CHAPTER 1

Understanding the Bicycle as a Product

Abstract A bicycle is an artefact, a product made from a complex set of activities based on various technologies and materials. A bicycle encompasses a long list of pieces that can be arranged to form a product architecture, which helps to understand how a bicycle is fabricated and how the bicycle industry evolved over time. The manufacturing of a bicycle is rooted in the context of other metal-using industries and can be better understood through the hypothesis of technological convergence. The history of bicycle fabrication is also intertwined with the principle of interchangeable parts and the influence exercised on the automobile industry. The chapter expands its focus from how a bicycle is manufactured to the key categories of firms participating in the business system adopted within the bicycle industry.

Keywords Product architecture · Technological convergence · Interchangeable parts · Manufacturing processes · Business system

1.1 A Brief Glance at Four Generations of Bicycles

The history of what we now call *bicycle* is studded with controversial narratives about its origin, inventors, and technical evolution. When was the first bicycle invented? Who was the inventor? Which was the

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country leader in technological innovation? Which were the technical features of the bicycle? How did the bicycle evolve over time? This is a partial list of questions that have often received contentious answers within the community of both learned and scholarly people interested in bicycle history. The study of bicycle history has advanced since the 1990s and some valuable contributions are now available, helping to clarify controversies and broadening the knowledge base. It is not realistic nor consistent with the goal of this book to provide a concise history of the bicycle that would not add anything to the available sources, which instead are specifically focused on building such a history.

The goal of this opening section is to offer a short historical background to emphasize the idea of bicycle evolution over time and its implications for conceptualizing the bicycle as a manufactured product. Before sketching how the bicycle evolved, it makes sense to recall one of the controversies regarding its history and specifically the origin of the English word bicycle. According to bicycle history books (Hadland and Lessing 2014, p. 40; Herlihy 2004, p. 23), the word bicycle appeared in France in 1828 indicating a light cab drawn by a single horse and having two wheels on a single axle. Later in 1867–1868 was used in France and the United States meaning a two-wheeled velocipede. It was also introduced in a British patent granted to J. I. Stassen, filed April 8, 1869 (Josephsson 1902, p. 330).

The transition from the early velocipede to the safety bicycle can be described through the conceptual framework developed under the umbrella of a social constructivist approach to technology studies, usually identified with the acronym SCOT. The proponents of such an approach (Pinch and Bijker 1984) see the developmental process of a technological artefact as a search for a solution to a problem recognized by the various social groups involved in its production and use (Bijker 1995, p. 32). It means that a relevant social group (such as the bicycle riders at the time) shares the same set of meanings, attached to the bicycle, and perceives a problem concerning that artefact that needs to be addressed. A range of solutions can be identified through a process based on an alternation of variation and selection among designs. The relevant social groups select some of the problems for further attention, then a variety of solutions are generated, some of these solutions are then selected, which subsequently generate new artefacts (Bijker 1995, p. 51). This evolutionary process changes the artefact's meaning attributed to the bicycle by the relevant social group, whether the solution is implemented or not. The process continues until when all the problems attached to an artefact by various relevant social groups are overcome and a dominant design is institutionalized. The social construction of technology as a method for analysing the history of technologies is not without critiques (Humphreys 2005), but despite them, it is still a valuable model for understanding the multidirectional and complex process of technological innovation.

The present-day bicycle has undergone changes across four generations of bicycles since the 1810s to the late 1890s. These changes are linked to the problems perceived by the relevant social groups concerned with the bicycle and are the results of the developmental process aimed at introducing a new design.

The first generation of bicycles is broadly called the *early velocipede*, also known as draisine or hobbyhorse as a nickname (Hadland and Lessing 2014, p. xvii). It was introduced in Germany in 1817 and made of wood and iron tyres. The rider sat nearly erect and propelled the machine by pushing off the ground with one foot, then the other, as if running (Herlihy 2004, p. 21). Wheels were equal in size and the seat height made easier for the rider to put his feet on the ground (Hadland and Lessing 2014, p. 12). The more fundamental problems recognized by its users were the lack of comfort, the force needed to steer it, and the muddy feet (Bijker 1995, p. 25). The latter problem refers to the road conditions at the time when mud was very frequent and rider's feet were inevitably covered by it. The revision of the draisine gave birth to the second generation of bicycles called the *cranked velocipede*, also known as boneshaker as a nickname. It first appeared in France between 1866 and 1868. This new artefact was similar to the early velocipede, except for cranks attached to the axle of the front wheel. These cranks were pushed by the feet, thus enabling the rider to sit without walking in the mud. Initially, the cracked velocipedes had wooden wheels with iron hoop tyre, which made them noisy on paved roads and subject to sideslip. By 1869, some makers were offering rubber or leather coverings for the iron rims (Hadland and Lessing 2014, p. 59). The front wheel was bigger than the rear wheel and the seat was about one metre from the ground. The cranked velocipedes addressed the problems of the early velocipedes, but were affected by further problems recognized by other relevant social groups. Specifically, the tendency to push one's body backward and away from the pedals when the going became heavy and more force was needed, and the speed problem (Bijker 1995, pp. 28–30). The speed was limited by the pedalling cadence and the wheel diameter as the cranks were directly connected to the front wheel, consequently the only way to realize a greater speed over the ground was to increase the diameter of the front wheel (Berto 2006, p. 21). The answer to these problems was a new generation of bicycles called *high-wheeler*, also known as ordinary or penny-farthing as a nickname. It appeared in France in 1868–1869 and adopted in Britain and United States in the 1870s. The rider sat almost directly over the large front wheel that had a diameter between 43 and 60 inches. The rear wheel was smaller and the saddle height about 1.30 metre. The search for speed had become so important that the trend of enlarging the front wheel continued, and this made it necessary to move the saddle in order to keep pedals within reach of the feet (Bijker 1995, p. 43). The main problem perceived by both users and non-users of the high-wheeler was safety. Any sudden obstruction to the motion of the bicycle frequently had the effect of sending the rider over the handlebar. This element of insecurity soon led to the introduction of other designs of bicycles (Sharp 1896, p. 150).

Several solutions were developed to address this issue roughly in the same period from the late 1870s to the 1880s, but one became known as the fourth generation of bicycles and was called *safety bicycle*. It was invented in 1879, but attained popular favour in 1885 when British cycle makers show the new design to the public for the first time. The Rover, produced in Coventry by John Kemp Starley and William Sutton, was the first true safety bicycle, even though it took two years and three models to evolve into the definitive design of 1886 (Berto 2006, p. 38). The safety bicycle was based on the idea of applying drive to one wheel and steering the other, rather than trying to drive and steer the same wheel (Hadland and Lessing 2014, p. 156). It was a low wheeled bicycle with a saddle height of about one metre, a chain-driven rear wheel, equal-sized wheels, and a triangulated frame. This design formed the prototype of the modern rear-driving bicycle. It had the following advantages: the lower centre of gravity made it safer because it could not tilt forward and the foot could be put to the ground; the riding position was at the same time comfortable and efficient; the weight of the rider was better distributed between the two wheels, which was better for hill climbing and for descending; the bicycle with the chain drive could be geared up or down to suit the rider's needs (Ritchie 2018, p. 181). Table 1.1 provides a comparative analysis of some basic technical features that distinguish each generation of bicycles (Hadland and Lessing 2014; Berto 2006; Minetti et al. 2001).

Table 1.1 Technical data across four generations of bicycle

	Early velocipede	*Cranked velocipede*	*High-wheeler*	*Safety bicycle*
Year	1817	1866–1868	1868–1869	1885
Front wheel diameter (inch)	27	32–36	43–60	30
Rear wheel diameter (inch)	27	29	17–30	30
Tyres	Metal	Metal/solid rubber	Solid rubber	Pneumatic
Saddle height (metre)	0.86	0.99	1.31	1.01

The design of 1886 was further changed through incremental improvements to address the problem of vibration and of going faster on level ground and uphill. In the late 1880s, the invention of the pneumatic tyres by John Boyd Dunlop improved both speed and comfort over the solid rubber tyres. The pneumatic technology was, in turn, further developed through the detachable tyre principle, the repairable tyre principle, and improved valves. The problem of speed, particularly when taking account of factors such as gradients and wind direction (Hadland and Lessing 2014, p. 221), was addressed through the development of a multi-speed gearing mechanism. The first attempts to design a transmission were conducted between the late 1900s and 1910s. In the 1920s, in France and Italy, some small manufacturers created reliable and effective derailleurs that could be retrofitted, which is installed on existing bicycles (Berto 2006, p. 95). The derailleur came of age and became completely practical in the 1930s (Berto 2006, p. 142).

The safety bicycle has become the dominant design and its characteristics are taken for granted as the essential ingredients of the artefact called bicycle nowadays. The introduction and widespread adoption of the safety design gave an immense impetus to the bicycle industry. The safety bicycle was manufactured in large quantities in Europe and United States since the late 1890s. It played a key role in the evolution of the bicycle industry and, consequently, it is useful to deepen its meaning as a product built through a manufacturing technology. The starting point is to decompose a bicycle.

