**PhD in Technology, innovation and management - TIM**

**Definition and multi-level sustainability assessment of servitization opportunities in the steel sector**

By Mattia Galimberti

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### Introduction

Recently, worldwide Nations’ governments have recognized the need for prompt measures to tackle climate change. For instance, the European-Green Deal launched a new EU growth strategy to achieve climate-neutrality by 2050. The iron and steel industry, in particular, is paying close attention to this decarbonization issue, since it ranks first in CO₂ emissions, and second in energy consumption.

To remedy this situation, steelmakers are currently focusing on optimizing the production process in terms of carbon emission and energy consumption. In addition, the focus is on the development of new technologies potentially ground-breaking, that could be easily adapted to cut CO₂ emissions, for example, the adoption of hydrogen for the reduction of ore alone. An alternative strategy that might enable the sector to reduce its environmental impact could be the increasing adoption of servitization solutions. Indeed, many authors have already pointed out that a shift from the sales of products to the provision of services may be to reduce resource consumption by incentivizing companies to adopt more sustainable business models.

Discussing the adoption of servitization, it is necessary to take into account sustainability when assessing the different solutions, because it is essential to find answers to the problem that bring advantages not only from the environmental point of view but also from the economic and the social perspectives. According to the triple bottom line definition, being “sustainable” means expanding the traditional focus of businesses and organizations seeking at the same time the enhancement of economics, environment, and social dimensions.

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### Literature gaps identification

Steel companies are not fully aware of the benefits that might result from changing their business model, nor do they know precisely which are the steps to follow.

A literature analysis shows that the steel sector is quite backward from the servitization point of view.

In particular, there is a gap in the currently available methods to assess the product-service solutions related to steel production technologies from a sustainability perspective.

A number of models already exist to assess servitization opportunities at an early design stage, but most of these either are not easily applicable specifically to the steel sector or do not take the three sustainability dimensions into account. The formulation of such a methodological framework for the steel sector would therefore be strategically useful in boosting the adoption of sustainable servitization business models in this specific industry.

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### Framework methodology

In the first phase, the main experts in the field (e.g., sales engineers) are involved, since they can tell what the customer would accept and which are the technologies that could be object of the study. Similarly, in the second phase, a literature review is conducted, with the aim of assessing which parameters are usually used, in other sectors, for evaluations of this kind. The extensive list of criteria obtained will then be submitted to experts in the steel sector, who select the most relevant for evaluating sustainability in the sector and assign a weight to them.

Then, in the third phase, the evaluation methods to be used will be defined. It will be necessary to associate at least one evaluation method with each criterion.

At the end of the first level of evaluation, the most promising technology for achieving improvement in sustainability through servitization will be defined.

The second and third levels are addressed in a similar way to the first. In phases 4 and 5, scenarios are defined from interviews with experts in the field. For the second level, scenarios will be tackled, thus including different levels of servitization for the technology defined in the first level. For the third level, scenarios will include different operational conditions to be evaluated.

For the fourth level, criteria definition is phase will take place by specifying the wide list of criteria selected during phase 3. Likewise, starting from the more specific criteria from phase 4, a narrow list of criteria will be defined for phase 5. For these phases, the contribution of experts in the sector will be determinant.

Finally, phases 6 and 7 will help to determine the most correct evaluation methods for the criteria or KPIs defined in the previous steps, through a literature analysis.

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### Preliminary results

**Servitization of the slag granulation process**

The first selected servitization opportunity is about slag treatment. During steel production, two types of slags are generated: white slag and black slag. If these cool too slowly, they result in materials harmful for human health.

Tenova has developed a technology capable of rapidly cooling the slags, preventing the release of toxic substances into the environment and facilitating their transport.

The idea is to sell the slag treatment instead of the physical technology.

**Roll shop servitization case**

The second selected servitization opportunity is about the grinding of the rolling cylinders. During rolling operations, rolls are subject to friction and forces that cause surface wear. After a certain number of cycles, grinding of the rolling cylinders becomes necessary. At the moment, Tenova is selling machines capable of grinding cylinders.

The idea is to sell the grinding operation instead of the physical machines.

