Statement of Research

H. Onan Demirel

School of Mechanical, Industrial and Manufacturing Engineering
Oregon State University

Introduction

My research focuses on how to incorporate human needs, abilities and limitations during early stages of the design process. I am interested in the development of multi-disciplinary design theory and methods to explore inter-dependencies and co-evolution of human element in engineering, natural and social systems. My goal is to understand and optimize human well-being and the overall system performance.

In contrast to other scholars who interpreted human element in isolation, I find humans are better understood as the core of design activity. Design is an inherent human character. Its the central activity of engineering and a major propellant of our prosperity. Thus, incorporating human element in design process is inevitable. However, this is either neglected or not equally considered when compared to other design factors.

I currently focus on developing a human-in-the-loop design framework, which utilizes Digital Human Modeling (DHM) to integrate Engineering Design, Human Factors and Systems Engineering. This framework allows visualization and mathematical representation of humans in a computer or virtual environment. It reduces the cost associated with physical prototyping, decreases the design cycle-time and shortens the time-to-market (Fig. 1). DHM research has potential in resolving safety, health, and sustainability related concerns in complex coupled systems. It assists engineers to incorporate Human Factors design principles early in the design process. Thus, it reduces human-product related errors and safety concerns while improving overall performance of the system.

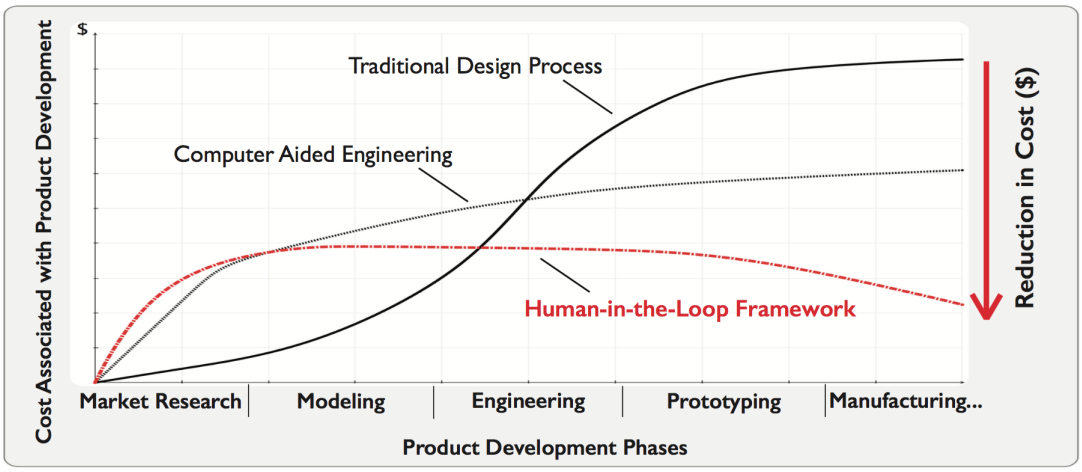

Figure 1: Potential cost savings associated with utilizing DHM early in the design process.

Current Work

1. Digital Human Modeling Research

Digital Human Modeling (DHM) is the method for representing humans in a simulation or virtual environment to facilitate the prediction of human performance and/or safety. Complex movements of the human body can be digitally represented, simulated and analyzed through DHM software. DHM offers advance visualizations (representation of human-body with segments and joints, etc.) with the math and science in the background (kinematics and bio-mechanics relations, etc.).

My research in DHM encompasses a wide-range of cross-disciplinary domains that have inter-connections with human in design domain. I develop design theory and methods that incorporate Human Factors aspects of design with the graphical and mathematical visualizations of human body. This approach assists designers to predict safety, risk and performance early in design process (Fig. 2). I conduct DHM research in:

- Product Development
- Advance Vehicle Design
- Industrial Ergonomics
- Product Lifecycle Management

