In this thesis, we study quantum aspects of the minimal renormalizable SO(10) Grand Unified Theory with the scalar sector consisting of $\mathbf{45} \oplus \mathbf{126} \oplus \mathbf{10}_{\mathbb{C}}$. It is an interesting candidate for a theory describing physics beyond the Standard model which has the potential to allow for proton lifetime prediction with Plank-scale-physics-induced theoretical uncertainties confined within the expected one-order-of-magnitude experimental proton lifetime improvement window.

With the complete information about the numerical one-loop scalar mass spectrum and analytical one-loop beta functions of all the dimensionless scalar couplings, we formulate consistency criteria that every viable region of the parameter space must satisfy; namely, we require the existence of a stable Standard-model-like vacuum, unification of gauge couplings and robustness of perturbative calculations.

Only narrow parameter space regions around symmetry breaking chains with $\mathrm{SU}(4)_C \times \mathrm{SU}(2)_L \times \mathrm{U}(1)_R$ or $\mathrm{SU}(3)_c \times \mathrm{SU}(2)_L \times \mathrm{SU}(2)_R \times \mathrm{U}(1)_{B-L}$ intermediate stages are demonstrated to be potentially realistic. Detailed analysis of the SO(10) Higgs model with $\mathbf{45} \oplus \mathbf{126}$ scalar sector indicates a preference for the former option, mainly due to increased perturbative instability and phenomenologically unsuitable values of energy scales predicted in the latter symmetry breaking case. Moreover, we calculate partial proton decay rates for two channels $p \to \pi^+ \overline{\nu}$ and $p \to K^+ \overline{\nu}$ with antineutrinos in the final states.

Afterwards the analysis is repeated in case of the full SO(10) Grand Unified Theory with the $\mathbf{45} \oplus \mathbf{126} \oplus \mathbf{10}_{\mathbb{C}}$ scalar sector in the symmetry breaking regime with $\mathrm{SU}(4)_C \times \mathrm{SU}(2)_L \times \mathrm{U}(1)_R$ intermediate stage. The existence of a realistic Yukawa sector is discussed. We identify the inability of the model to successfully accommodate Standard-Model-like low-energy Higgs boson in the perturbatively stable parts of the parameter space. Hence perturbativity criteria turn out to be a powerful tool to constrain viable regimes of the minimal SO(10) Grand Unified Theory.