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### Sustainable servitization opportunities assessment framework

<table>
<thead>
<tr>
<th>Strategy (Business Model)</th>
<th>Criteria</th>
<th>Servitization Method</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opportunities definition.</td>
<td>Sustainability criteria definition.</td>
<td>Business model evaluation methods definition.</td>
<td>Definition of the most promising servitization opportunities (understand what to servitize).</td>
</tr>
<tr>
<td>Scenarios (Business Process)</td>
<td>Sustainability criteria (narrower list).</td>
<td>Evaluation criteria (narrower list).</td>
<td>Definition of the best servitization opportunities (understand what to servitize).</td>
</tr>
<tr>
<td>Economic, environmental, and social advantages not only from the environmental point of view but also from the economic and the social perspectives.</td>
<td>Evaluation criteria (narrower list).</td>
<td>Evaluation criteria (narrower list).</td>
<td>Definition of the best servitization opportunities (understand what to servitize).</td>
</tr>
</tbody>
</table>

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### Expected results and contributions

At the end of this methodological process, it will be possible to show the company which technology to choose, the level of servitization to adopt, and which operational parameters to employ, in order to achieve improvement in sustainability with the adoption of servitization.

This multi-level assessment methodology could then be easily adapted to other sectors, different from steel, thus allowing the best servitization opportunity related to the specific case to be selected and evaluated.
PhD program in Technology, Innovation and Management

Definition of a method to support the decision-making process of an orthopedic surgeon by means of 3D Modeling and Motion Capture techniques

PhD candidate: Anna Ghidotti
Supervisor: Prof. Daniele Regazzoni, Prof. Miri Weiss Cohen

CONTEXT

3D Modeling and Motion Capture systems are two powerful techniques in the orthopedic field, to support the surgeons in their decision-making process. Virtual 3D models, obtained through a segmentation process from DICOM images, provide an accurate representation of the structures of an anatomical district. Morphological analysis of the 3D model is a potential tool for understanding the patient’s anatomy and his/her characteristics. Starting from the 3D reconstruction, it is possible to correlate the morphology to an injury, identifying the risk factors, or study the morphological impact on the choice of the surgical strategy. In the meanwhile, Motion Capture (MOCAP) systems allow to acquire the movement. Human movement analysis can help in identifying pathology, assessing the efficacy of an operation or rehabilitation.

AIM

The main aim is to define a method to support the decision-making process of an orthopedic surgeon by means of these two techniques, 3D Modeling and MOCAP. The secondary aim is the creation of a database with morphological parameters to assess the risk for injury.

PROPOSED APPROACH

The present PhD research proposal is based on the integration of 3D Modeling, Motion Capture (MOCAP) and Clinical Data.

1 3D MODELING

Machine learning techniques are employed for automated segmentation to overcome the limits of manual segmentation of the knee. Two CNN models U-Net and SegResNet are trained and hyperparameters (epochs and learning rate) are optimized. The performance is measured through Dice Similarity Coefficient and Hausdorff distance.

Morphological parameters are identified to distinguish between healthy and pathological conditions, e.g. shoulder rotator cuff injury and osteoarthritis.

Ad hoc modules are developed for quantitative assessment both for shoulder and knee compartments. Morphology is studied for shoulder instability and anterior cruciate ligament lesion in the knee.

An automatic methodology to design customized knee prosthesis is defined to overcome the limits of standard off-the-shelf prosthesis. Different scenarios are modeled and simulated by means of FEA to understand which is the most suitable combination of parameters for a customized prosthesis.

2 MOTION CAPTURE

Gait analysis is used to quantitatively assess the Trendelenburg disease in patients undergoing total hip arthroplasty (THA). A THA specific model of short-term gait change is developed to investigate how the gait domains are affected by surgery. The differences among the surgical approaches in the short-term are studied.

A tailored rehabilitation platform for shoulder motor function recovery is developed. The reference movement is recorded by means of Azure Kinect sensor and it is compared with the injured shoulder. Serious games are used to increase the patients’ engagement in shoulder rehabilitation.

3 CLINICAL DATA

The main result is a method, which can be applied to real cases. Its application in clinics, thanks to the collaboration with Humanitas hospitals, allows to validate and refine it. 3D Modeling and MOCAP systems can support the surgeon to get a clear view of the patient and a feedback of the surgery.
Real-time Framework for Ergonomics Evaluation in Industrial Collaborative Workstation

PhD Candidate: Daniel Lanzoni
Supervisor: Daniele Regazzoni Co-Supervisor: Manuel G. Catalano, Andrea Vitali

Context
The increased ease of use and the improvement of industrial robotics open to new innovative solutions based on cyber-physical systems. The collaboration between the operators and the collaborative systems in a shared workspace improves the quality and working conditions, increases the productivity and decreases the production costs. The introduction of these systems in industrial tasks requires innovative methods and tools to evaluate and optimize the Human-Robot Interaction (HRI) starting from the humans’ safety, ergonomics and acceptance.