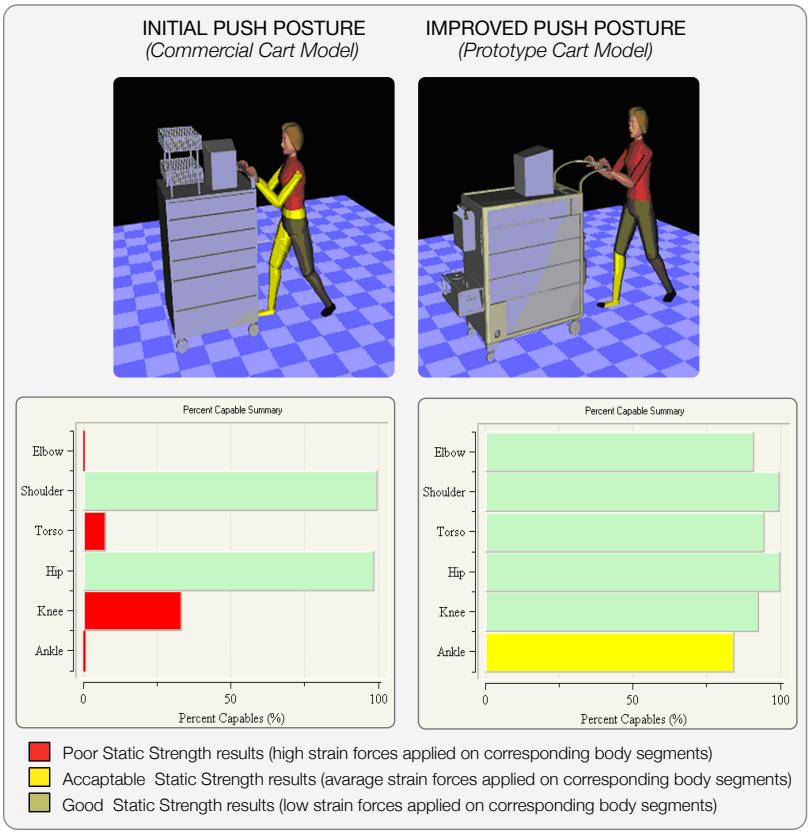

Figure 2: Applications of DHM in assembly simulations and performance assessment.

2. Design Theory and Methods

"How to systematically integrate human element into design cycle?" is the central question of my design research. Since humans are creators and users of products, processes, and environments, human element is the core of any design process. Therefore, understanding the nature of human element in design process is a major success contributor. However, human element in design cycle is either neglected or not equally considered when compared to other design contributors. In addition, a systematic understanding to integrate form, function and human element in product design is not fully examined.

My research focuses on development of a human-centered design theory and methods, which integrate human needs, abilities and limitations at early stages of design process (Fig. 3). This framework blends form and function aspects of products with a human-centered approach - from conception to creation. Topics that I am interested are:

- Engineering Design and Industrial Design
- Product Design and Development
- Systems Approach/Engineering
- Technology Integration in Design

