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PERSPECTIVE ARTICLE

Digital Human Modeling With RAMSIS: Key Features, Industrial Applications, Limitations and Future Directions

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ABSTRACT

The advancement of digital technologies over the past three decades has led to a fundamental transformation in the fields of ergonomics and user-centered design. The RAMSIS software, as a pioneer in Digital Human Modeling (DHM), leverages extensive anthropometric data and advanced capabilities to enable precise analysis of human interaction with diverse work environments from vehicle interior to workstation design. This article, while reviewing the development history of RAMSIS, its main features, applications across various industries, and its limitations, outlines future research directions in this area. The results indicate that RAMSIS goes beyond being an industrial design tool and has evolved into a multidisciplinary platform for improving user health, safety, and comfort.

KEYWORDS: *Industry 4.0; DHM; Posture Analysis; Vehicle Design; Biomechanics*

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INTRODUCTION

Until a few decades ago, ergonomic evaluation was primarily conducted through physical prototypes and field tests. Although this approach had relative accuracy, it came with problems such as very high costs, time-consuming processes, and difficulties in simulating diverse human populations [1,2]. The rapid advancement of computer-aided design (CAD) technologies, more specifically Digital Human Modeling (DHM), has made designers and engineers to seek tools that not only accurately model components and products but also perform human and ergonomic analyses in the early design stages [3]. This transformation has allowed designers to simulate and evaluate human interaction with complex environments without the need for physical prototypes [3,4].

Among DHM tools, the RAMSIS software is a specialized ergonomics tool specifically developed for the automotive industry. This tool was first developed in the late 1980s, aiming to replace two-dimensional and manual tools with three-dimensional digital models for more precise ergonomic analysis [5-7]. The development of RAMSIS was based on collecting anthropometric data from diverse populations worldwide to cover a wide range of users with varying characteristics in terms of gender, age, ethnicity, and body dimensions [7,8]. A key advantage of RAMSIS is its full integration with CAD software such as CATIA, Siemens NX, and SolidWorks, which enables the importation of 3D environmental models and the performance of detailed ergonomic analyses. This integration can lead to reduced design cycles, fewer human errors, and ultimately lower production costs [8,9].

The importance of RAMSIS is not limited to the

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automotive industry; today, this software is widely used in workspace design in aerospace [10,11], defense [12], medical industries [13], and even in specialized environments such as spacecraft [14,15]. For example, in the design of a pilot's or astronaut's cockpit and Shipbuilding, RAMSIS can simulate access to controls, field of vision, posture, and long-term comfort [10,14,16–18].

In summary, RAMSIS, by providing accurate human models and advanced analysis tools, enables the simulation of real-world product usage conditions. Using the software, designers can quickly identify ergonomic problems and apply appropriate solutions in the early design stages, even before building a physical prototype, and make the necessary modifications in the shortest time and at the lowest cost. The goal of RAMSIS is not only to reduce design costs but also to enhance user comfort, safety, and productivity in work environments and vehicles. Considering the importance of RAMSIS in the field of ergonomics, this paper aims to provide a review of the software's development history, capabilities, applications, and limitations.

HISTORY AND DEVELOPMENT ROCESS OF RAMSIS

The RAMSIS software was developed in the late 1980s by the company Human Solutions (now Humanetics Digital Europe GmbH) with the support of the German automotive industry [5,8,19,20]. The core idea for creating RAMSIS originated from the automotive industry's need to design user-friendly and safe vehicle cabins. At that time, automakers faced significant challenges regarding the demographic diversity of drivers and passengers, the high costs of building physical mock-ups, and the complexity of evaluating different body postures.

The development of RAMSIS began through a collaboration between research centers and German automotive companies, including Audi, BMW, DaimlerChrysler, Ford, Opel, Porsche, and Volkswagen [5,6,19,20]. The primary goal of the project was to replace two-dimensional tools and manual methods with a three-dimensional digital system capable of simulating a wide range of users. To this end, global anthropometric databases were compiled and integrated into the software. These databases included population data based on gender, ethnicity, age, and body measurements, enabling the accurate modeling of various user groups.

A historical milestone for RAMSIS was its integration with CAD software such as CATIA and Siemens NX [21]. This integration allowed designers to directly analyze digital product models with human manikins without the need for data conversion. The result of this development was a system that could simulate human models based on configurable characteristics like height, weight, and body proportions and test them within designed environments. This capability shortened the design cycle, reduced the need for physical prototypes, and significantly increased the accuracy of ergonomic analyses [8].