1.2 Decomposing a Bicycle

What is a bicycle? This is not a trivial question as someone, not taking very seriously the bicycle, might think. A bicycle is a multidimensional object that has social lives. It means that its forms, uses and trajectories are intertwined in complex ways with people's lives (Vivanco 2013, p. 41). Its heterogeneous nature encompasses five dimensions interconnected with each other. First, a physical dimension: a bicycle is a material object, a physical thing, an artefact, a tangible product of technology. Its physical properties interact with both the rider and the environment where the bicycle is used. The relationship between a rider's physical characteristics and a bicycle's physical properties is particularly relevant as it influences the performance of the cyclist in pedalling. Second, a functional dimension: a bicycle is an object performing some specific functions, a useful thing that can be used for transportation, leisure and racing purposes. It helps people to move around in urban areas, it contributes to leisure activities such as cycle tourism, it is an essential tool for practicing cycle racing in various disciplines such as road, dirt, and track. Third, an economic dimension: a bicycle is a manufactured object that circulates through complex relationships between producers, labourers, and consumers. These relevant social groups have a vested economic interest in the bicycle. Producers and labourers are interested in the continued proliferation of the artefact, whereas consumers seek a satisfying consumption experience in buying and/or using a bicycle. Fourth, a psychological dimension: a bicycle is an object of cultivated desire. Both bicycle users and potential users might experience a strong longing to a bicycle or a bicycle brand, their fervent desire for such an artefact is not simply based upon needs, but increasingly explained through the passionate feelings and powerful emotions in connection with consumption activities. The psychological dimension is influenced by how producers shape the branding of a bicycle and how people think and talk about a bicycle. Fifth, a temporal dimension: a bicycle has a story to tell with a past, present and future. Its story is connected to its production, exchange, use and eventual disposal. A bicycle has a life course that can be described through a biography based on the following partial list of data: the name of the producer, the place of production, the year of production, the name of the seller, the place of selling, the year of selling, the name of the buyer, the name of the user and the year of disposal.

The five dimensions of a bicycle share what is usually called a product architecture within the manufacturing context (Ulrich 1995). A product, such as a bicycle, is a bundle of components and the architecture is the scheme by which the function of a product is allocated to physical components. The product architecture includes the arrangement of functional elements, the mapping from functional elements to physical components, and the specification of the interfaces among interacting physical components (Ulrich 1995, p. 420). Functional elements refer to what a product does as opposed to what the physical components of the product are. For example, the function for a bicycle, at a most general level of abstraction, consists of a single functional element: transportation (moving from point A to point B). At a more detailed level of abstraction, a collection of functional elements can be specified: support rider weight, make cycling comfortable, make cycling safe and make cycling efficient. The second part of the product architecture refers to physical components and their relationships with functional elements. Each component is a separable physical part and its role is to implement the function of the product. The relationship or mapping between functional elements and components may be one-to-one, many-to-one, or one-to-many. For example, a physical component such as a brake lever contributes to the function of making cycling safe, whereas a bicycle saddle contributes to both functions of supporting rider weight and making cycling comfortable. The third part of the product architecture is the specifications of the physical interfaces among interacting components. Interfaces may adopt a standard protocol used across many different manufacturers and countries or may be based on proprietary protocol. For example, a physical component such as a bottom bracket that interacts with another component called chainring is available in various options, some of them are based on a standard protocol allowing a broader use within the marketplace, whereas others adopt a proprietary protocol which is exclusively compatible with a particular chainring.

The concept of product architecture has been categorized into two typologies: modular and integral. However, it is rather difficult to find real products exhibiting one typology of architecture, most products are somewhere between the extremes of modular or integral (Ulrich 1995, p. 424). A modular architecture allows a one-to-one relationship between functional elements and physical components, and includes de-coupled interfaces between components. Two components are coupled if a change made to one component requires a change to the other in order for the overall product to work correctly (Ulrich 1995, p. 423). An integral architecture includes a complex (many-to-one, or one-to-many) relationship between functional elements and physical components. Modular architecture adopts standardized components and interfaces making easier to change the product over time as components are highly independent, unlike a tightly integrated product architecture that tends to utilize highly interdependent components designed to work specifically or exclusively with other particular components. A modular architecture can also contribute to the ability to economically create product variety to meet customer needs and desires. The degree of modularity can be increased both by expanding the range of compatible components that, in turn, impacts on the range of possible product configurations, and by uncoupling integrated functions within components (Schilling 2000, p. 318).

On a continuum between modular and integral product architecture, a bicycle lies closer to a modular product. Most of its physical components and interfaces are standardized and exception to this practice is for a small number of components usually available for expensive bicycles. A modular product such as a bicycle can be decomposed into a number of physical components that can be mixed and matched in a variety of configurations. The decomposition or disassembly analysis consists of describing the product concept through its physical components at a different level of detail. It is usually based on a four-level analysis: product, systems, subsystems, and components. Systems and subsystems, also called subassembly, are a collection of components that can be assembled into a unit, and can be subsequently treated as a single component during further assembly of the product (Ulrich 1995, p. 423). There is also a fifth level resulting from a complete disassembly of an artefact, down to the last nut, bolt and washer. This decomposition is to the level of individual piece parts and it is usually shown in exploded view drawings available within the catalogues of some companies manufacturing bicycle components.

A bicycle decomposition is depicted in Figs. 1.1 and 1.2. These figures should be examined together to better grasp the four-level analysis. The fifth level of piece parts is omitted for the sake of clarity. This disassembly regards a present-day bicycle descending from the safety bicycle of the 1920s and it is based on various sources (Barnett 2000; Berto 2006; Downs 2005; Grew 1921; Hadland and Lessing 2014; Jones 2005; Oliver and Berkebile 1974; Sharp 1896; Takeuchi 1991; Ueda 1981; Wilson

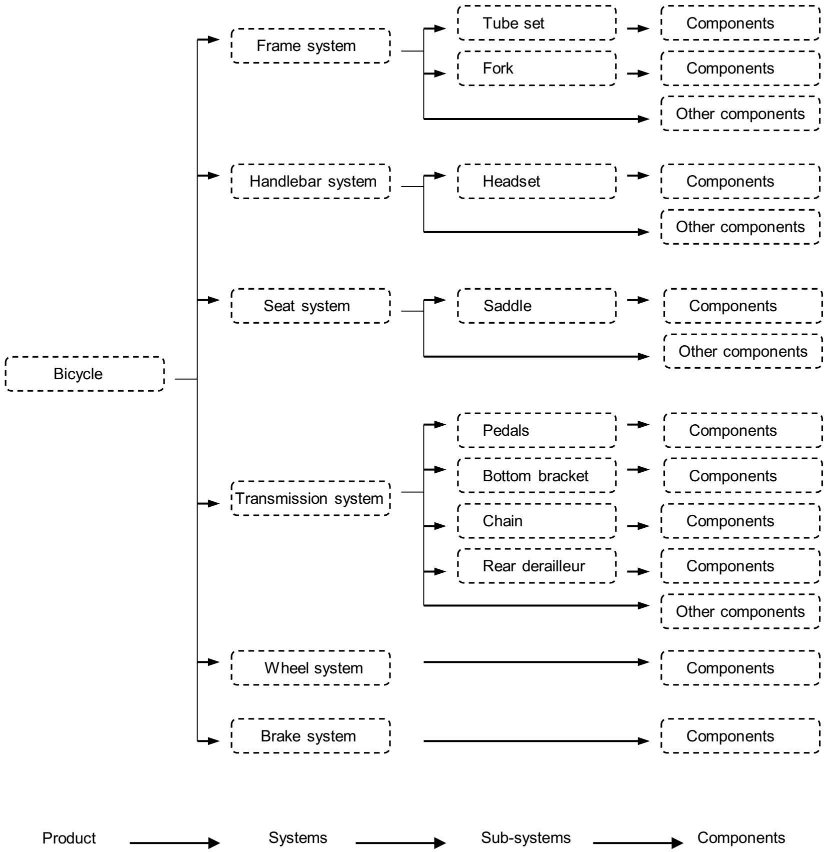

Fig. 1.1 Bicycle decomposition

and Papadopoulos 2004). Such a bicycle includes six systems: frame, handlebar, seat, transmission, wheel and brake.

