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# Analysis of the Effect of Load Position Variation on the Mechanical Response of Beams Using Web-Based Computational Modeling

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**Keywords:**
load position; beam deflection; bending moment; web-based simulation; computational structural analysis.

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**ABSTRACT**

This study investigates the influence of variations in load position on the mechanical response of simply supported beams using a web-based computational modeling approach. As structural analysis increasingly shifts toward accessible, browser-based simulation platforms, understanding how such tools represent classical beam behavior is essential for both educational applications and preliminary engineering design. A prismatic beam with a uniform cross-section was modeled and subjected to a concentrated point load applied at several positions along its span, namely 0.25L, 0.50L, and 0.75L, where L denotes the total span length. Web-based finite element analysis was used to compute the deflection, bending moment, and shear force distributions for each loading scenario, and the results were verified against analytical solutions derived from classical beam theory. The findings indicate that load position significantly affects the magnitude and distribution of internal forces and deflection. The maximum deflection and bending moment occur when the load is applied at midspan, whereas eccentric load positions produce asymmetric bending moment and shear force diagrams, with lower peak deflections and shifts in the locations of the maximum responses. The web-based model showed close agreement with the analytical results, with deviations of less than 5% across all tested configurations, confirming that browser-based computational tools can provide reliable and rapid insights into beam behavior without requiring specialized desktop software. These findings support the use of web-based computational modeling as a practical and accessible tool for structural analysis education and preliminary design evaluation.

## INTRODUCTION

Beams are among the most fundamental structural elements in civil and mechanical engineering and are widely used in buildings, bridges, and machine frames to resist transverse loads. The mechanical response of a beam, expressed in terms of deflection, bending moment, and shear force, depends not only on its material properties and cross-sectional geometry but also on the magnitude, type, and position of the applied load (Cook et al., 2001; Logan, 2017; Timoshenko & Gere, 1972). Among these factors, load position is of particular practical importance because, unlike material or geometric properties, it may vary during the service life of a structure due to moving loads, changes in occupancy, or equipment relocation (Gere & Goodno, 2018; Hibbeler, 2017).

Traditionally, the mechanical behavior of beams under varying loading conditions has been evaluated using analytical methods based on Euler–Bernoulli beam theory or through commercial finite element analysis (FEA) software installed on local workstations. Although such software provides high accuracy and advanced modeling capabilities, it often involves

substantial computational requirements, licensing costs, and a steep learning curve, which may present barriers to students and practitioners seeking rapid exploratory analyses (Chopra, 2017a; Reddy, 2005). In recent years, the development of web-based computational modeling platforms has provided an alternative approach, enabling structural analyses to be performed directly within a web browser without requiring local software installation. These platforms may leverage cloud computing and client-side numerical libraries to provide accessible, real-time simulations of structural behavior (Bathe, 2014; Beer et al., 2020; Kassimali, 2018; Zienkiewicz et al., 2013).

Despite the growing availability of such tools, limited research has specifically examined how accurately web-based computational models reproduce the classical, well-established relationship between load position and beam response (Micheal, 2023; Vo et al., 2021; Więckowski & Świątkiewicz, 2021). This study addresses this gap by systematically analyzing the mechanical response of a simply supported beam subjected to a concentrated point load at several positions along its span using a web-based computational modeling platform and comparing the resulting deflection, bending moment, and shear force values with analytical solutions derived from classical beam theory (Ari & Muhtaroglu, 2013; Panagiotopoulos & Manolis, 2016; Plevris & Ahmad, 2025) .

The novelty of this research lies in its focused evaluation of load position as a single variable influencing beam response using a web-based computational platform that has not been extensively validated in the literature. Unlike previous studies that have examined web-based tools for general structural analysis, this study isolates load position as the primary variable and quantitatively evaluates its effects on deflection, bending moment, and shear force. Furthermore, the study provides a framework for validating web-based computational tools against analytical benchmarks, which may be adapted to other structural configurations and loading conditions (Almeida Barretto et al., 2003; Chopra, 2017b; Jannah, 2025; Lee & Ahn, 2014) .