KEY FEATURES OF RAMSIS SOFTWARE

Over the past three decades, RAMSIS software has established itself as a comprehensive digital human modeling tool, offering designers a wide range of capabilities [4,5,20]. The core features of this software can be examined in the following areas.

Comprehensive Anthropometric Database

The first standout feature of RAMSIS is its extensive coverage of anthropometric data. Unlike many DHM software programs limited to specific demographic data, RAMSIS has compiled and integrated international databases into its core (Figure 1). These international populations cover age groups, genders, and documented growth trends over decades. This enables the simulation of users from diverse groups – in terms of age, gender, ethnicity, and body dimensions – allowing designers to optimize their products for a global target population. This capability is a critical competitive advantage for the automotive and aerospace industries, which operate in international markets.

Posture and Body Position Analysis

Alongside human data, RAMSIS provides advanced tools for posture and body position analysis. The software can dynamically simulate sitting, standing, and body movements based on scientific experiments and assess the effects of these postures on musculoskeletal disorders (MSDs)[10,22]; it produces joint angle values, as well as posture-dependent, maximal joint torques based on which it reports a discomfort function .

Furthermore, it can generate realistic scenarios reflecting how people actually sit, reach, and move, and analyze an individual's posture and body position for the specific performance requirements of a task (Figure 2).

RAMSIS's capabilities are not limited to static postures; by providing tools for modeling dynamic

Figure 1. The international anthropometric databases found in RAMSIS (Retrieved from https://www.human-solutions.com/en/index.html)

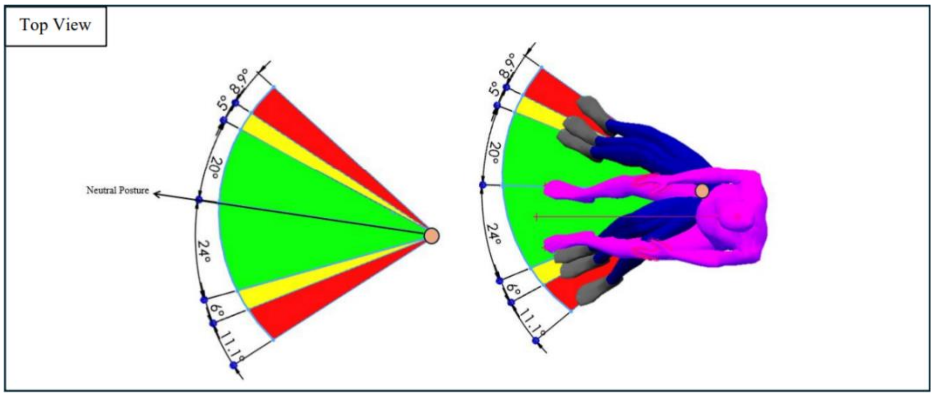

Figure 2. The top view of the hip joint movement illustrates the defined zones of comfort, acceptable, and unsatisfactory ranges of a tractor cab (Adapted from Jeddi (2024))

movements, it can also replicate complex and repetitive tasks, such as realistic movement sequences for vehicle ingress and egress. This is highly valuable for analyzing muscle loads and considering differing strength, mobility, and vision across various age groups and populations.

Advanced Visual Analysis

Another important feature of RAMSIS is vision analysis, which enables the simulation of users' fields of view and the identification of blind spots. By simulating sightlines to instruments, displays, and the surrounding environment, including mirrors, the software can evaluate obstacles to clear lines of sight and assess glare and reflection under day and night conditions. Additionally, it can determine visual acuity, glance time, and potential reflections, which are highly important in automotive and aircraft design.

Optimal Accessibility

The software can evaluate access to controls and instruments, allowing the assessment of the distance and ease of human interaction with environmental components. This feature is used particularly in the transportation industry to optimize the design of seat belts, mirrors, and seat positioning. Ensuring that drivers, pilots, and operators can reach all controls without any strain plays a crucial role in enhancing user safety and comfort.

Space Requirements

In RAMSIS software, Space Requirements, as a key feature, are based on the principle that occupants have sufficient space for comfort and safety. The advanced simulation capabilities of RAMSIS enable the evaluation of cabins, aisles, and interior spaces to ensure comfort and mobility in complex environments. The software provides the necessary tools for assessing confined spaces, ensuring confidence in the practicality and maintainability of the design in the real world.