Aim
The research work proposes a software platform to design, analyze and eventually simulate the work processes based on human-robot collaboration (HRC) to make the interaction as ergonomic and safe as possible and to reduce production costs and time (Fig. 1). The evaluation of working conditions is based on both the physical and the cognitive ergonomics and provides useful tools for workstation design and evaluation.

Workstation Design in Industrial Use Cases
The proactive approach is more economically favorable as it involves identifying and addressing potential ergonomic issues during the design and planning phases of the production system. Simulation tools are needed to simulate the tasks before the final implementation of the workstation. Combining the evaluation of the ergonomics and the design of the workstation is possible to obtain the optimal solution in terms of working conditions. In figure 2 are depicted two use cases: machining (Elettrocablaggi S.r.l.) and assembly (laboratory test) tasks.

Workstation Evaluation in Industrial Use Cases
The greatest mistake toward Musculoskeletal Disorders (MSDs) is to ignore them and wait for people to get injured before intervening. When the workstation already exists, it is advisable to take prompt actions for ergonomic assessment, rectifying any mistake during the process. For a more accurate, objective, and real-time evaluation, motion capture tools and Digital Twin can be exploited. This approach, referred to as reactive, proves valuable for unexpected situations and for continuously monitoring the ergonomic well-being of the operator, both physically and mentally. In figure 3 is shown the use cases analyzed: drilling (Elettrocablaggi S.r.l.), logistic (Brembo S.p.A.) and teleoperation (Fasi Gru S.p.A.) tasks.

Preliminary Results
Technologies such as Motion Capture systems, Mixed Reality, and Digital Twins enable the evaluation of physical ergonomics, resulting in time savings compared to traditional observational methods of about 30%. Also, using optical systems, an additional time savings of approximately 40% is expected. The results demonstrate a more objective and accurate assessment that can be conducted remotely. Furthermore, initial tests on cognitive ergonomics have been conducted using both traditional (questionnaire) and innovative methods (Machine Learning algorithm, ML). Using ML algorithm, is required the monitoring of physiological signals by means wearable device. Preliminary results show an accuracy of the model used to estimate the stress condition of about 97%.

Other Works

Contacts
Motivation and Objectives

Soft actuators are the core part of any soft robots, they are responsible for motion and manipulation. Soft actuators have many good characteristics (e.g., softness, flexibility, environmental-friendly design, low cost, etc.), however, they suffer from the capability to support low payloads and exert low forces. This is the main reason why we are interested in the design and development of soft actuators.

Furthermore, there are no guidelines in the literature for the design, prototyping and testing of soft actuators with enhanced capabilities. For this reason, the main aim is to define a methodology that can be applied to soft actuators in different use cases with a particular focus on sustainability issues.

The main objectives are:

- to develop concepts of soft bending soft actuators with enhanced capabilities;
- to define a methodology for test of performances (bending angle, blocked tip force, stiffening capability and suction cups detachment force) and sustainability (energy consumption).

Methodology

Design

The PneuNet with vacuum suction cups actuator is made of:
1. main body;
2. middle layer;
3. bottom layer;
4. embedded suction cups.

All the parts are made with silicone material (Smooth-On DragonSkin Medium 10).

The main body is made up of a series of channels inside an elastomer. These channels inflate when pressurized and this, combined with a greater rigidity of the bottom layer compared to the main body, causes the motion. The suction cups, instead, are actuated by vacuum to ensure a firmer grip on the objects.

Experimental and Simulated Tests - Performances

Bending test [1]

Blocked tip force test [2]

Stiffening capability test [3]

Suction cups detachment force [4]

Simulations

Comparison between (x,y) position of the center of each PneuNet chamber: FEM simulation and real deformation as the input pressure changes.

FEM simulations to extract the volume of the internal chamber as the input pressure changes from 6895 Pa to 41369 Pa.