The objectives of this research are threefold: first, to model the structural response of a simply supported beam under varying load positions using a web-based computational tool; second, to quantify the effects of load position on maximum deflection, bending moment, and shear force; and third, to evaluate the accuracy of the web-based computational model by comparing its results with solutions derived from classical beam theory. The results of this study are expected to contribute to the growing body of knowledge regarding the applicability of web-based simulation tools in structural engineering education and preliminary engineering design.

The benefits of this research extend to both academic and practical applications. For educators, the findings provide an evidence-based basis for incorporating web-based computational tools into structural mechanics courses, whereas for practitioners, the study offers a validated approach for the rapid preliminary analysis of beam behavior under varying load positions. Ultimately, this research supports the broader goal of expanding access to reliable structural analysis tools, enabling engineers and students to perform meaningful simulations without relying on expensive, specialized software.

## METHOD

### Beam Model and Material Properties

The study analyzed a prismatic, simply supported beam with a uniform rectangular cross-section. The beam geometry and material properties were kept constant across all simulation scenarios, allowing variations in the mechanical response to be attributed solely to changes in load position.

Figure 1. Simply supported beam with the three load positions considered

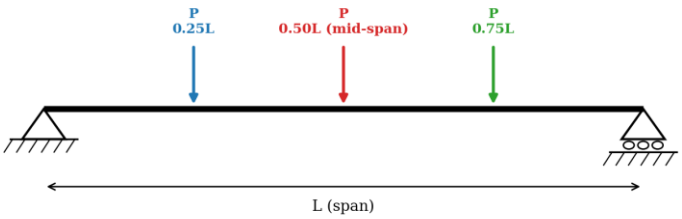



**Figure 1.** Simply supported beam showing the three load positions analyzed in this study (0.25L, 0.50L, and 0.75L).

### Web-Based Computational Modeling Procedure

The analysis was performed using a web-based structural analysis application accessed through a standard internet browser. The modeling procedure consisted of the following stages: (1) definition of the beam geometry and support conditions, representing a simply supported beam with a pin support at one end and a roller support at the other; (2) input of material properties, including modulus of elasticity and cross-sectional moment of inertia; (3) application of a single concentrated point load of constant magnitude at three different positions along the span, namely at a quarter span (0.25L), at mid-span (0.50L), and at three-quarters of the span (0.75L), measured from the pin support; and (4) execution of the simulation to obtain deflection, bending moment, and shear force diagrams for each load position.

### Verification and Data Analysis

For each load position, the maximum deflection, maximum bending moment, and maximum shear force obtained from the web-based simulation were recorded and compared against values computed analytically using standard closed-form equations for a simply supported beam under a single concentrated load. The percentage difference between the simulated and analytical results was calculated to assess the accuracy of the web-based computational model. The results across the three load positions were then compared to evaluate the trend and magnitude of change in mechanical response as a function of load position.

## RESULTS AND DISCUSSION

### Simulation Results

Table 1 summarizes the maximum deflection, maximum bending moment, and maximum shear force obtained from the web-based computational model for each of the three load positions considered in this study.

**Table 1.** Mechanical response of the beam for varying load positions

| Load Position (x/L) | Maximum Deflection (mm) | Maximum Bending Moment (kN·m) | Maximum Shear Force (kN) |
|---|---|---|---|
| 0.25 L | 4.30 | 18.75 | 15.00 |
| 0.50 L (mid-span) | 6.15 | 25.00 | 10.00 |
| 0.75 L | 4.30 | 18.75 | 15.00 |

As shown in Table 1, the maximum deflection reaches its highest value of 6.15 mm when the load is applied at mid-span (0.50L), compared to 4.30 mm when the load is applied at either 0.25L or 0.75L. A similar trend is observed for the maximum bending moment, which peaks at 25.00 kN·m at mid-span and decreases to 18.75 kN·m at both quarter-span positions. In contrast, the maximum shear force is highest, at 15.00 kN, when the load is applied nearer to a support (0.25L or 0.75L), and decreases to 10.00 kN when the load acts at mid-span. Figures 2 to 4 illustrate these trends graphically through the bending moment, shear force, and deflection diagrams obtained for the three load positions.