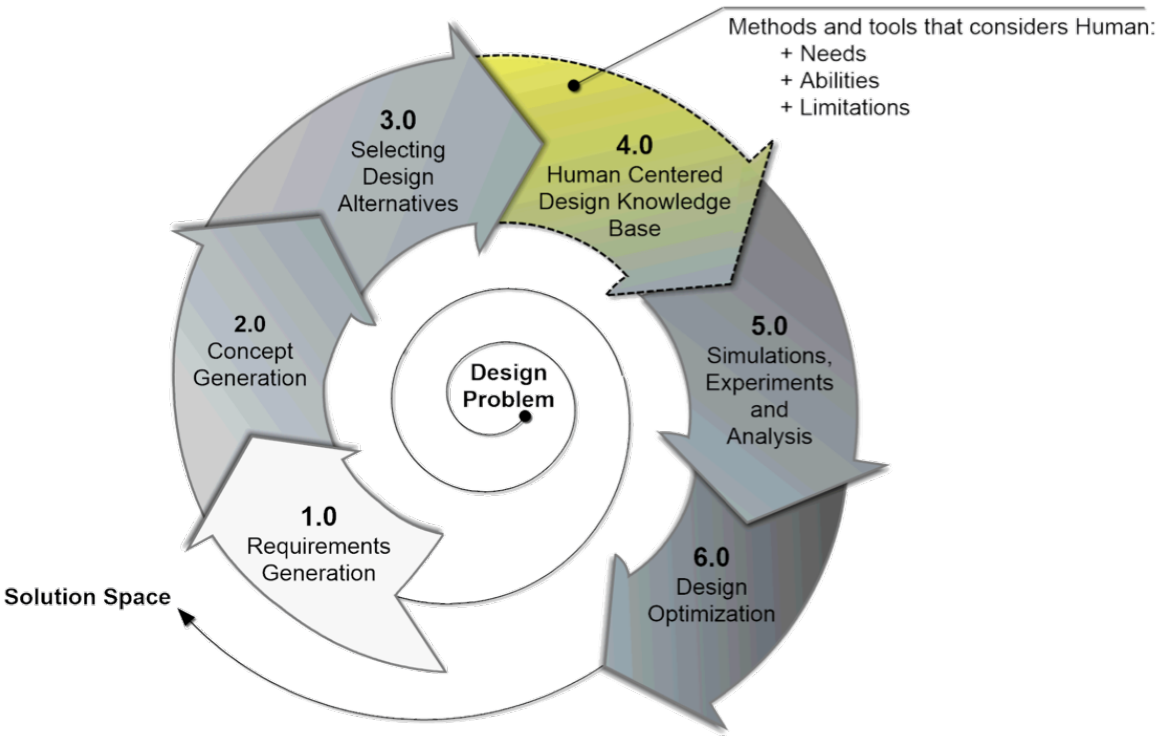

Figure 3: Product development framework integrates human element into design process.

3. Human Factors Engineering

Human Factors Engineering (HFE) is a scientific discipline with a broad scope of coverage. The discipline is concerned with the interaction between humans, artifacts and the environments. It is different than most of scientific disciplines related to human physiology and cognition (anthropology, cognitive sciences, psychology, etc.). The purpose of these disciplines is to understand and model human behavior. In contrast, HFE utilizes the knowledge gained from these disciplines to design and evaluate products, services, tasks, environments, and systems, which consider human needs, abilities and limitations.

The main focus of my HFE research is design of optimal products and systems. My HFE research involves developing both research and application framework to build a knowledge base about human needs, abilities and limitations, then apply this knowledge to design optimal human-machine systems. The very top-level goals are to increase human well-being and quality of life through optimizing the interaction between humans and artifacts (Fig. 4). This includes reducing hazard, discomfort, fatigue, etc. while maximizing utility, usability, safety, etc. of the overall system. My research includes:

- Human-Subject Data Collection
- Mixed Virtual Reality
- Human-Computer Interaction
- Ergonomics
- Bio-mechanics

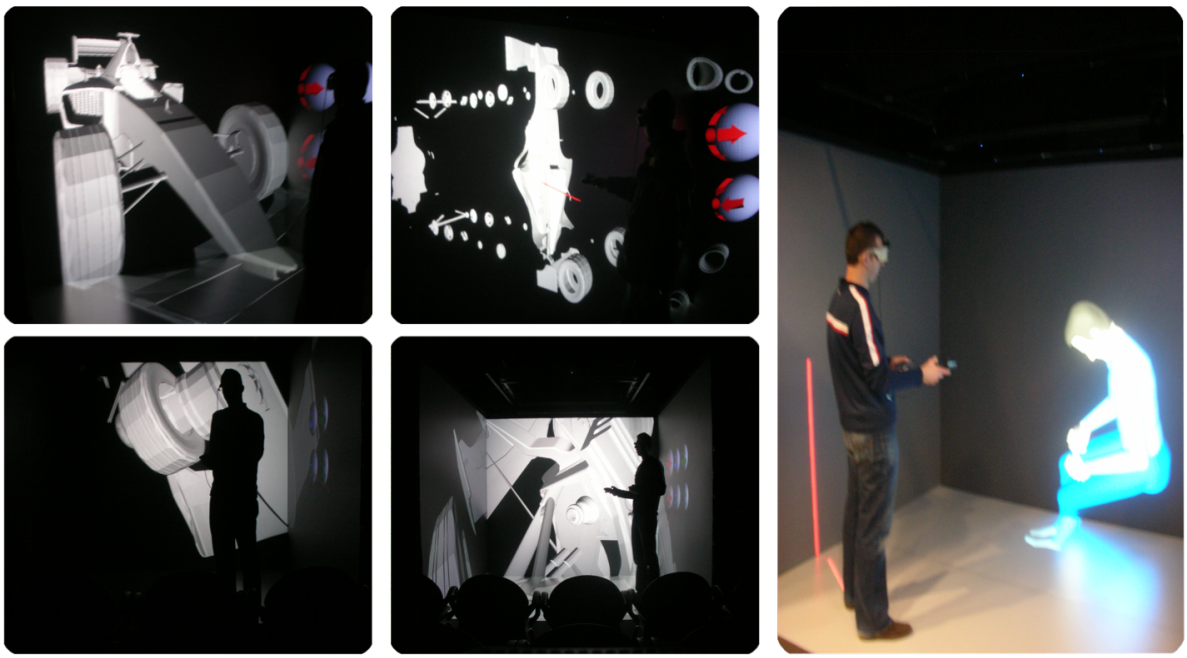

Figure 4: Representation of humans and products in a virtual environment.