The frame system contributes more than any other bicycle components to the safety, comfort and performance of the rider. It is the main component onto which the other components are attached. Its design reflects decisions about weight, strength, stiffness, geometry and cost, all of which are influenced heavily by the materials used (Snow et al. 2009). It includes two subsystems and further components: tube set, fork and dropouts (Fig. 1.2). A typical tube set consists of all of the structural

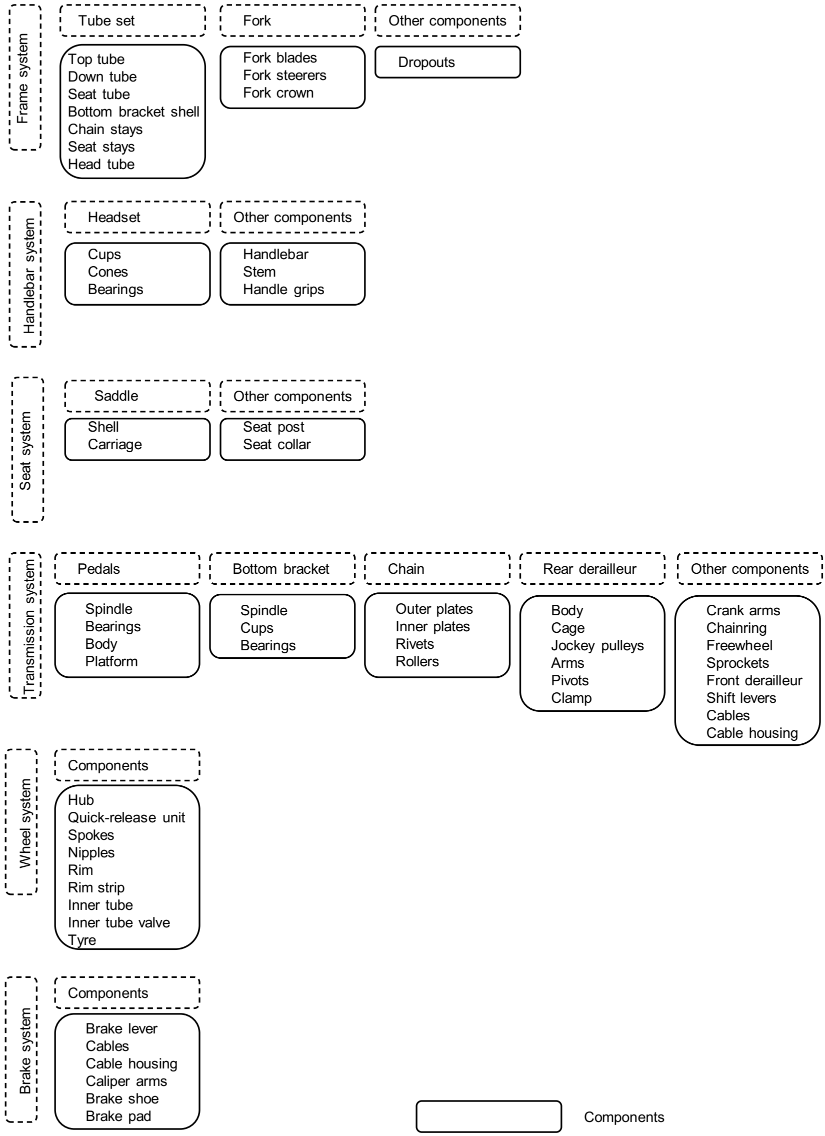

Fig. 1.2 Partial list of bicycle components

tubes required to build a bicycle frame, and its most common form is the diamond frame which includes two triangles. The main triangle composed of the head tube, the top tube, the down tube and the seat tube, and the rear triangle composed of the seat tube and paired chain stays and seat stays. Despite the common practice to use the name diamond, it is slightly misleading as very few bicycles have had a frame that, viewed on elevation, is a true diamond or rhombus, that is a quadrilateral with four equal sides (Hadland and Lessing 2014, p. 160). The frame system is completed with the fork subsystem, used to turn and allow the rider to control the bicycle, and the dropouts which are the slots in the rear triangle and fork where the wheel axles attach. The handlebar system includes a headset subsystem and further components. The headset is the bearing assembly that connects the fork to the frame and allows the fork to rotate inside the head tube (Barnett 2000, p. 2). Handlebar, stem and handle grips are the components that support the rider's hands and allow to control the bicycle. The seat system is composed of a saddle subsystem and further components. The saddle supports the greatest portion of the rider body weight when pedalling, and seat post and seat collar hold the saddle and secure inside the seat tube of the frame (Jones 2005, p. 167).

The transmission system encompasses two functions: to transmit power from the rider's feet and to do so in a way that enables the rider's limbs to move in as near optimum a manner as possible (Wilson and Papadopoulos 2004, p. 311). A transmission system is the connection between a bicycle's power source and the driving wheel. It is also called a drive train system. It includes four subsystems and further components. The pedals subsystem supports the rider's foot and acts as the pushing surface for the foot.

The bottom bracket subsystem is the bearing assembly that allows the cranks to rotate. The chain subsystem connects the front chainrings to the rear sprockets. It is a loop of links made of repeating pairs of outer plates and inner plates, held together by rivets. A roller separates the pair of inner plates (Jones 2005, p. 88). The rear derailleur subsystem moves the chain between the selection of gears on the rear wheel, it works by pushing or derailing the chain from one sprocket to another. Other components complete the drive train: the front derailleur moves the chain from one chainring to another by applying pressure to the side of the chain; the sprockets, also known as cogs or pinions, mesh with the chain and drive the rear wheel and bicycle forward; the chainrings are sprockets attached to the right crank arm that help the transmission of human power to the chain; the crank arms are levers turned by the rider's feet that connect the pedals to the bottom bracket.

The wheel system's function is to convey a load with low resistance when a bicycle rolls forward (Wilson and Papadopoulos 2004, p. 207). This system includes a set of components that allow a smooth ride of a bicycle as one of them (that is the tyre) is the outer portion of the wheel which actually touches the ground. The brake system has a twofold function: to improve bicycle handling and to control speed. It encompasses some components for both the front and rear brake.

The artefact decomposition described through Figs. 1.1 and 1.2 is shared by most types of bicycle, however, there are some differences in the list of components, not shown here, regarding particular bicycles such as the All-Terrain Bicycle (ATB), also known as MounTain bike (MTB) or off-road bicycle, that do not affect the four-level analysis. Moreover, some categories of bicycles had and still have further components such as mudguards, lamps, and bags which are classified as accessories and not included within the previous analysis.

Decomposing a bicycle helps to understand the various components needed to build it and provides some hints on the number of piece parts in a bicycle. The latter topic is not easy to address as it is one of the controversies surrounding the history of the bicycle. According to two sources of the late 1890s, the individual parts of a bicycle were 800 in a man's bicycle and 1000 in a woman's bicycle (Norcliffe 1997, p. 270), or 800 separate pieces (Herlihy 2004, p. 277). Norcliffe cited a British magazine of 1894 and Herlily a British magazine of 1896 in which there was an interview to Albert A. Pope, an American bicycle maker, who was in London for a business trip and provided the data about the number of parts contained in the bicycle manufactured by his company. Another source (Lloyd-Jones and Lewis 2017, p. 157) indicates that the bicycle made by Raleigh, the British bicycle maker, consisted of 1411 parts and if fitted with a Sturmey-Archer gear 1515 parts, during 1920–1934. This information is consistent with a further source (Babaian 1998, p. 41) that cited a British book of bicycle history published in 1955. A safety bicycle consisted of about 300 major components made up of some 1500 individual parts, and the chain alone had over 500 pieces. Wilson (1973, p. 88) indicates that the average bicycle has well over 1000 individual parts, but he did not mention any source for this information. In Japan, during the 1930s, a bicycle consisted of some 200 different parts (Takeuchi 1991, p. 151). A study of the bicycle industry claims that a bicycle may require as many as 200 different components (Mody et al. 1991, p. 20). The most detailed source is an article published, in 1923, by a French magazine that was the official bulletin of bicycle and car makers of Saint-Étienne (Anonymous 1923, pp. 30–31). This town was the centre of the French bicycle industry and it is often referred to as the French Coventry. The article provides a complete disassembly of a bicycle to the level of individual piece parts and the result is 1427 components excluding the accessories. It is possible to know the number of components for each system: frame 51, handlebar 79, seat 34, transmission 844, wheel 347 and brake 72. The drive train system is the most complex component, it has about 60% of the total number of parts followed by the wheel system which has about 25% of the parts of a bicycle. Presumably, the differences between the number of parts of each source depend on both the level of detail at which the components are considered and the evolution of the bicycle over time. The number of components changes at each level of the decomposition analysis: at a higher level (that is, more aggregated) the number is small whereas it increases at a lower level (that is, less aggregated).

The degree of modularization of a bicycle and the possibility to decompose the product in different levels of aggregation have a direct impact on bicycle maker's decisions regarding both component standardization and product variety. These decisions, in turn, affect the manufacturing process used to produce a bicycle and how the industry structure evolves over time. The manufacturing technology is the next step in understanding the bicycle as a product.