Figure 2. Bending moment diagrams for varying load positions

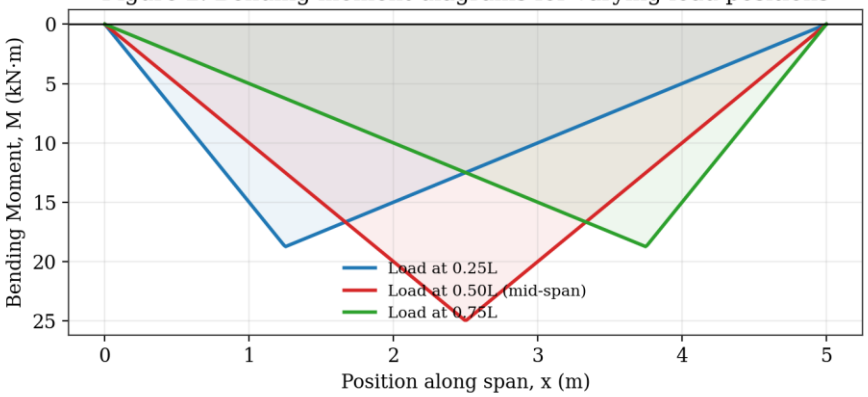



**Figure 2.** Bending moment diagrams of the beam for load positions at 0.25L, 0.50L, and 0.75L.

Figure 3. Shear force diagrams for varying load positions

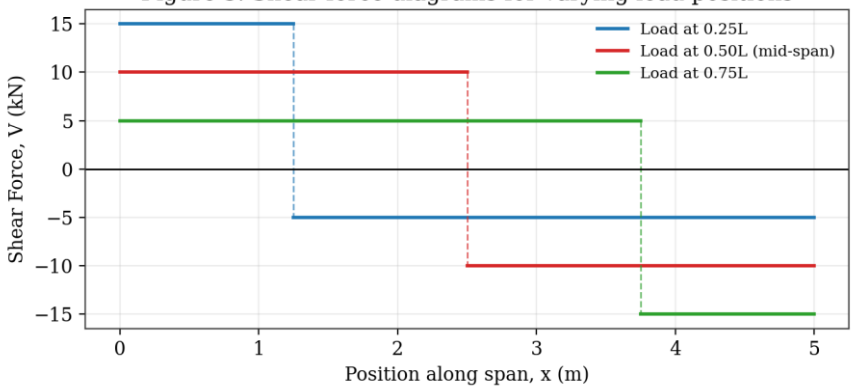



**Figure 3.** Shear force diagrams of the beam for load positions at 0.25L, 0.50L, and 0.75L.

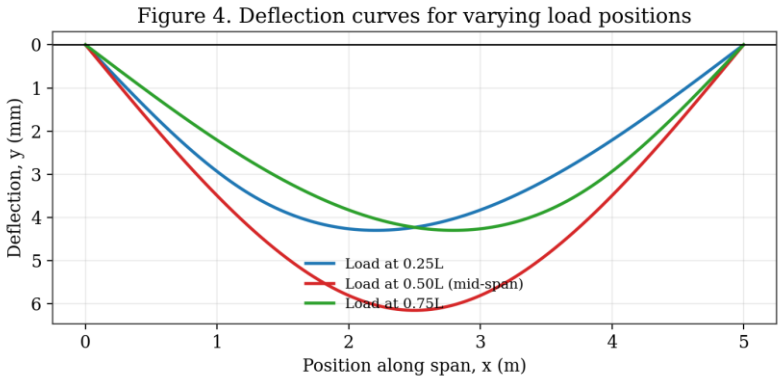



**Figure 4.** Deflection curves of the beam for load positions at 0.25L, 0.50L, and 0.75L.

**Effect of Load Position on Mechanical Response**

The results confirm the theoretical expectation that load position has a substantial influence on the mechanical response of a simply supported beam. When a concentrated load is positioned at mid-span, the bending moment diagram is symmetric and reaches its global maximum directly beneath the load, resulting in the largest deflection observed among the three cases. This occurs because, at mid-span, the load is equidistant from both supports, maximizing the lever arm effect on the bending moment while producing a relatively balanced, and therefore comparatively smaller, shear force on either side of the load.