Future Work

1. Human-in-the-loop Design Framework

Human-in-the-loop design framework provides a systematic (visual and mathematical) representation of the humans inside digital design work-flow from conceptual modeling to human factors, structural analysis and photo-realistic rendering (Fig. 5). This framework presents interactions between abstraction (arts, form) and structure (engineering, function). Primary goal of this research is to assess human well-being (e.g. safety, comfort) and product performance.

1. **Design Requirements:** Product development starts with identifying consumer needs, which leads to concept idea generation.
2. **Understand:** Conceptual design (low-fidelity 2D/3D models) starts through brainstorming, sketching and doodling around design parameters.
3. **Conceptualize:** Concept designs are linked with human modeling knowledge-base. Alternative models are created and further analyzed to capture best fit for human use/interaction through DHM tools.
4. **Create:** Best model(s) from a pool of alternatives are selected, and high-fidelity models are refined by using structural simulations to create digital prototype(s). Concept model(s) go in digital and physical tests for further refinement until a prototype for beta-model is realized.

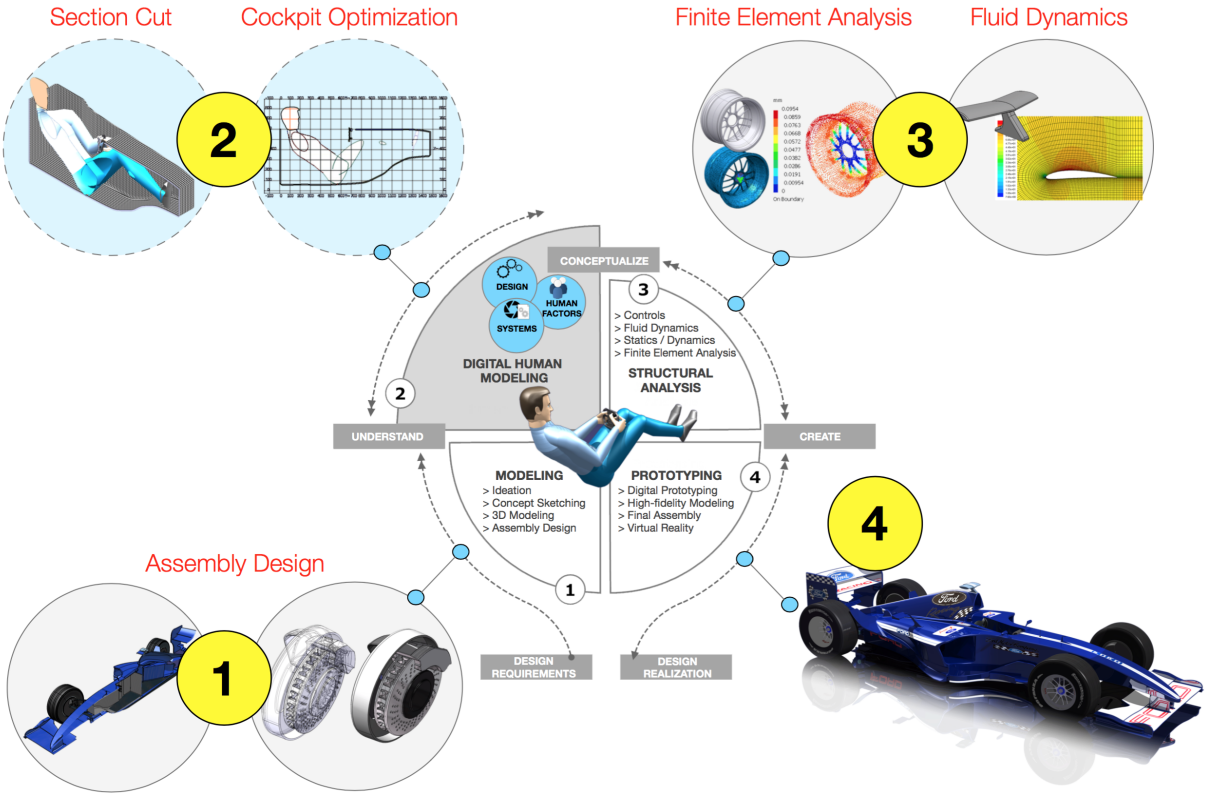

Figure 5: Design flow that represents conceptual development of F-1 cockpit design.