1.3 Manufacturing a Bicycle

The production of a bicycle is rooted within the context of other metal-using industries, particularly those already experienced in the production of durable goods requiring small, even intricate, mechanisms and parts (Harrison 1985, p. 51). There is a historical trajectory that links the manufacturing of a bicycle to the production of small firearms, sewing machines, and automobiles. The relationship between these industries can be understood through the hypothesis of *technological convergence* developed by Rosenberg (1963). He studied the industrialization of the American economy focusing on the role played by the capital goods industries, and more particularly the machine tool sector, in introducing and in diffusing technological change. His argument is that machine tools firms appeared as adjuncts to factories specializing in the production of a final product (Rosenberg 1963, p. 418). They worked with manufacturers in various industries to overcome production problems relating to metalworking. As each problem was solved, new knowledge went back into the machine tools firms, which then could be used for solving production problems in other industries (Hounshell 1984, p. 4). Both machinery producing and metal-using sectors showed common processes, initially in the refining and smelting of metal ores, subsequently in foundry work whereby the refined metals are cast into preliminary shapes and then in the various machining processes through which the component metal parts are converted into final form preparatory to their assembly as a finished product (Rosenberg 1963, p. 423). These industries were technologically convergent because there was a close relationship built on a technological basis, regardless of the final product manufactured by each of them. The manufacture of a wide range of products depended upon common metalworking processes, and the machine tool industry originated as a response to the machinery needs of a succession of particular industries making consumer durable goods or other capital goods. The machine tool industry was instrumental both in the initial solution of technological problems and in the rapid transmission and application of newly learned techniques to other uses (Rosenberg 1963, p. 425). The centre of technological convergence was the machine tool industry that performed two tasks: first, it developed or improved new skills and processes in response to problems that arose in particular industries; second, it transferred those new skills and processes to technologically related industries. The machine tool industry may be considered a pool or reservoir of skills and technical knowledge which are employed throughout the entire machine-using sectors of the economy (Rosenberg 1963, p. 426).

Initially, around 1820, the production of machine tools was undertaken by textile firms and arms makers on an ad hoc basis as there was no separately identifiable machine tool sector. These industries were both producers and users of machine tools designed to address the special requirements and specifications of their own manufacturing processes (Rosenberg 1963, p. 417). Textile firms produced heavier, general-purpose machine tools such as lathes, planers and boring machines, whereas arms makers needed lighter, more specialized high-speed machine tools such as turret lathes, milling machines and precision grinders (Rosenberg 1963, p. 419). Other industries played a similar role during the second half of 1800, particularly the manufacturers of sewing machines, bicycles and automobiles. Their evolution is intertwined with the growth of independent machinery-producing firms that occurred in a continuing sequence of stages roughly between the years 1840–1880. This historical sequence began with the small arms industry that impacted the production processes of the sewing machines industry, which, in turn, affected the manufacturing of the bicycle industry that, finally, influenced the technology used by the automobile industry. These sectors were related on a technological basis and each time a solution to the technical problems of a single industry was achieved, it became available for applications in other industries via the machine tool industry which acted as an agent of transmission (Fig. 1.3).

The starting point was the firearms industry during the first half of the nineteenth century when the United States Ordnance Department laid the foundation of a basic aspect of modern manufacturing, the interchangeability of parts (Hounshell 1984, p. 3). The Ordnance Department was an army bureau created in 1812 to inspect and distribute military stores, which in 1815 was in charge of controlling the Springfield and Harpers Ferry armouries, both federally owned arms plants (Hounshell 1984, p. 33). The army bureau spent a lot of money over a forty- or fifty-year period to change the current practice of craft manufacturing

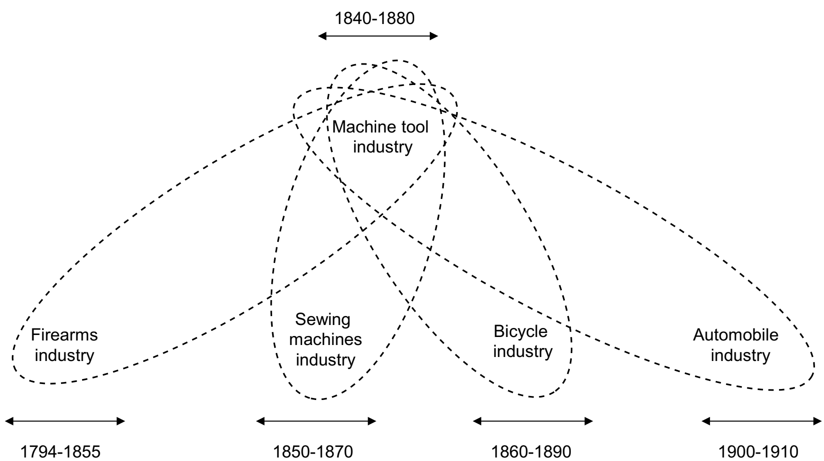

Fig. 1.3 Technological convergence

and reach the uniformity of parts (Hounshell 1984, p. 4). Originally the production of small arms was a handmade activity performed by skilled craftsmen which made each part of the gun by hand, carefully fitting piece to piece. It was a costly, time-consuming, and not very efficient way of fabricating metal parts because no two parts could be made exactly alike. The shortage of skilled gunsmiths and the high cost of production suggested developing an alternative approach to the manufacturing of firearms. The new approach, known as the *American system of manufactures* or *American system of manufacturing*, was based on the manufacturing involving the sequential series of operations carried out on successive special-purpose machines that produce interchangeable parts (Hounshell 1984, p. 15). The key to this system was the complete interchangeability of parts and the ease of attachment them to each other. More specifically, the principle of interchangeable parts was based on the following elements: precision machine tools, precision gauges or other instruments of measurement, uniformly accepted measurement standards and certain techniques of mechanical drawing (Woodbury 1960, p. 247). The system introduced the use of a set of tools called jig and fixture to hold or mount a piece of work. Jigs were simply a metal pattern to guide the machine at the correct angle for turning, drilling or boring and could be moved with the work. Fixtures were fastened to the machine and hold one or more pieces of work in the proper position when more than one machining operation was involved. Fixtures were usually divided into three main categories: holding, measuring, and bending fixture. The idea of interchangeability parts was imported from French military thought and practice which sought to rationalize its armaments in 1765 by introducing standardized weapons with standardized parts. The Ordnance Department through both its establishments and private contractors succeeded in reaching the uniformity of parts using machines by the mid-1850s.

This method of production was adopted and adapted by sewing machine manufacturers, which also hired personnel from small arms firms. The sewing machine industry developed from the 1850s through the 1870s and its machining requirements and processes were similar to those of firearms production. It played a major role as a source of machine tool innovations such as the turret screw machine, the universal milling machine, and the universal grinding machine (Rosenberg 1963, pp. 430–432). These innovations were applied to the production of other metal-using industries, particularly the bicycle sector that became an option for many sewing machine manufacturers, which lost their share of the market, in England and in the United States, and chose the bicycle as a new business. The bicycle industry built its technology of production, from approximately the 1860s through the 1890s, on both the armory practice and the sewing machine manufacturing through the transmission of machine tools and personnel, which played an equally important role in diffusing know-how as they moved from those sectors to bicycle production (Hounshell 1984, p. 5). The requirements of bicycle production revolved around the need for lightness, hardened precision parts and efficient power transmission and friction reduction. The solution to these problems impacted, directly or indirectly, all forms of manufacturing where friction reduction and power transmission were of considerable importance (Rosenberg 1963, p. 434). The bicycle manufacturers were responsible for introducing novel technologies and improved technologies which were made available for numerous new uses. The bicycle industry first employed steel tubing for frame construction, ball bearing, chain drive, differential gearing, pneumatic tyre and tangent-spoked wheels (Harrison 1977, pp. 88–103). It also developed techniques of quantity production utilizing special machine tools, sheet metal stampings and electric resistance (Flink 1990, p. 5). The bicycle manufacturers also stimulated the search for cheaper, lighter and more durable steel which further fostered the rise of the bicycle parts makers (Trescott 1976, p. 55).

The most important direct beneficiaries of the innovations in bicycle production were the automobile makers (Rosenberg 1963, p. 434). Some of them were first bicycle manufacturers such as Humber, Morris, and Rover in Great Britain; Bianchi in Italy; Clément, Darracq, and Peugeot in France; Opel in Germany; Pope, Peerless, Rambler, Winton and Willys in the United States. The transfer of technology from the bicycle sector into automotive production happened during the 1890s and early 1900s through the machine tool industry. The problems of large-scale automobile production involved the extension to a new product of skills and machines not very different from those which had already been developed for bicycles. There were significant continuities regarding the productive processes (Rosenberg 1963, p. 437). The bicycle industry developed both the practice of interchangeable parts and the sheet steel stamping technology which provided the technical basis for the development of mass production within automobile manufacturing in the early twentieth century (Hounshell 1984, p. 190).

The manufacturing processes used to build a bicycle are based on a variety of material conversion technologies that change the physical properties or appearance of materials, or combine them. It means that each workpiece material is altered to create the desired shape through one of the following transformation methods: processes for changing physical properties, processes for changing the shape of materials, processes for machining parts to a fixed dimension, processes for obtaining a surface finish, and processes for joining parts or materials (Hayes and Wheelwright 1984, pp. 167–170; Kalpakjian and Schmidt 2014, p. 16). For example, the starting material (that is the workpiece) may be in the shape of a plate, sheet, bar, rod, wire, or tubing and it can be transformed through a *forming* process that changes its shape to become a part needed to build a bicycle. Another example is the *rolling* process that involves reducing the thickness of a long workpiece by compressive forces applied through a set of rolls. One version of this process, particularly useful in the bicycle industry, is the rotary tube piercing, also known as the Mannesmann process developed in the 1880s. It is a hot-working operation for making long, thick-walled seamless pipe and tubing (Kalpakjian and Schmidt 2014, p. 332).