Seamless CAD Integration

Finally, the deep integration of RAMSIS with CAD software must be mentioned. This feature allows ergonomic analyses to be performed directly on 3D design models without the need for data transfer

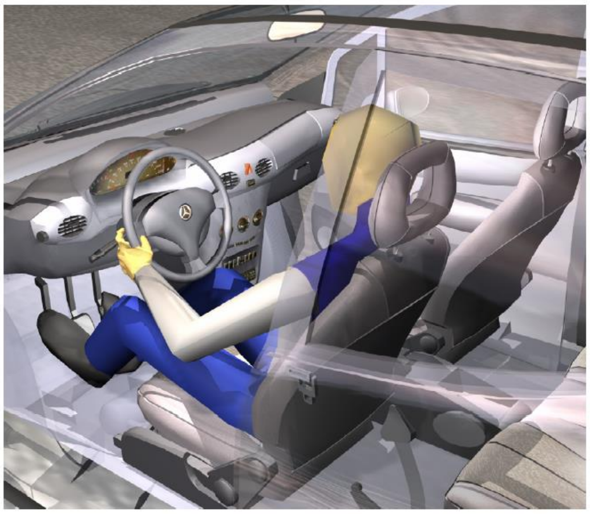

Figure 3. **The** Posture and Body Position Analysis in a Vehicle (Adapted from Van der Meulen and Seidl (2007) [20]

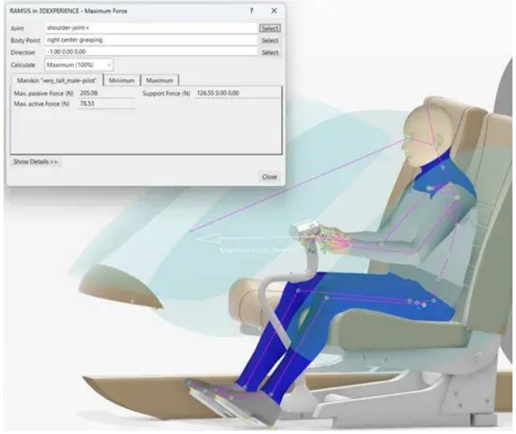

Figure 4. The external forces analysis of driver exerting or exposed to, such as pushing a pedal (RAMSIS in CATIA 3DEXPERIENCE [6])

or conversion (Figure 4). Such integration not only increases the accuracy of analyses but also reduces product development time. This has made RAMSIS an efficient tool in the digital design cycle and part of the modern Digital Twin process.

In general, RAMSIS can be considered software that lies at the intersection of engineering, ergonomics, and medicine. With access to the world's largest collection of anthropometric databases and by combining human data, advanced analytical capabilities, and direct interaction with CAD, it helps designers not only guarantee user safety and comfort but also minimize development costs by eliminating physical prototypes and reducing rework.

STAGES OF USING RAMSIS IN A DESIGN PROJECT

The use of RAMSIS software in an industrial or each vehicle project typically involves several stages. These stages allow designers and engineers to incorporate ergonomic considerations from the very beginning of the product development process, significantly enhancing the quality and safety of the design [9].

1. Definition of the Design Environment (vehicle, aircraft, etc.): A digital model of the design environment space (including seats, steering wheel, pedals, etc.) is created.

2. Selection of a Human Model Based on Anthropometric Data: A digital human model (manikin) with specific body dimensions and physical characteristics (e.g., average male driver) is added to the model.

3. Adjusting Body Posture and Simulating Interaction with the Environment: A specific body posture is defined for the manikin (such as a driving position), and if necessary, the manikin's posture and position are adjusted.