2. Human-Centered Design in Complex Coupled Systems

The Grand Challenges described by National Academy of Engineering and recent initiatives of the National Science Foundation (e.g. smart systems and services) demonstrate a strong interest in holistic design engagement. Often, these challenges are centered around human element and require systematic consideration of human needs, abilities and requirements. However, conventional engineering design methods have a limited scope when bridging human aspects of design process with multi-disciplinary design domains.

My research in human-centered design domain utilizes human-in-the-loop design strategies to blend multi-disciplinary domains (technology, society, policy-making, education, etc.) with a human-centered focus (Fig. 6). This approach utilizes Digital Human Modeling and concurrent engineering tools to extend current solution space.

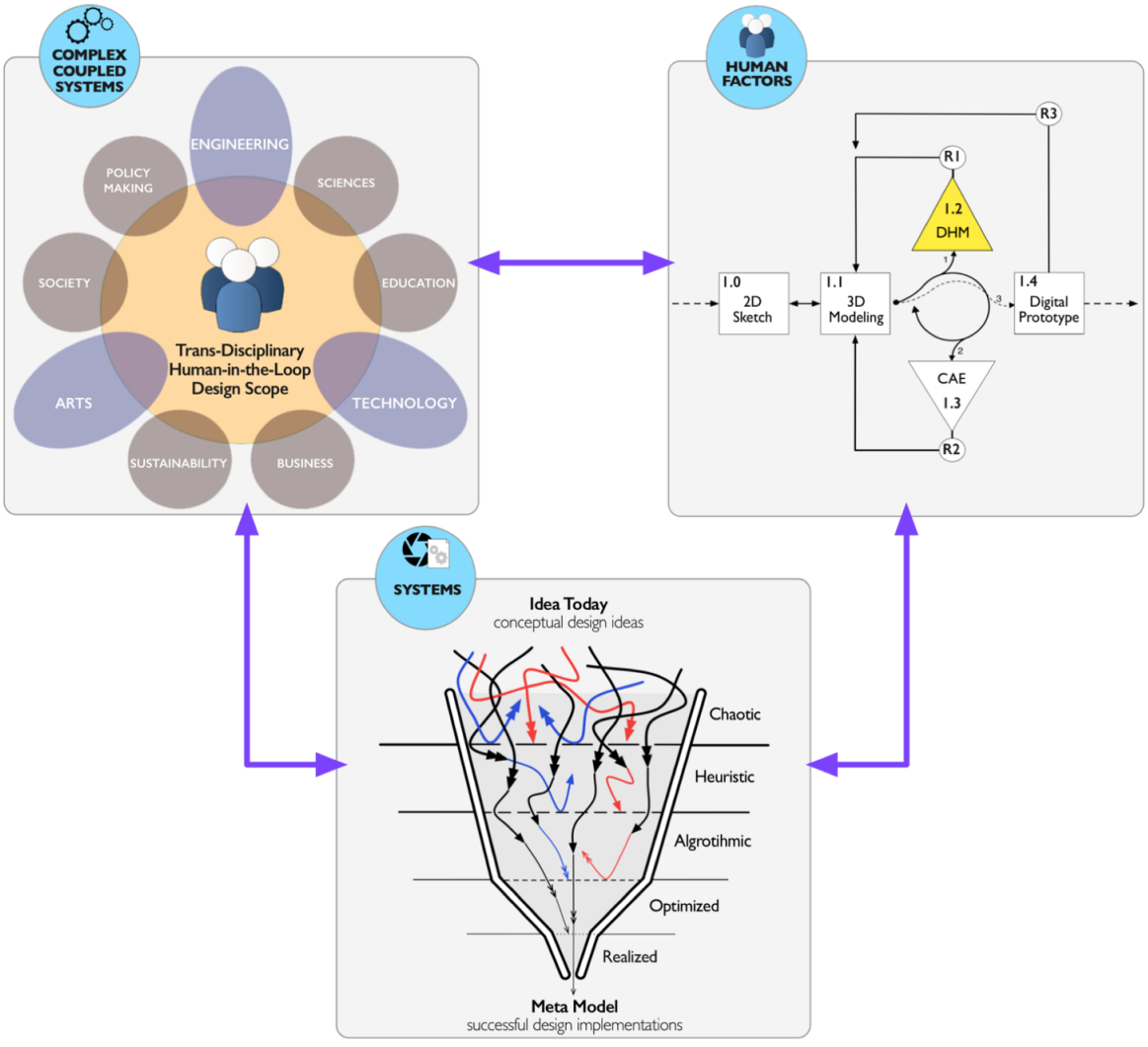

Figure 6: Human-in-the-loop design approach bridges complex-coupled systems, human factors and systems approach.