The production process used in the bicycle industry is a hybrid structure employing both a batch and an assembly line process. It means that items are processed in periodic small lots or batches and the assembly line is used as the final step in a long series of production activities. For example, components parts may be made in a metalworking department, a variety of those components may be combined into subassemblies, and these subassemblies may be assembled and tested using an assembly line (Piloni 1982, p. 116; Hayes and Wheelwright 1984, pp. 177–178). A bicycle is usually an assemble-to-stock product as it combines multiple component parts into a finished product, which is then stocked in inventory to satisfy customer demand. It can also be an assemble-to-order product to customer specification.

The basic elements of the production process involved in building a bicycle are shown in Fig. 1.4. The starting point is the drawing department where bicycles are designed in order to satisfy the needs and wants of potential customers. The outcome of this activity is the list of specific products that will be manufactured and their technical specifications. Identifying such specifications is a key task for deciding which raw materials, such as steel and aluminium, and components have to be bought. The procurement of raw materials and components allows to stock all

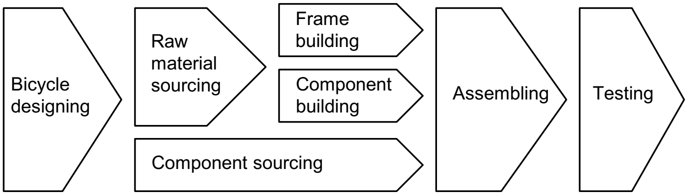

Fig. 1.4 Bicycle production

the items necessary to manufacture the bicycles. Those items are used to build both bicycle frames and some components such as lugs, chainrings, sprockets, hubs, and spokes. A number of finished components are not made but purchased from outside sources such as saddles and tyres. When all the components (including bicycle frame) are available, it is possible to start assembling the complete bicycles, which later are tested for quality and accuracy.

The fabrication of the bicycle frame is the most important activity in the production process and it is also a very distinguishing feature among the bicycle makers, which has significant implications for understanding the historical evolution of the bicycle industry. How is a bicycle frame made? It is possible to make a comparison between the fabrication process of a safety bicycle frame during the nineteenth and twentieth century. Such a process is a sequence of steps, shown in Fig. 1.5, which highlight the main manufacturing technology employed by the bicycle industry. In the 1920s, a bicycle frame was based on steel tubes that could be made in two alternative ways: welded tubing and seamless tubing (Grew 1921, pp. 35–36; Snow et al. 2009, p. 6). Welded tubes started as a flat ribbon of metal that was shaped into the form of a hollow tube and then the joints were welded. This manufacturing process was used, for example, by the British company Raleigh (Lloyd-Jones and Lewis 2017, p. 84) and the Italian company Bianchi (Ministero per la Costituente 1946, p. 279). Seamless tubes started from a bar of metal, called billet, which was transformed through the rotary tube piercing process (Roseo 1912, pp. 75–76). It means that a hole is drilled in the billet that was then pushed through a die and over a mandrel. The internal surface took the form of the mandrel and the external surface took the form of the die. Seamless tubes can be made in different shape and thickness. They are

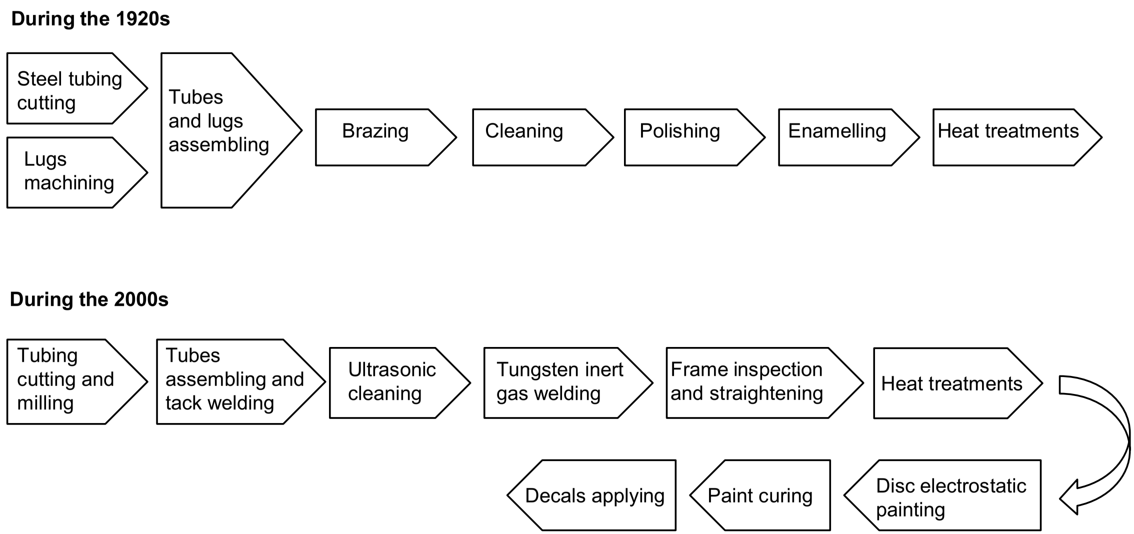

Fig. 1.5 Bicycle frame fabrication

considered to be superior in terms of performance because welding introduces thermal stresses into the metal that compromises its strength. In the 2000s, a bicycle frame was based on both steel and aluminium tubes made as a seamless tube (Bianchi 2005). It was also possible to build a bicycle frame using other materials such as titanium and composites made from carbon fibres.

After manufacturing or buying from an external source the tubes, it is necessary to cut them in various sizes according to the tube set (already explained in Sect. 1.2) and the geometry of each bicycle frame, which was planned to be produced. In the 1920s, tubes also needed a further component, called lug, which was a metal sleeve that surrounds the frame tube at the joint, holding two or more tubes together and strengthening the joint. Each lug added material to the stressed areas (that is the joint), distributing the stresses over a larger area. Lugs were made through machining in the form of castings of stampings. In the 2000s, lugs were rarely used and tubes needed to be shaped on the edges, through milling, so they could easily fit when joined to form the frame. The next step in bicycle frame fabrication is the preliminary assembling of tubes and lugs. This activity is performed using a jig for the correct alignment of the tubes and for keeping the tubes in place. In the 1920s, metal pegs were used to keep in place the lugs, whereas in the 2000s tack welds were used as a temporary weld before applying the final weld.

In the 1920s, the pre-assembled bicycle frame was sent to the brazing shop where the final joint of tubes was done through hearth or liquid brazing (Grew 1921, p. 36; Millward 1999, p. 142), and later to the cleaning shop where the frame went into vats for a bath of corrosive liquid that attacked the rough spelter or, alternatively, it was cleaned through a sand blasting treatment. In the 2000s, the pre-assembled bicycle frame was sent, firstly, to the cleaning shop where a new way of bath based on ultrasound was used and, later, to the welding shop where a new technology, called Tungsten Inert Gas (TIG) welding, replaced the brazing process.

The fabrication of bicycle frame, in the 1920s, encompassed three further steps: polishing, enamelling and heat treatments. Polishing was a process for making the frame surface highly smooth and without any imperfections ready for being painted. Enamelling was a bath of liquid black enamel in vats, which could be repeated three times for high quality bicycle frames. These frames received three coats of thin enamel and were baked, between each application, at a high temperature for a few hours in gas heated stoves (Grew 1921, p. 41). The fabrication of bicycle frame, in the 2000s, encompassed more steps highlighting some technological improvements adopted by the bicycle industry. After a frame was welded, it needed to be inspected for any imperfection that required straightening through a squaring stand. The next step was based on heat treatments to increase the strength properties of bicycle frame. Later, the frame went to the painting shop where a disc electrostatic technology was used to reach a smooth end result. The painted frame was then baked in a curing oven to prepare it for further painting or decals applying. For example, some bicycle frames could receive a further coat through a brushing paint technique or a powder coating. The final step was the application of graphics and decals on bicycle frame.

How a bicycle and its components are manufactured impacts on how the bicycle industry is organized, particularly the behaviour of firms in determining their boundaries. Which is the extent of a bicycle firm's activities in production? Is outsourcing a common practice within the bicycle industry? The next section provides an answer to these questions through the lens of a conceptual tool called the business system.