Experiment and Simulated Tests - Sustainability

Energy Consumption

\[ \varepsilon = \gamma \cdot F \]

Volume of the internal chamber at internal pressure \( P \).

Pneumatic Energy Consumption

\[ \text{Volume of the internal chamber} \times \text{at internal pressure} \times \gamma \]

\[ \begin{array}{ccc}
\text{No} & P_{00} & \text{\( m^3 \)} & \gamma \\
1 & 6895 & 3.211 & 0.22 \\
2 & 13790 & 3.781 & 0.53 \\
3 & 20684 & 4.601 & 0.91 \\
4 & 27579 & 5.076 & 1.46 \\
5 & 34474 & 5.786 & 1.99 \\
6 & 41369 & 6.544 & 2.73 \\
\end{array} \]

Energy consumption

\[ \text{Pressure required to reach a certain value of bending angle} \]

Vacuum Suction Cups Energy Consumption

\[ \begin{array}{ccc}
\text{No} & F_{00} & \gamma \\
1 & 0.20 & 0.05 \\
2 & 0.30 & 0.05 \\
3 & 0.40 & 0.05 \\
4 & 0.50 & 0.05 \\
\end{array} \]

Lift force \( F \) perpendicular to the adhesion surface \( \gamma \), volume \( V_{00} \) of air aspirated by the suction cup and calculated energy consumption \( \gamma \) for vacuum actuation.
Corso di dottorato in Technology, Innovation and Management (TIM)

Study of the application of Additive Manufacturing technologies and simulation techniques within the healthcare industry
di Francesca Sala

Additive Manufacturing (AM) in the medical sector

Freedom of design, realization of complex geometries regardless of production costs and reduction of waste and scrap material are some of the benefits driving the promising expansion of Additive Manufacturing (AM) technologies in the industrial sector.

Research background. The increasing interest of the medical sector in AM-based techniques is linked to the possibility of transforming patients’ care by shifting the focus toward custom medicine. This growing trend is reflected in several implementations, ranging from 3D models that mimic the anatomy of the patient for educational or surgical planning purposes, to sophisticated implantable devices that must seamlessly interface with the human environment.

Materials and methods. The integration of advanced manufacturing systems into clinical practice is based on the study of AM processes and materials. Specifically, the AM technologies under investigation are:

- Material Extrusion (MEX), based on the extrusion of thermoplastic filaments or filaments filled with metal powder;
- Powder Bed Fusion (PBF), based on the selective melting of metal powder.

Key findings:

- Rapid prototyping and customization of medical devices
  - Customized polymeric orthoses dedicated to the immobilization of the wrist joint were designed and developed to address the drawbacks related to traditional medical practice [1].
  - The AM orthoses proved to be cost-effective and compliant in terms of simulated strength and displacements [2].
- Customized lattices structures for implantable prostheses are investigated.
- Integration of AM in the clinical practice through the use of a Graphical User Interface (GUI)
  - A GUI was designed as a collection of automatic and user-friendly commands able to transform the anatomical scan into a 3D-printable model of wrist orthoses [3].
  - The validity and repeatability of the developed system was tested using anatomical regions (upper limb joints) with different size and level of detail [3].
- Reduction in manufacturing cost
  - A cost model was formulated and demonstrated the cost-effectiveness of the customized orthoses produced with AM compared to the conventional methods [1].
  - Recent studies, focusing on optimal process parameters, are exploring the feasibility of implementing the metal MEX to medical applications. The well-known economic competitiveness of the elements is complemented by superior mechanical performances.

Discrete-Event Simulation (DES) in the medical sector

Discrete-event simulation (DES) is a well-established simulation approach focused on modelling the operations of a real-world system as a series of events that occur at distinct points in time.

Research background. Over the past few years, healthcare organizations have eagerly embraced DES software, captivated by its potential to enhance the efficiency and the standard of care within hospitals and clinics. Among the several areas of interest, two promising aspects demonstrate the wide-ranging potential of DES:

- Optimal Resource Allocation for finding the most efficient and cost-effective resource allocation methods, particularly in resource-constrained scenarios.
- Patient flow and capacity planning for improving patient throughput, reducing wait times and enhancing the overall patient experience.

Materials and methods. The simulation study is a comprehensive process encompassing a series of crucial activities: formulation of the objectives, collection of data, model creation of the system under investigation, validation and verification of the accuracy and reliability of the model, planning and conducting experimental trials, statistical analysis of the data and documentation. The software used to conduct the simulation study was FlexSim Healthcare.

