Design for supply chain has become an essential consideration while designing a new product. Previous studies pointed out that early supplier involvement can contribute to the success of the product development and enhance the competitive advantage of the enterprise. However, most of the studies coordinating supplier selection and supply chain configuration make these decisions during the detail design stage, which is the last phase of product design. This research aims to investigate the supply chain scenarios for their relevant performance at the conceptual design stage. The performance of different supply chain scenarios (i.e., centralized and decentralized), are compared and discussed. The results show that the decentralized supply chain scenario is advantageous for the time performance of the supply chain network, whereas the centralized supply chain scenario demonstrates superiority on the cost performance.

Fig. 1. Overview of methodology.
Fig. 2. Foundation of the proposed method.

Fig. 3. Bicycle supply chain structure.
Background of the Case Study

The bicycle was first introduced in the eighteenth century for the purpose of transportation. Based on modern functions and usage, bicycles can be divided into five different types: road, mountain, city and path, child, and bicycle motocross (BMX) [31]. The general architecture of a bicycle can be broken down as the structure (comprised of three subsystems: fork, frame, and saddle), the braking system, the transmission system, and the wheel system. The braking system, as its name implies, is responsible for decelerating a bicycle’s speed. The transmission system defines the functions and usage of the bike. The wheel system enables the bike to move by creating friction with the ground. Together with the structure, these subsystems are modular designs, which are mutually independent but cooperate as a whole product. Two optional subsystems are an electric motor with a battery and accessories that save physical effort and take into consideration the environment in which the bicycle will be used. The EMS model considers a total of seven components and functions, and it excludes the motor. The supply chain structure of a bike can be arranged in four layers. The upstream layer in Fig. 3 consists of subsuppliers (Tier 2) who provide raw materials. The second layer (Tier 1) is made up of suppliers who produce the components of the bike. The next layer is the focal company, which focuses on the assembly process and manufacturing key components. Finally, the last layer is the distributors who set up the market channels and provide services to customers. Further subdividing the last category, there are three major distributors in the bicycle supply chain. Mass-market distributors include Wal-Mart and Target, which emphasize the mass-market segment with unit prices lower than $250 [33]. Both independent bike distributors and sports stores sell specialized bikes in niche market areas. The U.S. bicycle business was a $6 billion industry in 2008 [33]. Of interest to this study, road bike sales occupied 30.6% of the market share in 2005 [34], which is the largest segment of the market.

In our case study, X-bike is a bicycle company located in central Pennsylvania, and it is currently a high-end product leader. However, the size of the high-end market is small, and manFig. 4. (a) Two-Module and (b) Three-Module product architectures. agement has decided to extend the company’s business to the mid-market products. The purpose of the product design function is to create a road bike with a price range of $400 to $1,000 USD and a production quantity of 10,000 per month. Company managers would like to have an acceptable lead-time interval to ensure responsiveness to market dynamics. The lead-time target is 130 days, beginning with component manufacturing and ending with completion of the final assembly process. The mission of the design team is to develop one or more design concepts that satisfy both product design and supply chain considerations regarding cost and time.