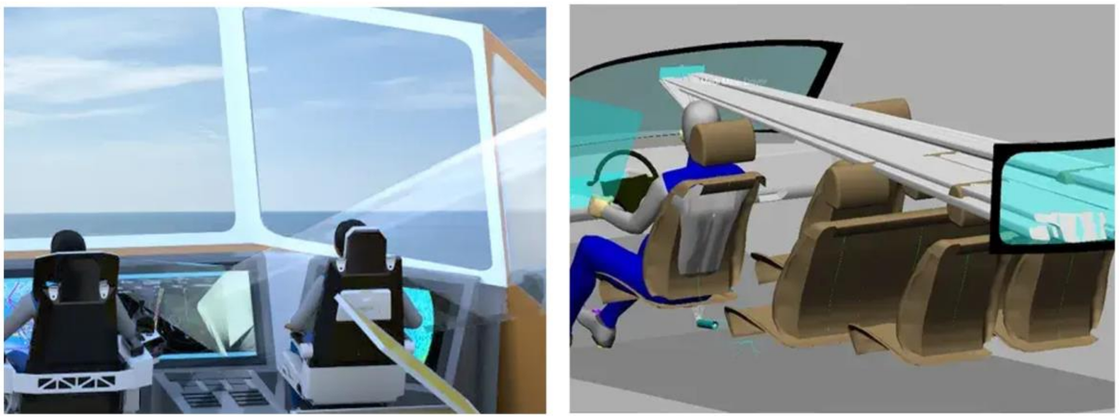

Figure 5. The advanced visual analysis such as lines of sight and assess glare and reflection (Retrieved from https://www.human-solutions.com/en/index.html)

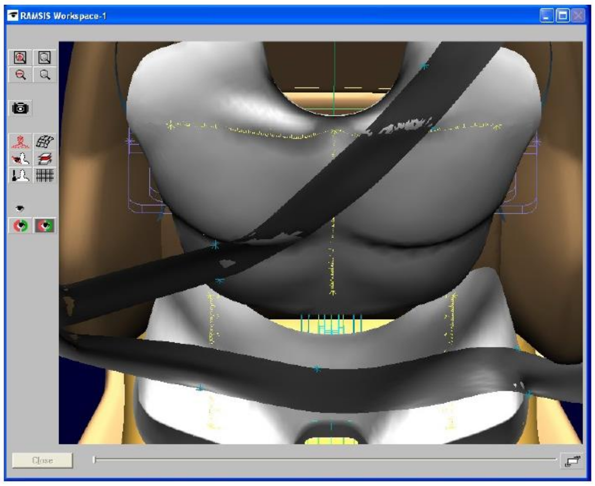

Figure 6. The design of seat belts (Adapted from Van der Meulen and Seidl (2007)[20]

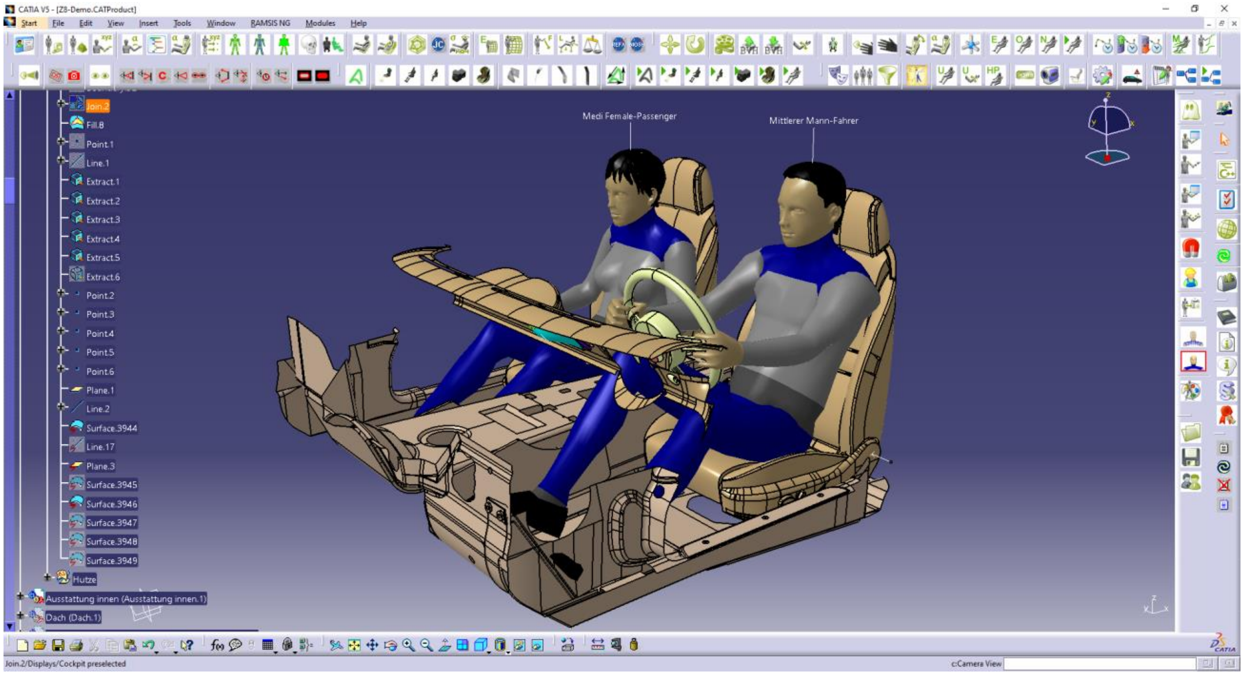

Figure 7. The Space Requirements (RAMSIS in CATIA V5, retrieved from Dassault Systèmes at https://www.3ds.com)