Key findings:

- Healthcare policy evaluation
  - Evaluation of the impact of policies and reforms against the proliferation of SARS-CoV-2 with the professional support of Gruppo San Donato. The activities of a diagnostic imaging department of an outpatient clinic (Smart Clinics) were virtually replicated and analyzed in terms of operational and productivity indicators. The study clustered and quantified the performance reductions induced by the implementation of healthcare reforms. Alternative process strategies that could partially contain and restore the observed performance reduction were developed and tested [4].
- Preparation for pandemics and crisis situations
  - Simulation was used to model a Mass Vaccination Center (MVC) located in a Universitary Sports Center (CUS) through the cooperation of civil protection volunteers, the president of CUS and ASST Ovest. The study analyzed the performance of the facility, providing evidence on the efficiency of an untraditional physical and organizational layout for the delivery of vaccines [5].

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References:
Identification and implementation of innovative telemedicine solutions lead to ecological and digital transaction

of Anna Savoldelli
Supervisor: Caterina Rizzi, Co-supervisor: Daniele Landi

CONTEXT

Telemedicine uses ICTs to provide and support health care when distance separated the participants (Institute of Medicine)

Growing trend of telemedicine adoption to achieve following benefits:

- Enhanced management of emergency situations
- Limitation to long travel of patients
- Reduction of waiting lists and staff shortages

Telemedicine enables a reduction in emissions related to avoided patient travels. However, there is a limited consideration of wider factors influencing the adoption, the use and the carbon footprint of the entire clinical pathway

OBJECTIVE

- Definition of methodologies to systematically quantify environmental, social and economic impacts of telemedicine
- Definition of guidelines to support hospital facilities through a sustainable development framework, adopting telemedicine solutions

APPLICATION AND RESULTS

1. Identification of methods and tools available in literature to measure and to quantify the environmental sustainability in the healthcare field, with a focus on telemedicine stakeholders

   Evaluation of devices: \( n = 19 \)
   - Study of a single object (\( n = 2 \))
   - Comparison of alternatives (\( n = 8 \))
   - Comparison disposable vs reusable (\( n = 9 \))

   Evaluation of hospital processes and activities (also telemedicine activities): \( n = 31 \)

   Telemedicine studies are limited to the investigation of climate action (i.e., SDG 13) generated by the travel of patients

2. Formalization of healthcare process knowledge to support the transition to telemedicine practices

   - Definition of tables to collect and combine the merging sources of knowledge
   - Use of IDEF0 diagrams to represent and formalize complex care processes
   - Mapping of health care process of heart failure patients
   - Application of a problem-based approach to outline the patient’s medical history

3. Definition of a methodology to improve user experience and support medical personnel in perform usability analysis

   Televisit and telemonitoring for HF patients (TeleCovid project):
   - High usability (81.7%-91.7%) and satisfaction (65.2%-65.8%)
   - Central role of the medical engineer

   Telemonitoring for fragile patients (MIRATO project):
   - Definition of satisfaction parameters from questionnaires
   - Service perceived as useful and well-structured

4. Definition of a new methodology to preliminary quantify the equivalent \( CO_2 \) related to a televisit process, comparing with a in-person examination

   Systematization of the analysis by means of 4 parameters: physical wastes, device energy consumption, telecommunications and transportation

DISCUSSIONS

- The bibliographic research highlights the need to define integrated standard methodologies that can simultaneously meet multiple sustainable development goals
- The use of processes and formalization of knowledge play a crucial role for following analyses. Specifically defined tables and parameters facilitates data collection
- Considering various stakeholders (i.e., patients, hospital staff, environment) and the entire care process (i.e., direct and indirect activities) allows for a more comprehensive and realistic analysis

Given the ongoing growth in the adoption of these technologies, enhancing the care processes in which they are integrated can result in a significant reduction of the generated impacts

CONCLUSIONS AND FUTURE DEVELOPMENTS

The proposed methodologies offer tailored tools for the healthcare sector to assist hospital organizations in transitioning towards telemedicine and a more sustainable approach to care

- A quantitative evaluation is proposed using a systematic and reproducible approaches
- The next steps involve incorporating additional environmental sustainability indicators for a more comprehensive investigation of telecommunications.
- Aspects related to the social impact generated by the entire process will be considered and quantified

REFERENCES
Introduction

Firms are nowadays called more and more often to answer their customer, their employees, and their investors about the ultimate goal of their business. This research aims to generate knowledge helpful for firms coping with the current cultural changes that influence how people perceive organizations, such as the increasing attention towards sustainability.

