# Chapter 1
# Model–Driven Adaptive Enterprise:
## A Conceptual Outline

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## ABSTRACT

*Modern enterprises are large complex systems operating in dynamic environments and are therefore required to respond quickly to a variety of change drivers. Moreover, they are systems of systems wherein understanding is only available in localized contexts and is partial and uncertain. Given that the overall system behaviour is hard to know a-priori and that conventional techniques for systemwide analysis either lack rigour or are defeated by the scale of the problem, the current practice often exclusively relies on human expertise for adaptation. This chapter outlines the concept of model-driven adaptive enterprise that leverages principles from modeling, artificial intelligence, control theory, and information systems design leading to a knowledge-guided simulation-aided data-driven model-based evidence-backed approach to impart adaptability to enterprises. At the heart of a model-driven adaptive enterprise lies a digital twin (i.e., a simulatable digital replica of the enterprise). The authors discuss how the digital twin can be used to analyze, control, adapt, transform, and design enterprises.*

## INTRODUCTION

Modern enterprises are complex systems of systems operating in an increasingly dynamic environment. Due to their large size and scale of operation, understanding is usually limited to localized contexts. Even this localized understanding is typically partial and quickly gets outdated as some of the assumptions made of the operating environment no longer hold. In order to respond to a wide variety of change drivers, an enterprise must adapt by constantly changing its strategies, policies, business practices, and systems. However, such an adaptive enterprise cannot be realized without adequate understanding of its global behavior which is difficult to know a-priori as it emerges out of complex interactions among constituent systems.

Enterprise modeling practice views an enterprise on three related planes namely *Strategy plane*, *Process plane* and *Systems plane* as shown in Figure 1. The strategy plane focuses on goals, strategies, and policies that are expressed using modeling languages such as i* (Yu, Strohmaier, & Deng, 2006), KAOS (Dardenne, Lamsweerde, & Fickas, 1993), and TROPOS (Bresciani, Perini, Giorgini, Giunchiglia, & Mylopoulos, 2004). The process plane focuses on realizing these strategies and policies to achieve the stated goals using modeling languages such as BPMN[1], System Dynamic models (Meadows & Wright, 2008), and Event-Driven Process Chains (Mendling, 2008). The systems plane focuses on implementing these processes through software systems using modeling languages such as UML[2] and SysML (Friedenthal, Moore, & Steiner, 2014). However, the links across these models whether in a plane or across the planes are informal and typically in document form. As a result, these models are not amenable to rigorous analysis and hence cannot establish whether a given implementation achieves the intended goal.

*Figure 1. Three planes of enterprise*
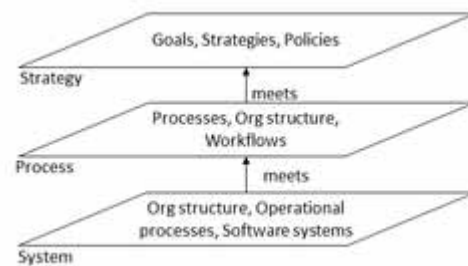


To meet the needs of an adaptive enterprise, the three plane view of Figure 1 needs to be refined as shown in Figure 2 where an enterprise is viewed in terms of three related planes namely: *Intent* plane addressing the *why* aspect in terms of goals, capabilities, and measures; *Design* plane addressing the *what* aspect in terms of models of organisational structure, processes, and information systems required to achieve the desired intent; *Implementation* plane addressing the *how* aspect in terms of organisation and its information systems; and interactions of the three planes with the environment as shown in Figure 2. An adaptive enterprise should be able to change its goals and capabilities in response to changes in its operational environment. It should then be able to effect appropriate modifications to its organizational

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