4. Joint Definition: The starting joints are adjusted to ensure the manikin is in a comfortable position.

5. Importing the Environment Design into the Software via CAD: For example, the vehicle geometry is loaded, and endpoints for seat analysis are defined.

6. Performing Analyses on Vision, Reach, Posture, and Forces

7. Evaluating Comfort and Safety: For example, the comfort and safety of the sitting posture are evaluated by examining the steering wheel distance, roof height, and the manikin's sitting position, and any potential issues are recorded [6,22].

APPLICATIONS OF RAMSIS IN THE INDUSTRY

During its existence, RAMSIS has expanded beyond the automotive industry and has been also employed in aerospace, medical, and defense sectors. Table 1 shows DHM studies using RAMSIS in their design evaluation.

This software has been widely used for designing the cabins of transportation, industrial and agricultural machinery [7,8,18,21,23] and has moved towards being used for evaluating aircraft cockpits [10] and designing spacecraft cabins, as well as analyzing the physical conditions of astronauts in microgravity environments (6,14). Recently, its application has also extended to the maritime sector [16].

Furthermore, in medical environments, this tool has played a significant role in designing medical equipment and therapeutic environments [13]. Today, RAMSIS is recognized as a comprehensive Digital Human Modeling (DHM) software packages and, alongside tools such as JACK, CATIA Human, DELMIA Human, and AnyBody, is a primary reference in digital ergonomic analysis, whereas, its specific focus on the automotive and transportation industries distinguishes it from other similar software [4].

Automotive Industry

The most important and widespread application of RAMSIS is in the design of automobiles and vehicles. Besides the classical car driver posture model, additional driving models are also available, e.g., for trucks, aircrafts, and motor bikes [25]. This software allows automakers to evaluate the fit of seats, steering wheel positions, pedals, mirrors, and seat belts in the early stages of design. For example, in a study by Nanda and colleagues, ergonomics analysis for comfort, reachability, visibility obstruction, and potential reflection during nighttime for heavy truck drivers was conducted [21]. In the Weber et al project, discomfort analysis, reach analysis, maximum-size backseat passenger calculation, obstructive vision analysis, and reflective vision analysis in automobiles were performed [18] and Silang Liu did similar analysis for Baja Racing Car [24]. Jeddi also designed the cabin of agricultural tractors in his study [7]. Today, almost all major automotive companies, such as BMW, TOYOTA, HYUNDAI, MAZDA, VOLVO, SCANIA, and ... use RAMSIS as the main ergonomic analysis tool [19,20].

Aerospace Industry

The application of RAMSIS in the design of aircraft and spacecraft is important due to the severe space constraints and the critical importance of safety. In the cockpit, this software is used to evaluate the seat position, field of view, access to controls, and pilot comfort during long flights. Chawla et al., in their study, evaluated pilots for vertical take-off and landing for an aircraft [10]. In another study, Dishman & Paulter simulated ergonomic changes that can potentially be implemented to decrease the overall incidence of work-related MSDs for forklift operations and air traffic control (ATC) operations [11]. In space environments, RAMSIS is used to simulate weightlessness and assess the body position of astronauts in confined cabins. In studies, Islam et al. designed a Mars rover's seat [14] and Jin et al. used RAMSIS to create manikins, optimize seat range, evaluate location/visibility, and perform other relevant ergonomic-related analyses [15].

Special environments

In addition to the above areas, RAMSIS is also used in special environments such as marine vessels and the medical field. In environments such as ships, space constraints, difficult access to tools, and unusual working conditions multiply the importance of ergonomics. By accurately simulating these conditions, RAMSIS allows designers to create safer, more comfortable, and more user-friendly environments. Dobbins and colleagues demonstrated the application of RAMSIS to develop effective ergonomic solutions for the complex marine environment in a study [16]. In the medical field, the software allows for the assessment of different body positions and the reduction of MSDs by simulating the movements of patients and medical personnel. In one study, Marcus and colleagues redesigned a laparoscopic operating room [13].