Objective

“How do family firms use business model innovation to realize a responsive purpose revision?”

The idea is to investigate how new cultural trends are affecting what is expected as a societal role and behavior of firms, and especially how this is reflected in their activities. New cultural elements can be introduced and shared in an organization through either an informal style, as word of mouth and actions, or formal statements as mission, vision, and business model. But it is still not clear how the consequent effect on the companies’ practices is or can be managed. Moreover, a purpose drift in a family firm could be more critical, affecting the relationship between the family and the business: a responsive revision of purpose in such firms would not only mean to question the organization about its role with respect to the society, but also with respect to the owning family.

Background

The main concepts at the back of this research are:

- **Purpose:** the essence of an organization’s existence by explaining what value it seeks to create for its stakeholders. In doing so, purpose provides a clear definition of the firm’s intent, creates the ability for stakeholders to identify with and be inspired by, the firm’s mission, vision, and values, and establishes actionable pathways and an aspirational outcome for the firm’s actions (George et al., 2021).
- **Business model innovation:** a change that introduces novelty in the business model, that is a representation of the company as a set of activities organized in a structure and managed through a governance to propose value to the market (R. H. Amit & Zott, 2010).
- **Family firm:** a business organization where most of the ownership and/or top management positions are held by individuals related by family ties (Papier et al., 2021).

Sample

The firms are selected through **purposive theoretical sampling** (De Massis & Gallier, 2014), among those participating to a “entrepreneur’s learning community” based in Italy. There is just one company located in the center of Italy, while all the others are located in the north, mostly in Lombardy region.

The “entrepreneur’s learning community” is a peculiar context that helps to find firms aware of the most up-to-date societal challenges and more prone to discuss their position, and it is mostly composed by entrepreneurs and CEOs who meet regularly to discuss a specific topic (this year topic is indeed corporate purpose).

Method

This research is set in the ontological tradition of relativism, following a social constructionist epistemological approach. It is based on an inductive explorative case study methodology (Sessa et al., 2015), but it will not neglect previous knowledge while discussing the results as learned by the **abductive logic** (Dubois & Gadde, 2002). The study has a multiple holistic design, as multiple members of multiple organizations are included but the unit of analysis coincides with the firm level. The interviews for each company include the main shareholder, the CEO or a board member or a minor shareholder, a manager, an interviewee, and a long-time external business partner (eg., a client).

For each firm:
- 5 interviews
- Direct observation
- Multimedia
- Data gathering and analysis
- Data inductive coding
- Report and paper writing

Table 1:

<table>
<thead>
<tr>
<th></th>
<th>SMALL</th>
<th>MEDIUM</th>
<th>LARGE</th>
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<tbody>
<tr>
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<td>3</td>
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<tr>
<td>NON-FAMILY</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
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Results

**External trigger**

- **Business Model Innovation**
  - Activities (what)
  - Governance (who)
  - Structure (how)

**Purpose framing**

**Purpose realizing**

**Purpose formalizing**

**Incoherencies? (Sense of loss?)**

- Yes
  - New status quo
- No

Conclusion

The causes of the responsive revision projects undertaken can be identified in a sense of loss with respect to values, ideals, and identity that corresponds to a purpose drift, usually generated by a business model change made to adapt to a new context.

As the business model innovation was already pursued in most of the cases, we can hardly identify any strong cause-effect relation between purpose and innovation. Anyway, we can say that reasoning on the company’s purpose led often to adjust the innovation process. In such cases, the realization of the purpose revision would represent an incremental business model innovation.

An organizational purpose, anyway, seems to affect only specific elements of a business model:

- The most relevant is the effect on the activities performed and the relative human resources involved, and so on the activities (what) and governance (who) side. Questioning why the company should do something could lead in dropping some activities that are not worth and embrace some other one that help in reaching the objective. An example could be found in one of the firms, enlarging its scope and acquiring new people to leave the boiler supplier dimension and become a energetic efficiency partner.
- Another element, which could be affected, is the value proposition (why) when the reason of the company to work is not aligned to the reason of the customers to establish a business transaction. An example could be offered by another firm, where they do not see their product just as an object anymore but also as a mean to bring joy to people.
- What appear to not being related to purpose drift is the structure (how) of the activities within the company.