1.4 Bicycle Industry Structure

The organization and the evolution of the bicycle industry over time are intertwined with both the product architecture and the manufacturing of a bicycle. How a bicycle is decomposed and manufactured helps explaining the structure of the bicycle industry. A key feature for understanding the organization of a generic industry is to focus on the boundaries of a firm, in particular the extent to which a firm is vertically integrated and which activities are no longer internally carried out, but instead it purchases from other firms. This is usually framed as a make-or-buy decision. It means determining what to do internally versus what to outsource in the market (Churn and Ware 2000, pp. 63–64). Vertical boundaries are usually depicted through a sequence of stages or activities, called the vertical chain, performing two distinct types of function: a physical function and a market mediation function. The physical function includes converting raw materials into parts, components and eventually finished goods, and transporting all of them from one point in the chain to the next. Less visible but equally important is market mediation, whose purpose is ensuring that the variety of products reaching the marketplace matches what consumers want to buy (Fisher 1997, p. 107). Vertical integration occurs when these stages are organized within a single firm. The concept of the vertical chain has been studied from various perspectives and called in different ways. For example, in the 1970s French economists introduced the words *filières de production* or *filières industrielles* (Bellon 1984, pp. 111–112), during the 1980s management scholars referred to it as a *business system* (Gluck 1980, p. 26; Buaron 1981, p. 33) or a *value chain* (Porter 1985, p. 33), and in the 1990s US sociologists called it a *global value chain* (Gereffi et al. 2005, p. 79). In this book, the terms business system is preferred to suggest that the stages are interdependent and form a complex unity. A business system is shown as a sequential chart encompassing the key elements of the system by which companies in a given business produce their goods or services and deliver them to the customer. For example, in a technology-based manufacturing company, these elements might be technology, product design, production, distribution, sales and service. At each link of the business system, there are a number of choices management can make about how to conduct the business. Obviously, these are often interdependent: product design will partially constrain the choice of raw materials; decisions on physical distribution will constrain manufacturing capacity and location and vice versa. A business system can differ from industry to industry and frequently even from company to company. It emphasizes the benefits that firms derive in breaking the system into discrete parts to help them look for innovative organizational and managerial practices.

A generic representation of the business system of a firm manufacturing a complete bicycle is shown in Fig. 1.6, it is relatively standard for the industry, but may vary in some essential details from firm to firm. This business system encompasses five stages: (a) market opportunity analysis, which means to conduct some form of market research to understand what consumer want and what competitors are doing in the marketplace; (b) production, which is the set of activities for manufacturing a bicycle as already explained in Sect. 1.3; (c) distribution, which means building a network of intermediaries involved in making bicycles available for consumption; (d) sales, which means managing the relationship with consumers; and (e) post-sales service, which is the activity mainly focused on bicycle repairing. Companies involved in manufacturing a complete bicycle can be broadly categorized as a maker or an assembler. The main difference between them is the frame fabrication that, in the former case, is done in-house, and in the latter case is outsourced to a supplier. The

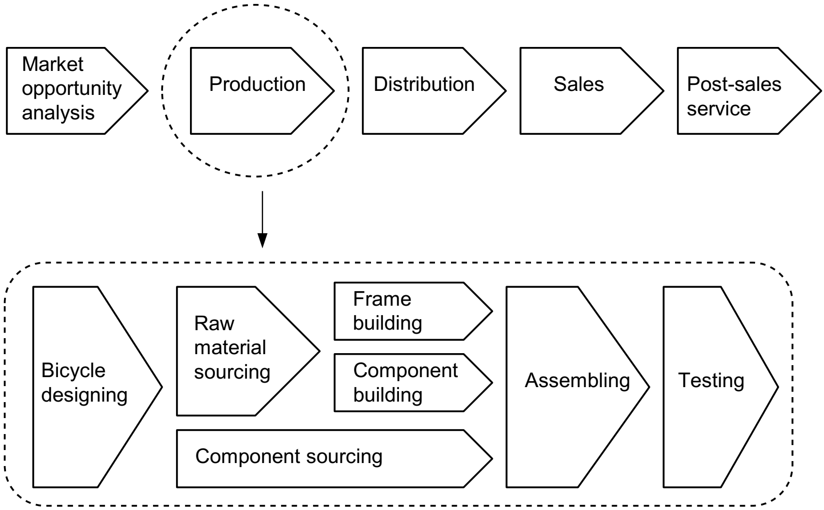

Fig. 1.6 Business system of a bicycle firm

maker is a more vertically integrated firm as it decided to manufacture frame internally, whereas the assembler is completely relying on outside suppliers as it decided to do frame production externally. The choice of manufacturing frame internally or externally has a direct impact on the business system of a firm that changes accordingly to the stages needed to produce a complete bicycle. If bicycle frames are bought from outside sources, the business system will not include the stages associated with frame fabrication. The distinction between makers and assemblers has been a feature of the bicycle industry since its birth and it has become even more marked with the success of the safety bicycle.

Besides makers and assemblers, further companies contribute to the bicycle industry even though they do not manufacture a complete bicycle. These firms are suppliers of components, other than a bicycle frame, which have to be incorporated in a bicycle. It is possible that a maker decides to manufacture internally some components and this choice increases its degree of vertical integration. In some cases, big bicycle makers built a high vertically integrated company such as Raleigh in UK, Bianchi in Italy, and Pope Manufacturing Company in the United States. Raleigh and Bianchi manufactured each component, including the frame, except for chains, saddles, and tyres. Pope Manufacturing Company was also able to produce tyres. A myriad of component manufacturers was, and still is, the backbone of the bicycle industry all over the world. This industry adopted, since its birth, a disintegrated system of production based on specialized capabilities associated with the manufacture of the various components (Galvin and Morkel 2001, p. 32). It was difficult and costly for most of the firms to have the capabilities to manufacture the full range of components that were required to construct a bicycle. Due to the specialized skills necessary in different bicycle manufacturing technologies, it was more efficient to source the components from external suppliers. The consequence is a highly fragmented industry where suppliers have developed specialist capabilities, which make them more competitive than vertically integrated companies. In some cases, such as the Taiwan bicycle industry, suppliers are very specialized, with over 90% manufacturing only one type of component (Chu and Li 1997, p. 63). It is also a common practice that specialist firms or component manufacturers organized themselves in functional tiers, where each first-tier supplier formed a second tier of suppliers under itself. Companies in the second tier were assigned the job of fabricating individual components.

The business system perspective and the categories of maker, assembler, and component manufacturer help to clarify further features of the bicycle industry, which are usually applied to the whole industry regardless of the role played by different firms. Previous studies (Harrison 1977; Millward 1999) have highlighted the following characteristics: bicycle industry is not regarded as a capital-intensive industry, the technology for bicycle production is relatively simple, accessing the industry is easy due to low barriers of entry, a very common practice is copying other firm's products, and the market has a seasonal pattern that affects how companies organize their own activity. The first three statements are true if applied to assemblers, but are more questionable in regard to makers or component manufacturers. It is easier to start a firm whose activity is exclusively bicycle assembly. A new entrepreneur requires a limited amount of both technological capabilities and money to assemble bicycles. There are no particular barriers that prevent starting a new business whose goal is to assemble bicycles. Instead, it is quite a different situation if someone decide to become a bicycle maker or a component manufacturer. The technological capabilities required are more demanding and so it is the investment to begin the activity. Consequently, there are barriers that make the access less easy in comparison with hindrance facing an assembler. The practice of copying products of each other is common within the whole bicycle industry and involves the three categories of firms (maker, assembler and component manufacturer). This practice is a direct effect of the division of labour and increasing specialization that generates a fragmented industry. This way of organizing the system of production is aimed at creating economies of scale through standardized components, including bicycle frames, which makes easier copying other firm's products. The seasonal pattern of the bicycle market involves the whole industry and has an annual cycle. This way of doing business characterizes the industry since its birth (Roseo 1912, pp. 214–215) and is still in place nowadays as described in the annual report of a Dutch bicycle firm (Accell 2019, p. 6). The cycle has an almost fixed pattern every year and lasts for twelve months from September to August of the next year. Each firm that manufactures complete bicycles has to deal with two offerings of bicycle simultaneously. In September of each year, the current offering of bicycles is launched in the marketplace and, at nearly the same time, the firm starts thinking about the new offering that will be launched in twelve-month time, based on preliminary data drawn from the current offering. September is also when bicycle firms have to begin to negotiate sales agreements with their own network of dealers, particularly the decisions focused on sales goals (how many bicycles the dealer is going to order) and margins (which is the profit margin granted to the dealer). During the timeline shown in Fig. 1.7, the activities involving both offerings are intertwined in an unceasing cycle that repeats itself every year. The seasonality of the bicycle industry is also connected with weather conditions, which explain why the delivery peak is between February and June, and consumer sales peak is usually in spring and summer seasons, with obvious differences between geographical areas.

The concept of the business system is a useful lens for understanding the evolution of bicycle industry in various countries providing that some data is available. In many instances it is not possible to say for sure whether bicycle firms were actually a maker or an assembler. The following is a sketch of how the bicycle industry evolved in Italy since its inception. The Italian experience shares similarities with other countries that developed a domestic bicycle industry and, therefore, it can help to shed light on the role played by the different categories of firms participating in the industry, regardless of the peculiarities of any geographical context.

