

training, re-skilling and up-skilling to its operators, to stay in touch with new technologies to be used inside the organization, but also to improve productivity and quality by improving (re-)assembly processes, thus, maintaining its competitiveness and edge in the market.

Organization Aspect	Cactus trait	Technology - Methods	Purpose	Sustainability
Product - Services	Roots	IoT – Agile	Information on market changes - Customization	Economic
Energy	Stem	Renewable Sources	Eco footprint	Economic - Environmental
Production resources	Stem	Direct & Reverse Logistics - Lean	Raw material – EoL returned products	Economic – Environment – Social
Production	Spine	CPS – Digital Twin	Minimize waste - safety	Economic – Environment – Social
Supply Chain	Spine	Digital Twin – ML – information and data mining	Connection with customers – EoL products	Economic - Environmental
Crisis management	Roots	IoT – data analytics – forecasting – Customer communication	Market turbulences and crisis avoidance	Economic
Strategy & Objectives	Structure	Agile – CPS – ML – Digital Twin	Transparency and flexibility	Economic - Social
Decision making & communication	Structure	IoT – Cloud Infrastucture	Transparency	Economic – Social
Production	Stomata	Robot/Cobot	Human-centric	Economic - Social
Maintenance	Areoles	AI – Big Data analytics	Forecasting - Predictive	Economic
Recycle - Remanufacture	Stomata - Roots	Reverse Logistics	Circular economy	Economic - Environmental
Security	Needles	Cybersecurity	Protection of data	Economic - Social
Safety	Structure	Human Factors/Ergonomics – I4.0 & I5.0 frameworks	Human -centric	Social
Maintenance	Spines	ML - AI	Avoid downtime in production	Economic

Fig. 3. CACTUS Approach - Linking organizational aspects with smart technologies and sustainability focus.

IV. Conclusions

As digitalization with robotics and artificial intelligence are establishing themselves in production and services, while bolstering competitiveness, it is essential for organizations to utilize them to stay competitive. Implementation of those methods comes with several challenges if an organization aims to be sustainable. However, for sustainability to be achieved, measures should aim in satisfying both three dimensions, economical, environmental and social. In line with Industry 5.0 framework, which promotes Industry 4.0 technologies in a sustainable and human-centric environment, our conceptual proposal draws from nature and the cactus plant. As the cactus plan has features and traits that allows it to be sustainable in even extreme conditions, the CACTUS approach utilizes an organization's structures along with the tools and technologies of Industry 4.0, aiming towards sustainability. Economical sustainability, through transparency and adaptation; Agile principles add flexibility in how organization operations and reacts to market fluctuations and customer demands. Use of technological tools, such as machine learning, AI and Digital Twin for simulations, aiming at preventive maintenance and forecasting. It gains Environmental sustainability, through the use of recycling, remanufacturing and lean principles. And, It reaches the social sustainability, by staying connected with its customers and open communication, all the while practicing safe methods to protect its customers from malicious intent and its operators inside the organization.

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