Further elaboration on the family dimensions will be added when more interviews will be performed.
Towards human-centered systems: the role of Lean 4.0 practices in creating inclusive manufacturing environments

Matteo Zanchi

Research objective

1. The objective of the research is to understand which benefits different Lean 4.0 techniques may bring to the working conditions of neurotypical and of those with neurodiverse traits by framing them in a structured approach (in the form of guidelines) to assist the workplace in carrying out job-related tasks. Such guidelines consider the context variability due to differences between working environments and individuals, and therefore be valid under specific circumstances.
2. Such guidelines would allow to fully unleash the hidden potential of neurodiverse workers' capacities, especially in the case of autistic people, go in some cases even beyond the cognitive abilities possessed by the neurotypical counterparts.
3. This would result not only in the company employing neurodiverse personnel to acquire higher social reputation and, therefore, visibility, but also in increased performance for those activities where people with such traits are highly specialized.

Methodology

Based on a mixed inductive-deductive methodology, the research plan revolves around 9 different steps:
1. Definition of physical and cognitive traits of individuals
2. Identification of working context dimensions
3. Influence of Lean 4.0 tools over the working context
4. Expression of the individual characteristic traits over the working context
5. Pervasiveness of Lean 4.0 tools over company welfare

If, on the one hand, the literature review and expert interviews (organized in the form of ‘panel sessions’) that characterize the first 4 stages allow relationships to be established between Digital Lean tools, working contexts and personal traits, according to a deductive approach, the final analysis of multiple case studies allows these relationships to be refined on the basis of empirical evidence that has emerged in reality, according to an inductive approach.

Results

Current scientific literature focuses on the treatment of neurodivergent people primarily within the school setting, and thus in childhood or otherwise adolescence. A gap has not yet been filled on how these people should be treated in a work context, and what arrangements should be put in place to offer the right degree of support to such individuals. A first attempt to frame the role of traditional Lean tools (and thus not in the 4.0 meaning) as compensatory means for people with neurodiversity in production environments has been made by redacting three relationship maps, one for each neurodiversity, showing the degree to which Lean Management practices and tools might serve as a compensatory mechanism for such people (physically, cognitively and/or organizationally). Highlighting their potential role in their working lives.

Overall, Lean Manufacturing tools appear to have the potential to be used as support tools for neurodiverse people, the effectiveness of which also depends on the respective set of strengths and weaknesses of the operators involved. These initial results, in the end, would be broadened by including all the categories of employees (neurotypical as well as neurodiverse) along with their degrees of diversity, finally assessing to what extent Lean 4.0 practices and tools generally contribute to the company welfare, in terms of:

- Employee goals
- Operational performances – depicting how the adoption of Lean 4.0 tools is directly responsible for the improvement of production system performances, and also indirectly, as employee well-being also concur with a contingent improvement of operational outcomes.

Conclusions

Combining technological, organizational, psychological, and neurological perspectives, this research enables the development of an integrated normative model aiming at helping managers to define and optimize strategies for the inclusion of production employees about their distinctive characteristics (neurotypical or neurodiverse) and to the context in which they operate. The value of the proposed research is therefore twofold:

- Research: Have insight in the knowledge related to the field of ‘production environment’, resulting from the integration of technical and organizational disciplines with those belonging to the areas of psychology, neurocognitive and special pedagogy.
- Industrial: Creation of a normative model supporting the (ideally)linearization of existing strategies, according to the peculiarities of the considered context.
- Societal: Moving towards the full inclusion and valorization of people, the model will also be representative of the inclusion of people affected by neurodiverse conditions, with particular reference to ADHD, Autism, and Down’s syndrome, in modern manufacturing companies, providing the right training strategy to fully exploit the potential of such subjects as to make the current working environments inclusive in respect of these people.