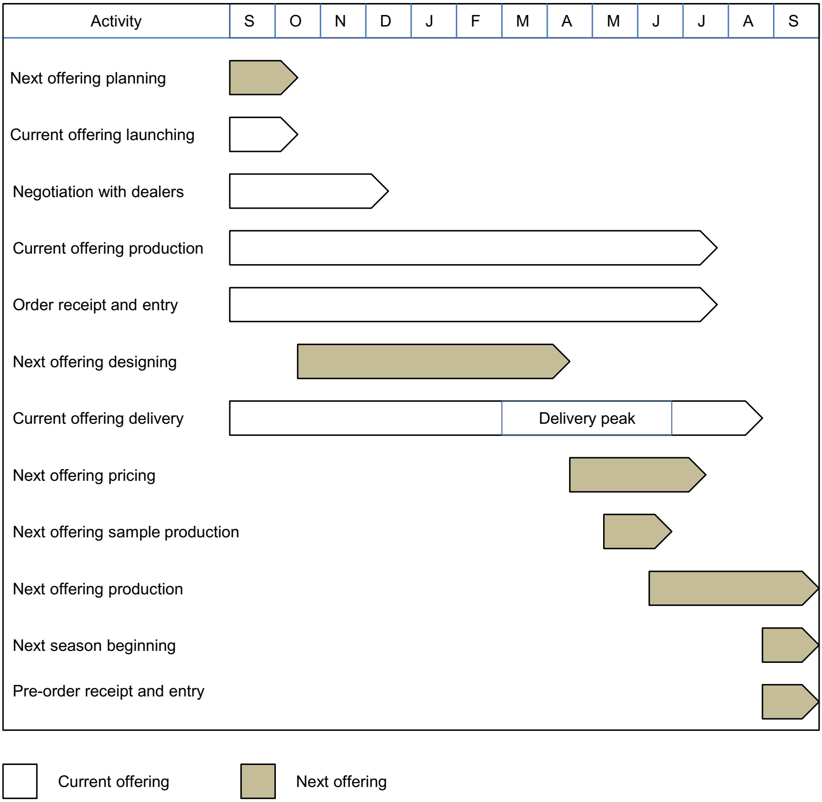

Fig. 1.7 Seasonal pattern of bicycle market

The history of the Italian bicycle industry can be broadly divided into four phases spanning from the 1880s to the present time. Before the 1880s, there were initial attempts to build bicycles in 1867 in the city of Modena, and between 1872 and 1878 in Milan, Bologna and Turin (Vota 1954, pp. 19–20). The first phase, from 1880 to 1890, saw an increasing number of small craftsmen joining the nascent industry. Their businesses were very small and did not specialize in bicycles, but produced or repaired a wide range of mechanical products. They focused on repairing foreign bicycles. Most of those artisans were in the northern part of the country, primarily located in Milan and Turin (Roseo 1912, p. 147). A notable exception was Edoardo Bianchi who run a small mechanical repair shop in Milan and developed the first safety style bicycle in Italy in 1886, inspired by an imported English bicycle (Mari 2015, p. 134). Form his shop he was able to build one of the world's leading and most popular bicycle firms. During the first phase, the contribution of Italian bicycle firms to the business system was limited to the post-sale service stage through their repairing activity. Other stages were carried out by foreign companies exporting bicycles to Italy.

In the second phase, between 1890 and 1900, the industry experienced a significant growth, made possible because the financial needs of those firms were limited as most of them bought components that were assembled to sell standard products (Piloni 1982, pp. 9–10). The Italian market was dominated by bicycles imported from abroad, principally England, Germany, France and the US (Roseo 1912, pp. 164–167). Italian bicycle firms broadened the number of activities carried out within the business system, and were involved in understanding the market, assembling complete bicycles, distributing, selling and repairing them. The production stage, as depicted in Fig. 1.8, encompassed an assembly

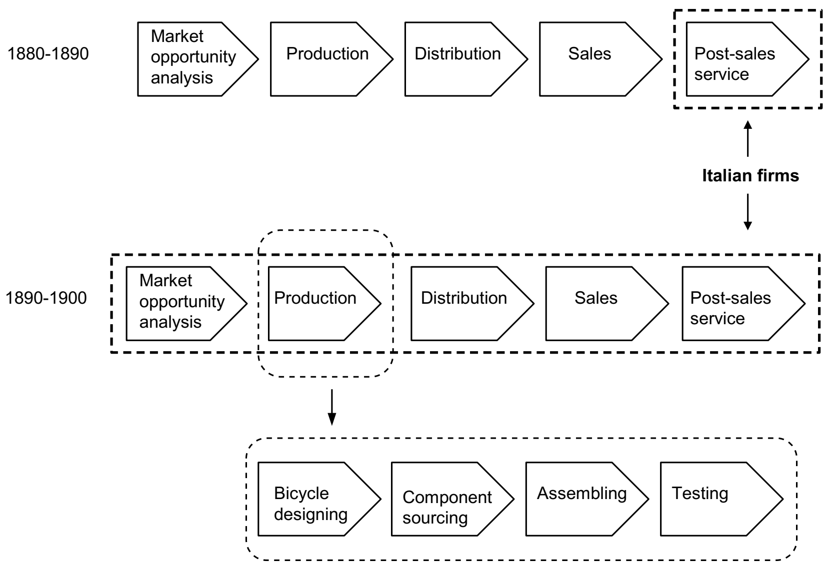

Fig. 1.8 Business system of Italian bicycle industry 1880–1900

activity based on designing a bicycle offering, sourcing the components needed to assemble it, and testing the complete bicycles.

The third and longest phase began in the 1900s and lasted until the 1970s. Domestic production of complete bicycles began to take off due to the increase in bicycle sales in Italy and the start of an export trade (Roseo 1912, pp. 183–189). Although production was still dispersed in a myriad of small workshops and craftsmen, some firms started to access external financial sources that led to the birth of a few joint-stock companies (Piloni 1982, pp. 70–72). Most of the bicycle components were manufactured in Italy and the industry was highly fragmented. Five distinct groups of firms were involved in the industry: a very few vertical integrated companies that carried out all the manufacturing processes on their own premises and sold complete bicycles, some makers of bicycle frames that bought components from other firms and sold complete bicycles, a large number of small assemblers that bought everything was needed for building a bicycle from outside sources and sold complete bicycles, a high number of local artisans mainly involved in bicycle repairing and very limited bicycle assembly, and some small and medium firms that carried out the fabrication of components and spare parts (ANCMA 1953, p. 362; Piloni 1982, pp. 18–19). The backbone of the industry was located in three geographical areas, specifically, in order of importance, Lombardy, Veneto and Piedmont (ANCMA 1953, p. 363). In 1949 most of the key firms were in Lombardy: 46% of those building complete bicycles and 60% of those manufacturing components (Piloni 1982, p. 58). Milan was the capital of the Italian bicycle industry and the following firms had their headquarters in the city: Bianchi, Legnano, Borghi (whose brand was Olympia), Focesi (whose brand was Gloria), Viscontea, and Taurus. The geography of Italian bicycle industry also included Varese, where Ganna started his firm; Padua, where Rizzato (whose brand was Atala) and Torresini (whose brand was Torpado) built their bicycles; Vittorio Veneto where Carnielli (whose brand was Bottechia) began his business; Bassano del Grappa, where Willier Triestina was active; and Celle Ligure, where Olmo manufactured his bicycles. In the summer of 1920, in Milan, the most important companies founded a national organization to protect its members' commercial interests (Borruso 1996, p. 167). Its acronym was ANCMA (Associazione Nazionale del Ciclo Motociclo e Accessori) and included makers of bicycles, motorcycles and accessories for both kinds of vehicles.

This phase witnessed the coexistence of vertically integrated firms, frame makers, assemblers, craftsmen and specialized suppliers of components. Very few firms had both financial resources and capabilities to manufacture a complete bicycle. Most firms did not find advantageous to internalize activities through formal integration and chose to focus on frame building or assembling. The business system of these five groups of firms highlights some differences as depicted in Fig. 1.9, particularly the missing activities that each category of firms did not carry out at the production stage. Obviously, vertically integrated firms showed the whole range of activities for manufacturing bicycles internally, whereas other firms did not perform some tasks consistently with their choice to buy most or all the components from external sources. For example, assemblers outsourced everything, including bicycle frames; and local craftsmen usually did not have enough capabilities to design a bicycle. At the same time, other stages of the business system, such as marketing opportunity analysis, distribution, sales, and post-sales service were carried out at a different degree of completeness and professionalism by each group of firms. For example, a vertically integrated company was able to develop resources in any of the stages, whereas an artisan was mainly devoted to bicycle repairing and, consequently, other stages of the business system were compressed or completely missing. In a similar vein, component manufacturers performed all the stages, even though they did not build and sell bicycles. Their activities were performed in relationship with other firms within the industry, for example, their post-sales service was available to consumers through bicycle dealers.

The fourth and last phase is from the 1980s to the present and is characterized by the progressive decrease in the number of both vertically integrated firms and frame manufacturers. Fierce competition from foreign countries, particularly from Far East, drove this shift in the Italian bicycle industry. At the present time, the whole industry is made up of assemblers and component manufacturers. This change affected also the long-standing tradition of fabricating high quality steel frames which are, now, almost completely disappeared, except for a few artisanal makers that build a limited number of custom frames. The business system of this phase overlaps with the one depicted in Fig. 1.9. The key difference, not shown in the chart, is that there is only one vertically integrated firm in Italy, its name is Bianchi and it was acquired by a foreign group in 1997. The main category of firms within the industry is now the assembler, which has become synonymous with a bicycle company.