3. Human Factors Engineering for Sustainability

Methods for conservation, recycling and creating alternative energies would not solely replenish the natural resources. Sustainability should be integrated into every aspect of life that would have inner, inter and trans-disciplinary relationships with the human element. In this context, I am working on the development of a DHM based design framework that focuses human-compatibility challenges in sustainability research. I am specifically interested in the development of novel simulation tools (e.g. air quality and metabolic energy expenditure) to map human needs, abilities, and limitations to system requirements (Fig. 7). This includes design and evaluation of smart interfaces, sustainable communities and toxic/hazard management (Fig. 8).

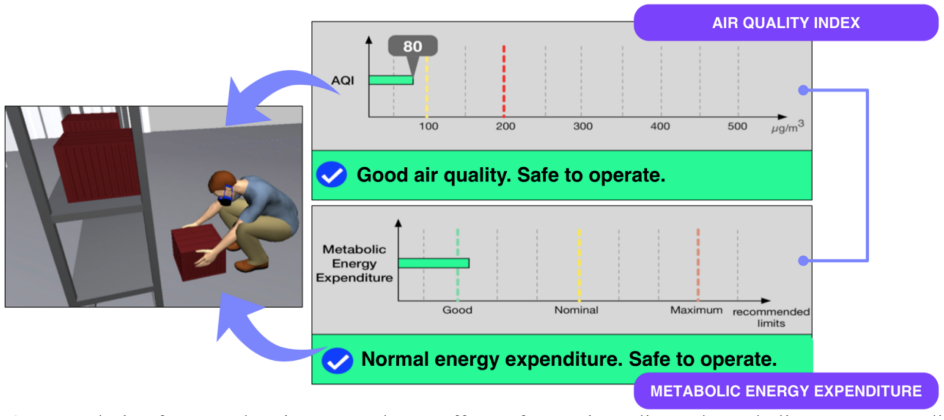

Figure 7: HFE approach used for assessing adverse affects of poor air quality and metabolic energy expenditure.

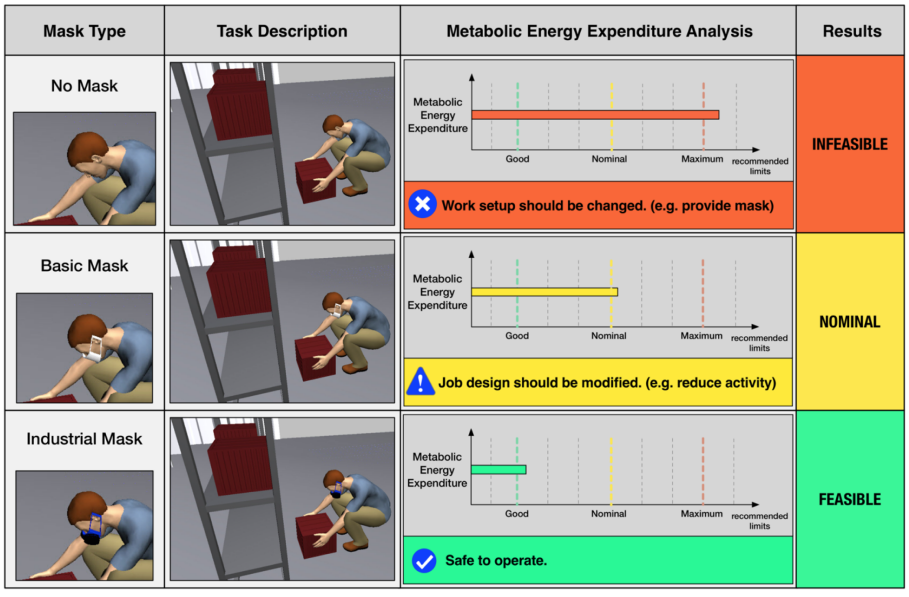

Figure 8: Different types of masks are analyzed in their potential to reduce adverse effects of indoor air pollution.