Influence of Lean Management tools on people with ASD

Scuola di alta formazione dottorale

Tecnologico, Innovation and Management (TIM)

Corso di dottorato in Technology, Innovation and Management (TIM)
Doctoral Program in Technology, Innovation and Management
PON 2014-2020 DOTTORATI DI RICERCA SU TEMATICHE DELL’INNOVAZIONE E GREEN (D.M. N.1061/2021)

Digital Rehabilitation: Advancing Sustainable Healthcare for Chronic and Acute Patients
Ph.D. Candidate: Andrea Cattaneo

Context
Rehabilitation is a process during which a person with disabilities is brought to achieve the best possible level of autonomy on the physical, functional, social, intellectual and relational level, with the least restriction of his/her operational choices, even within the limits of his/her impairment.

• There is a profound unmet rehabilitation need around the world
• Due to aging population, the demand for rehabilitation services is rapidly increasing (+70% compared to 1990)
• Greater access to rehabilitation services is required to reach the Sustainable Development Goals (SDGs)

Aim
The aim of this research proposal is to develop innovative digital solutions for a sustainable evolution of rehabilitation services.

Methods
The proposed approach is developed through four closely interconnected modules.

1. Rehabilitation Needs: although rehabilitation principles are generally shared, each disorder requires unique therapeutic approaches. Moreover, individual patients have different situations, requiring tailored rehabilitation sessions to address their specific needs

2. Technologies: while the expertise and human supervision of rehabilitation physicians remain crucial for therapy success, innovative technologies can offer significant benefits, especially in delivering rehabilitation at home. Key technologies include:
   • Motion Capture Systems
   • Virtual and Extended Reality (VR & XR)
   • Serious Games

3. Remote medicine: modifying treatment plans as patients progress is essential for achieving optimal recovery. Implementing remote medicine delivery via a cloud platform is essential to meet the ever-increasing demand

4. Sustainability: as in any field, improving current practices should be quantitatively evaluated across the three pillars of sustainability: environmental, social, and economic aspects

Applications
Musculoskeletal disorders
Musculoskeletal disorders encompass a range of medical conditions that primarily affect the musculoskeletal system, resulting in pain, discomfort, and restrictions in mobility or function. This thesis focuses on osteoarthritis (OA), a common joint condition characterized by cartilage degeneration. In the context of hip OA, total hip arthroplasty (THA) is a surgical procedure involving the replacement of the damaged joint with a prosthesis. We conducted gait analysis on thirty-six individuals with hip OA who underwent THA at Humanitas Gavazzeni. Main results:

The identification of gait characteristics affected by hip OA through factor analysis.

Development of a novel methodology for evaluating the Trendelenburg gait, an abnormal gait often observed after THA

Development a software module to assist patients with home rehabilitation using a wearable IMU. The system is integrated into a commercial telemedicine platform developed by our partner MediaClinics srl.

Neurological disorders
Neurological disorders encompass a broad range of medical conditions that affect the nervous system, comprising the brain, spinal cord, and peripheral nerves.

Specifically, ischemic strokes can lead to hand mobility issues due to impaired motor control and unilateral spatial neglect (USN), a condition where individuals may lack awareness of one side of their body or surroundings, posing challenges in daily activities and spatial perception. This thesis proposes tailored rehabilitation solutions through serious games:

Fine-motor hand rehabilitation through tasks demanding precise hand control, tracked using an optical hand tracking system. A preliminary usability study has shown promising results.

Several serious games for both assessing and rehabilitating USN.

They utilize VR headsets and eye tracking to create an immersive environment, stimulating patients with prismatic shifts, audio cues, virtual motor augmentation, and visual constraint.

Neoplasms
Breast cancer, one of the primary neoplasms affecting women’s health, often necessitates mastectomy, a surgical procedure that involves the removal of one or both breasts.

After surgery, it is crucial to focus on shoulder rehabilitation to improve range of motion, prevent lymphedema, enhance strength, and improve posture. To this aim, our work centers on:

Implementation of a serious game for shoulder rehabilitation.

Movements are tracked using a low-cost markerless motion capture system, monitoring unwanted postural imbalances and compensatory patterns.

Integration of the solution into a developed telerehabilitation platform that empowers healthcare providers to closely monitor their patients’ progress remotely

Digital Rehabilitation for Sustainable Development
We use Agent-Based Models (ABMs) to simulate macro-level phenomena that arise from interactions among individuals, such as patients, caregivers, and rehabilitation specialists. Primary results include:

Forecasting future rehabilitation service demand

Understanding caregiver burden and challenges

Identifying optimal resource allocation to facilitate informed decision-making

Assessing the environmental, social, and economic sustainability impacts of rehabilitation services

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