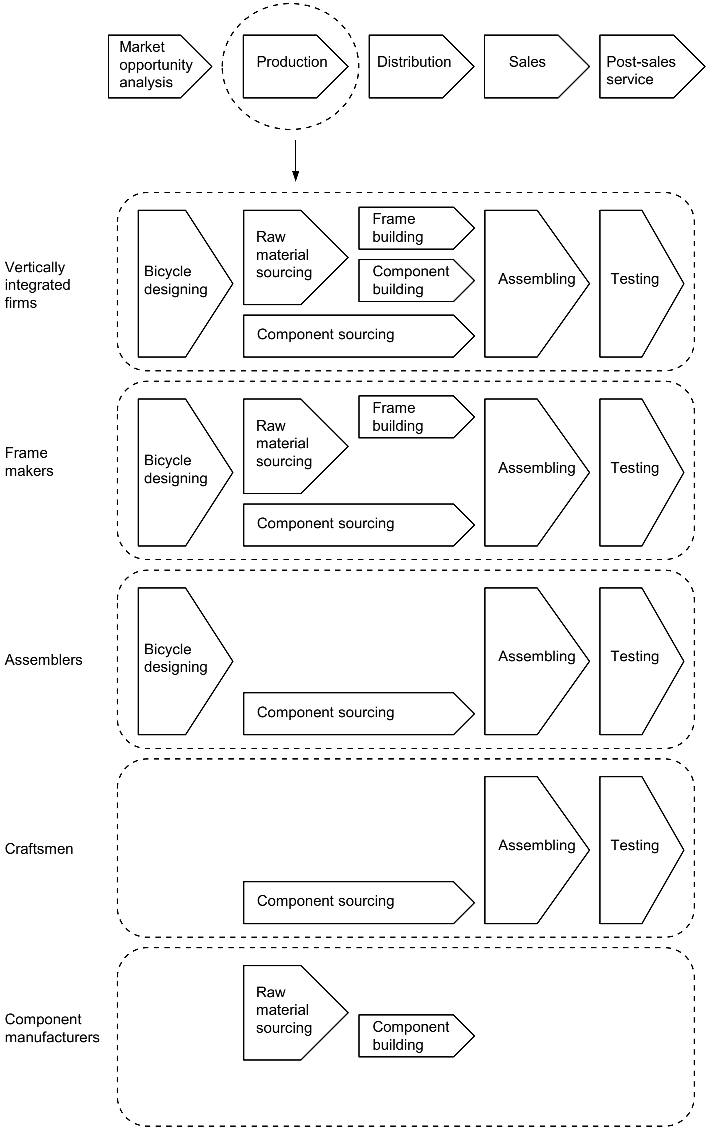

Fig. 1.9 Business system of Italian bicycle industry 1900–1970s

The Italian bicycle industry evolved through an import-substitution industrialization model aimed at replacing foreign imports with domestic production. Both complete bicycles and components were imported. The former were what consumers wanted and the infant industry was not ready to provide yet. The latter were the easiest way to establish a form of industry through the assembly of bicycles, which was the manufacturing technology most accessible for starting a firm. The accumulated learning during the import years enabled the industry to expand its capacity quickly. From the 1880s to 1907, the import of foreign bicycles was the main source for the Italian marketplace, particularly the British products. In 1908, the domestic production took off, and the import of bicycles from other countries decreased accordingly (Piloni 1982, p. 49). The import-substitution model was the same path followed by other countries both in Europe and Asia, such as France, the Netherlands, Japan, China and Taiwan. France is credited with initiating the bicycle industry in the 1860s, but it lost its advantage when UK assumed the major position in bicycle production at the beginning of the 1870s and was to be the main supplier to world markets for the following twenty years (Millward 1999, pp. 72–73). One of the earliest large-scale bicycle firm in France was the Manufacture française des armes et cycles (MFAC) based in Saint-Etienne, a town and region that was a key centre of the French bicycle industry (Dauncey 2012, p. 79). MFAC was founded in 1885 and was initially only concerned with the sale and repair of imported British bicycles, but in 1888 started producing bicycles for the growing market and it became the first vertically integrated firm in its country. From the late 1890s to the mid-1920s, in Saint-Etienne area the bicycle industry was organized around a small number of large firms and a myriad of subcontractors providing components. The Dutch market imported bicycles from UK, Germany and US since the 1880s until 1925. Afterwards, the local industry began to manufacture complete bicycles through domestic makers and assemblers (Tjong Tjin Tai et al. 2015, p. 21). The bicycle industry in Japan inherited from UK complete bicycles, components, and most importantly the first vertically integrated firm. The imports from UK started in the 1890s and lasted until the 1910s (Takeuchi 1981, p. 38). Japanese entrepreneurs developed a method of bicycle assembly known as *set fitting* or knock-down system. It meant that Japanese firms imported unassembled components in sets that were put together to form complete bicycles. In 1910, in the city of Kobe, a British bicycle firm established a branch factory that was instrumental in developing the native industry in Japan (Takeuchi 1981, p. 46). The Japanese industry used extensively the putting-out system of production based on complex multilayered subcontract relationships. Each bicycle component or, in some cases, manufacturing process was entrusted to a subcontractor that could be committed to just one company and heavily rely on family labour (Takeuchi 1991, pp. 159–160; Ueda 1981, p. 14). China imported bicycles from UK, Germany and Japan between 1879 and the 1920s. Its native bicycle industry was connected to a Japanese entrepreneur who started three firms in China between 1936 and 1938 (Petty 2001, pp. 198–199). These three firms were confiscated and nationalized by the government in 1949 and the imports ceased because of the Sino-Japanese war and the US trade embargo (Rhoads 2012, pp. 105–106). Since the 1950s, the Chinese government played a key role in developing the domestic bicycle industry through investment for firm expansion, company restructuring and creating zones were foreign investment was permitted. In Taiwan the bicycle industry started later than in other countries and it was greatly influenced by the experience of the Japanese industry (Chen et al. 2009, p. 207). Taiwan imported both complete bicycles and components from Japan between 1946 and 1951, afterwards the government adopted policies that limited imports and the domestic bicycle industry expanded its manufacturing capabilities (Chu and Li 1997, p. 57). The bicycle industry, in Taiwan, consisted primarily of frame makers and component manufacturers. The former fabricated no components except the bicycle frame, the latter were very specialized with each manufacturing a very limited number of products. Component manufacturers became increasingly independent from domestic frame makers, exporting over 50% of their production (Chu and Li 1996, pp. 43–44). In 1969, Taiwan began to export its bicycles to the United States and until the 1980s the industry experienced significant and continuous growth. In the 1970s, Taiwan's bicycle firms went to Japan to learn about standardization of bicycle components, which helped them to improve their technological knowledge. During the 1980s, the government helped bicycle firms to deal with the issue of low-quality products through the development of more advanced manufacturing processes and skills within the whole business system.

1.5 Conclusion

The business system perspective is a fruitful approach to study the evolution of the bicycle industry as it provides a neglected lens to interpret how vertical chains are organized locally and globally. It is particularly useful to highlight the trajectories followed by different categories of companies over time and in various geographical areas. It could also help to envision what the bicycle industry will be like in the future.

The current situation indicates a polarization between assemblers and component manufactures as the best equipped to survive, and perhaps prosper, within the bicycle industry in the coming years. An evident phenomenon is the rise of the so called mega-suppliers in various industries, including the bicycle sector (Donovan 1999, p. 1). Mega-suppliers are big firms manufacturing and assembling entire modular packages such as the transmission system, the brake system, the wheel system or the front and rear suspension. Their approach is different from the traditional supplier of bicycle components for three reasons: they build an integrated system made of many components, rather than providing some single pieces, which contribute to define current and new standards within the bicycle industry; they will likely lead the industry in the technological innovation as their size allows them to invest in research and development, so that the locus of bicycle innovation will be concentrated in a small number of firms; and they can use ingredient-branding as a tool for advertising directly to consumers, which will likely search for a bicycle assembled with a particular brand of components.

Power within the bicycle industry is progressively flowing away from assemblers towards the large component manufacturers. Today, there are two mega-suppliers in the global bicycle industry: a Japanese firm (Shimano) and a US firm (SRAM). An Italian company (Campagnolo) could also be considered a potential mega-supplier, even though its size is smaller than its competitors. Moreover, Campagnolo's offering is narrower than what both Shimano and SRAM are currently manufacturing for the marketplace.

A further impetus for establishing mega-suppliers is the birth of a large market for both pedal electric cycle, or pedelecs, and electric bicycles. The former are bicycles with electric motors that assist riders, the latter can be propelled without pedalling. This new market is incessantly growing in many countries and manufacturers of electric motors, not already involved in the bicycle industry, are providing their offering to bicycle assemblers, which are dependent on using a technology developed by an outside source.

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