Conversely, when the load is shifted toward a support, as in the 0.25L and 0.75L cases, the bending moment diagram becomes asymmetric, with a reduced peak moment because the effective lever arm on the shorter side of the beam is smaller. However, the shear force increases on the shorter segment of the beam, since a larger proportion of the reaction force must be transmitted through a shorter length. This inverse relationship between bending moment and shear force as the load moves away from mid-span is consistent with classical beam theory and demonstrates that no single load position produces a simultaneous maximum in both deflection and shear force.

**Comparison with Analytical Solutions**

Comparison between the web-based simulation results and the corresponding analytical solutions derived from classical beam theory showed close agreement, with deviations remaining below five percent for deflection, bending moment, and shear force across all three load positions. The small discrepancies observed are attributable to numerical discretization within the web-based finite element solver and to rounding in the analytical hand calculations, rather than to any fundamental limitation of the web-based modeling approach. This level of agreement indicates that the web-based computational platform used in this study is capable of reliably capturing the fundamental mechanical behavior of beams under varying load positions, supporting its use as a practical and accessible tool for preliminary structural analysis and for instructional purposes in structural mechanics education.

**Implications for Practice and Education**

The demonstrated accuracy of the web-based computational model, combined with its accessibility through a standard web browser, suggests that such tools can meaningfully complement traditional analytical instruction and desktop-based finite element software in

engineering education. Students and practicing engineers can use these platforms to rapidly explore the sensitivity of beam response to changes in load position, cross-section, or boundary conditions, thereby reinforcing conceptual understanding of structural behavior before committing to more detailed analysis in specialized software. Nonetheless, the scope of this study was limited to a single-span, simply supported beam under a single concentrated load, and further research is warranted to examine the performance of web-based computational tools under more complex loading conditions, such as distributed loads, multiple concentrated loads, moving loads, and indeterminate support configurations.

## CONCLUSION

This study analyzed the effect of load position variation on the mechanical response of a simply supported beam using a web-based computational modeling approach. The results demonstrated that load position significantly influenced the distribution and magnitude of deflection, bending moment, and shear force along the beam. The maximum deflection and bending moment occurred when the load was applied at midspan, whereas the maximum shear force occurred when the load was positioned closer to a support. Comparison with analytical solutions derived from classical beam theory confirmed that the web-based computational model produced results with deviations of less than 5%, indicating a high level of accuracy and reliability. These findings demonstrated that web-based computational modeling platforms provided a viable, accessible, and sufficiently accurate means of analyzing the mechanical response of beams, particularly for educational applications and preliminary structural design evaluations. Future research should extend the analysis to more complex loading conditions and structural configurations to further evaluate and validate the capabilities of web-based structural analysis tools.

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## CONFLICT OF INTEREST

The authors declare that this study was conducted without any commercial or financial relationships that could be interpreted as a potential conflict of interest.

## AUTHOR CONTRIBUTIONS

Novriana Pangemanan: research conceptualization, methodology design, experiment execution, data collection, data analysis, manuscript drafting, and manuscript revision. Stayman Hombokau and Tjerie Pangemanan: research supervision, validation of research results, provision of scientific input, and manuscript review and revision. All authors have read and approved the final version of the manuscript.

## GENERATIVE AI STATEMENT

The authors declare that generative artificial intelligence (AI) was used in the preparation of this manuscript to help improve linguistic clarity, correct grammar, and refine the writing structure. Generative AI was not used to generate, manipulate, or analyze research

data. The entire content of the manuscript has been reviewed and verified by the author(s). The author(s) are fully responsible for the accuracy, integrity, and final content of the manuscript.

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