Table 1. DHM studies using RAMSIS in their design evaluation

	Authors (year)	Study	Country	Sector and participants	Objective
1	Satyaswaroop Nanda, Martin Pohlmann, Sameeran Kanade & Vincent G. Duffy (2024)	Digital Human Modeling and Digital Twin: A Literature Review and Case Study	USA	Transportation (car drivers)	Ergonomics assessment of comfort, reachability, visibility obstruction, and potential reflection during nighttime
2	Silang Liu (2025)	Study on Ergonomic Design Optimization and NVH Characteristics of Baja Racing Car	China	Transportation (professional car drivers)	Ergonomics assessment of comfort analysis, reachability, and visual field analysis, and optimizing the design of the cockpit layout of a racing car
3	Dorsa Jeddi (2024)	Developing a human-centric strategy for the future design of agricultural tractor cabs: optimizing user interaction and ergonomics	Canada	Agricultural (tractor drivers)	Evaluating comfort and discomfort of the vehicle as well as determining the optimal visual field
4	A. B. Rathod & R. T. Vyavhare (2024)	Optimization of Truck Driver Cab Ergonomic for Commercial Truck Based on Ramsis: Enhancing Driver Comfort and Safety	India	Transportation (truck drivers)	Modelling driver position, and the cab arrangement and examination of spatial and reachability
5	Vani Chawla, Rashmila Mahajan, Vincent G. Duffy & Martin Pohlmann (2024)	Ergonomic Evaluation of a VTOL Aircraft Using RAMSIS	USA	Aviation (aircraft pilots)	Ergonomics assessment of reachability, outside visibility, comfort level, obstructions, acuity, and reflection for different anthropometries
6	Frederik A. Weber, Martin Pohlmann & Vincent G. Duffy (2023)	Coupling the Vehicle Design Phase with an Ergonomic Simulation to Accommodate Different Driver Shapes in the United States in 2023	USA	Transportation (car drivers and passengers)	Discomfort analysis, reach analysis, max-size backseat-passenger calculation, obstructive vision, and reflective vision
7	Md Tariqul Islam, Kamelia Sepanloo, Ronak Velluvakkandy, Andre Luebke & Vincent G. Duffy (2023)	Enhancing Ergonomic Design Process with Digital Human Models for Improved Driver Comfort in Space Environment	USA	Aerospace (Mars rover drivers)	Ergonomics analysis of driver comfort and postures in simulated design of a mars rover's seat by considering eyesight, reachability, and forces
8	Kevin Jin, Mackenzie Richards & Kevin Lee (2023)	Application of Ramsis Digital Human Modeling to Human Factors in Space	USA	Aerospace (Mars rover design)	Simulating and modeling a new Mars site
9	Jonathan T. Breese, Adam M. Fuhrmann, Vincent G. Duffy & Andre Luebke (2022)	Developing Ergonomic Design Recommendations Using Human-Centric RAMSIS Analysis	USA	Construction (excavator operators)	Adjusting cabin components translation and rotation to improve comfort, improving touch screen reach and interaction, and evaluating visibility and comfort during control actuation

Continued Table 1. DHM studies using RAMSIS in their design evaluation

	Authors (year)	Study	Country	Sector and participants	Objective
10	Samantha Dishman & Katie L. Paulter (2022)	Implementation of Ergonomic Modeling Software to Predict and Decrease Incidence of MSDs	USA	Aviation (forklift and air traffic control room operators)	Simulate ergonomic changes that can potentially be implemented to decrease the overall incidence of work-related MSDs by optimizing work layout and field of view
11	T. Dobbins, J. Hill, Sean McCartan, Tim Thompson(2011)	Enhancing Marine Ergonomic Design Via Digital Human Modelling	UK	Maritime (marine vessels operators)	Investigating specific seating/postural support consideration and joint mobility restrictions of wearing military equipment in the marine environment
12	Patricia Marcos a , T. Seitz a b , H. Bubb a b, A. Wichert a , H. Feussner a (2006)	Computer simulation for ergonomic improvements in laparoscopic surgery	Germany	Healthcare (medical staff)	Increase the safety and efficiency of an integrated operation room by defining ergonomically "ideal" postures, and optimal solutions for key elements of an ergonomic design of the work layout

DISCUSSION AND CONCLUSION

Digital Human Modeling (DHM) is considered one of the most significant advancements in ergonomic design over the past three decades. This technology enables the simulation of complex interactions between humans and their environment in a virtual setting, allowing designers to evaluate the quality of a design from the perspectives of safety, comfort, and productivity before physical prototypes are built [1,4]. Among these tools, RAMSIS is recognized as a pioneer in this field due to its focus on precise anthropometric data and integration with CAD software [3,5,6].

From an ergonomic perspective, RAMSIS plays a crucial role in reducing discomfort and MSDs. Many occupational injuries result from improper postures and repetitive physical strains [11]. Simulating these conditions in the RAMSIS environment allows designers to proactively identify high-risk areas of the body and reduce the likelihood of injury by modifying the product or environmental design [10,22]. This feature is particularly important in the transportation and medical industries, as users in these fields are exposed to long and stressful working conditions [13,16].

Over more than three decades of activity, RAMSIS software has managed to become one of the most reputable and widely used Digital Human Modeling (DHM) tools. The primary focus of this software has been on ergonomic analysis in the automotive and transportation industries, but over time, its scope of application has expanded to broader domains such as aerospace, medicine, defense, and specialized environments [5,12]. Features such as global anthropometric databases, posture and join mobility analysis, field of vision and reach analysis, and full integration with CAD software have enabled RAMSIS to play a critical role in many user-centered design projects of vehicles and workstations by elevating performance, and well-being of operators of work systems [2,10]. These are very features that transform RAMSIS from a mere engineering tool into a multidisciplinary platform.

RAMSIS limitations and its future direction

Despite these advancements, it must be noted that RAMSIS still has some limitations. First, the software remains constrained by its high acquisition and licensing costs, which can limit accessibility for many research and industrial teams. Second, effective deployment of RAMSIS requires substantial user expertise—particularly when applied in the early conceptual stages of design—reducing its practicality for non-specialist users or rapid iterations. Third, RAMSIS also presents limitations in its representation of global anthropometric diversity, as some population groups remain insufficiently modeled or underrepresented within its databases. This incomplete coverage can reduce the accuracy of posture predictions and ergonomic assessments when applied to user populations whose body dimensions deviate from the available datasets. Lastly, the software has a relative weakness compared to other specialized tools like AnyBody or OpenSim in providing more precise biomechanical analyses (internal muscle and joint forces) [3,4]. Therefore, the best approach for the future may be to combine the capabilities of RAMSIS with specialized biomechanical software to provide a more comprehensive picture of human-environment interaction [21].

From a future research perspective, the literature shows that three key trends can define the development path of RAMSIS:

1. Integration with Virtual Reality (VR) and Augmented Reality (AR) technologies: This evolution will allow designers and users to experience a more realistic interaction with the environment and product before manufacturing [3].

2. Convergence with Biomechanical and Medical Models: A promising direction for future research would be the integration of digital human simulation with detailed biomechanical modelling pipelines. Specifically, exporting kinematic outputs from RAMSIS and importing them into advanced musculoskeletal simulation platforms (e.g., OpenSim or AnyBody) could enable quantitative estimation of joint loads, muscle forces, and stability metrics that RAMSIS alone does not compute. This combined workflow would allow ergonomists and designers to translate realistic posture and interaction scenarios into biomechanical outcomes, facilitating more precise assessment of musculoskeletal risks, balance demands, and fatigue development across tasks [4].

3. Advancements in the Digital Twin domain: RAMSIS can become part of the users' digital twin, playing a central role in designing the next generation of smart vehicles, spacecraft, and medical equipment [3,21].

To conclude, over the decades, RAMSIS has evolved into one of the most established and widely adopted Digital Human Modeling tools. While originally developed for ergonomic analysis in the automotive and transportation sectors, its use has expanded into fields such as aerospace, medicine, and defense. Through its global anthropometric databases, advanced posture and mobility analysis, vision and reach assessments, and seamless CAD integration, RAMSIS supports user-centered design across diverse applications from vehicle to workstation design. These capabilities position it not merely as an engineering tool, but as a multidisciplinary platform for optimizing operator performance and well-being.

Conflict of Interest
The authors declare no conflict of interest.

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Author's Contributions
Study Conception or Design: MKD
Manuscript Drafting: MA
Critical Manuscript Revision: MKD
All authors have approved the final manuscript and are responsible for all aspects of the work.

AI Statement
During the preparation of this work the author(s) used ChatGPT in order to edit the manuscript. After using service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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